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The World Nuclear Industry
Status Report 2024

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The World Nuclear Industry Status Report 2024

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As one of only two other people who have been with the project from the start, Antony Froggatt has been a reliable partner in developing the report concept, drafting chapters, editing or proofing others, and presenting the outcome at numerous occasions. For reasons independent of this project, your role is likely to change in the future. Whatever path you are taking, thank you for everything, especially for being who you are, an exceptional energy policy analyst, a kind person, and a close friend.

At the core of the WNISR is its database designed and maintained by data manager and information engineer Julie Hazemann—the other person who has been there from day one. She also develops most of the drafts for the graphical illustrations and expanded her contributions significantly over the past few years, including pre-drafting statistical sections and analysis. As ever, no WNISR without her. Thanks a million.

This is the tenth edition in a row M.V. Ramana has contributed to, and the number of sections covered has significantly increased if compared with number one. I am very grateful he has again cut out time in his insanely busy schedule to support this project with expertise and advise. Thank you so much.

Tatsu Suzuki, with whom I continue to enjoy—as with Ramana—cooperating under other organizational frameworks, has turned from a foreword author in 2014 into an indispensable member of the core team. Thank you for contributing some essential parts to the report for the third year in a row and for the first time in cooperation with Yuki Kobayashi who we welcome on the team. Thanks to both of you for continuing the development of the chapters you have taken on.

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Doug Koplow, who was a key author of WNISR2009, has returned fourteen years later as a key author of WNISR2023. I am glad I could lur him into an—excellent—follow-up in 2024. Thank you for the quality of your work and your patience, not only concerning the report itself but also for the series of presentations that we have enjoyed with you.

Tim Judson has now contributed for the third year in a row and depth of his knowledge comes as a great value added to the WNISR Project. Thank you so much.

Hartmut Winkler joined the team in 2023… and expanded his excellent contributions in 2024 to two chapters. It is a real pleasure working with you, thank you very much.

What began with a "little blip" in WNISR2023 turned into a full-scale chapter in WNISR2024 drafted by my old buddy Sebastian Stier. Thank you for your expertise, advise, and incredible engagement into this work. Such a pleasure. Hopefully, we can build on this in the years to come.

Amongst the newcomers in the team, we are fortunate to count Özgür Gürbüz who contributed two well-researched pieces, Paul Jobin who provided a well-documented and well-written piece, Ed Lyman who drafted a short but incredibly insightful chapter on a difficult issue, as well as Andy Stirling and Phil Johnstone who drafted a chapter that follows up directly on work discussed in WNISR2018 (welcome back!) and presents original and thought-provoking research.

Andreas Molin has been a senior government official for decades. I could not have thought of a more qualified and appropriate author for the Foreword to WNISR2024. The result provides historical context and depth. It was also a fruitful and pleasant experience working with you. Thank you so much.

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Note

This report contains a very large amount of factual and numerical data. While we do our utmost to verify and double-check, nobody is perfect. The authors are always grateful for corrections and suggested improvements.

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FOREWORD

by Andreas Molin[1]

This is the 19th Edition of the World Nuclear Industry Status Report or WNISR. What started in 1992 became a remarkable success, and an indispensable source of reliable, fact-based information. Having worked some 30 years as a civil servant for the Government of the Republic of Austria, implementing Austria's nuclear policy, I have come to particularly value the importance of empirical evidence, reliable data, and sound analysis of relevant developments. Since 2007 all of that has been provided by the WNISR on an annual basis.

For the global readership of the WNISR, it may be recalled that during the 1960s Austria had been embarking on a nuclear power program too. Groundbreaking for the Zwentendorf Nuclear Power Plant (NPP), located on the banks of the Danube River some 40 km upstream from Vienna, took place in 1972. Two more NPPs were at the planning stage, one in St. Pantaleon, also in Lower Austria, and one in Carinthia. Construction of the Zwentendorf NPP was finished in 1978 and the plant was slated for startup in the fall of the same year (fuel assemblies were onsite, but not yet loaded). But then, on 5 November 1978, the Austrian electorate decided in a very close referendum not to start the operation of the NPP (49.33% yes and 50.47% no). Within a month the Austrian Parliament passed an Anti-Nuclear Law prohibiting nuclear power in Austria, and the Zwentendorf NPP got mothballed.

Only a few months later, in March 1979, the wider consequences of an accident at the Three Mile Island NPP in the U.S. (INES-5)[2] were seen by many in Austria as confirmation of the majority vote against nuclear power. But it took until 1985 for the consortium of public utilities owning the Zwentendorf NPP to decide on a "quiet" liquidation. As the NPP has been preserved almost entirely, today it is a tourist attraction and houses a vocational training facility. There are not many places in the world where you can visit a nuclear power plant free of any contamination.

After the catastrophic events in Chornobyl in 1986—Austria being among the most affected countries in Central Europe—the opposition to and concerns about nuclear power became deeply rooted in the Austrian population, at all levels of society. Information regarding the safety deficits of NPPs of Russian design, which became public after 1989, reinforced these apprehensions, leading to explicit government policy in 1990.

When I was entrusted with the implementation of Austria´s nuclear policy in 1991, it was difficult, if not almost impossible to get reliable information about nuclear power plants close to the Austrian border, and elsewhere. That is until Mycle Schneider and Antony Froggatt began to publish the WNISR, and thanks to their persistence and dedication it has been an annual publication for 17 years providing not only reliable and important data in an understandable and informative way but also a wealth of sound and profound analysis.

During my long professional career in the nuclear field, I have witnesses several "ups and downs" of the nuclear power sector. Sometimes it had been called a "nuclear renaissance", sometimes "renewed interest in nuclear power." But what really happened in the global and

1 - Former Director, General Coordination of Nuclear Affairs at the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, Government of Austria.

2 - The International Atomic Energy Agency's International Nuclear Event Scale (INES) ranges from 0 to 7.

regional power markets, the WNISR tells us. Apart from a steady increase in installed capacity in Asia, in China in particular, the promise of nuclear never materialized. In the early years of the 21st century some construction projects were started or resumed, but they all went substantially over budget and have been plagued by technical difficulties and delays. More reactors have been retired than brought on-line. In fact, global production of nuclear power peaked already in 2006. I would not call that a "nuclear renaissance".

In parallel, the urgency of reducing greenhouse gas emissions became increasingly evident. But as electricity production from renewable sources thrived, the global share of nuclear power declined, steadily.

To fight cost-overruns and delays, so-called "Small Modular Reactors" or SMRs receive a lot of attention nowadays. More or less "shop-fabricated", proponents of SMRs claim they would be more or less "shop-fabricated", licensing procedures would be shortened, cost predictable and step-by-step capacity additions possible. And, of course, they should play a major role in fighting climate change. And, finally, they should be safer, allowing their deployment also in densely populated areas.

Though most of the technological concepts are not new at all, technological advances should now render possible what was not achievable earlier. And indeed, the OECD's Nuclear Energy Agency (NEA) lists altogether 56 models in its SMR Dashboard—impressive really. But how many reactors are in operation or under construction, or have at least their design licensed? The NEA informs on its webpage that "the first SMRs are expected to be built this decade, followed by accelerated deployment around the world in the 2030s."[3] The thorough analysis, drafted by M. V. Ramana and annualized since WNISR2019, sheds some doubts on this. But climate experts urge us to reduce greenhouse gas emissions fast, very fast. The European Union's target is a 55-percent reduction by 2030 (compared to 1990), 90 percent by 2040[4]. It is difficult to imagine that SMRs could play a significant role in achieving these targets.

There is a more fundamental problem though, that is the aging fleet of reactors and operators' efforts to extend the operating times of their reactors well beyond the limits envisaged at the time of construction and licensing. This is an enormous challenge for the nuclear power sector. Of course, operators as well as regulators subscribe to the concept of continuous improvement of nuclear safety. But nuclear safety is an extraordinarily complex issue, comprising not only technology but also human factors or institutional frameworks, to name just a few principal elements. Consequently, it is a legitimate question, if nuclear safety has improved over time. What can be observed is that more or less ambitious upgrading or improvement plans are delayed in many cases. For the European Union, the European Nuclear Safety Regulators Group's (ENSREG) 2021-Status Report on the Post-Fukushima National Action Plans[5] provides convincing evidence in this regard. Likewise, the Western European Nuclear Regulators Association's (WENRA) 2023-report on "reasonably practicable safety

3 - OECD/NEA, "NEA Small Modular Reactor (SMR) Dashboard", Nuclear Energy Agency, Organisation for Economic Co-operation and Development, 2024, see https://www.oecd-nea.org/jcms/pl_73678/nea-small-modular-reactor-smr-dashboard ; accessed 16 August 2024.

4 - European Commission, "Climate strategies & target", see https://climate.ec.europa.eu/eu-action/climate-strategies-targets_en, accessed 23 August 2024.

5 - ENSREG, "Post-Fukushima NAcP - Status Report 2021", 12 April 2022, European Nuclear Safety Regulations Group, see https://www.ensreg.eu/document/post-fukushima-national-action-plans-status-report-2021, accessed 25 August 2024

improvements and benchmarking"[6] shows that there is room for improvement in implementing already agreed upon safety upgrades. But, as you can see also from WNISR2023, the economic pressure for operators is quite substantial. Competent, strong, and independent regulators, backed by adequate national and international legal frameworks as well as sufficient resources, are indispensable in such a situation. Let us hope that in operating states, governments, parliaments, and the society as a whole are aware of this and act appropriately.

6 - Reactor Harmonization Working Group, "Summary Report—WENRA Safety Reference Levels 2014 – Implementation at the nuclear power plants reasonably practicable safety improvements and benchmarking", Western European Nuclear Regulators Association, 14 November 2023, see https://www.wenra.eu/sites/default/files/publications/RHWG_SummaryReport_on_Implementation_and_Benchmarking_for_WENRA_17-11-23.pdf, accessed 25 August 2024.

KEY INSIGHTS

Net Decline in Nuclear Capacity – Production Increases but Remains Below 2021

→ In 2023, 5 new nuclear reactors (5 GW) started up and 5 were closed (6 GW), thus a net decline by 1 GW in capacity.

→ Global nuclear power generation increased by 2.2 percent but stayed below 2021 and 2019.

→ Nuclear energy's share of global commercial gross electricity generation declined from 9.2 percent to 9.1 percent, little more than half of its peak of 17.5 percent in 1996.

→ As of mid-2024, 408 reactors with 367 GW were operating in the world, one more than a year earlier, 30 below the 2002-peak—34 units were in Long-Term Outage.

→ Between 2004–2023, there were 102 startups and 104 closures worldwide: an increase of 49 units in China; outside China, a net decline of 51 units.

Fewer Countries Building – Construction Starts Down – Russia Confirms Market Domination

→ 13 countries, three less than in mid-2023, are hosting 59 reactor construction projects. At least 23 are delayed; of these, at least 10 have reported increased delays.

→ As of mid-2024, China had the most reactors under construction (27) but none abroad. Russia dominated the international market with 26 units under construction, 20 of them in seven other countries.

→ Construction started on 6 reactors in 2023— down from 10 in 2022—including 5 in China and 1 implemented by Russia (in Egypt).

→ Chinese and Russian government-controlled companies launched all 35 reactor constructions in the world since December 2019 through mid-2024.

→ Besides Russia's Rosatom, only France's EDF is currently building nuclear power plants abroad (two units in the U.K.) as lead-contractor.

→ 93 percent of all ongoing construction projects are carried out either in Nuclear Weapon States (NWS) or by companies controlled by NWSs in other countries.

Major National Developments in 2023

→ **Belgium**. Nuclear generation dropped by 25 percent in 2023. Three of the remaining five units are to close by 2025, while operation of the two most recent ones is to be extended to up to 2037, subject to European Commission approval.

→ **Japan**. Two additional reactors were restarted in the second half of 2023 bringing the total to 12 operating units while 21 reactors remain in Long-Term Outage. Nuclear power generation surged by 49 percent, but nuclear's share in total electricity dropped again, from 6.1 percent to 5.6 percent.

→ **South Korea**. The country operates the fifth largest nuclear power program in the world. State-owned utility KEPCO's net debt stood at an unparalleled US$147 billion.

→ **Türkiye**. Startup of Unit 1 of the Akkuyu nuclear power plant was delayed to 2025.

→ **United Kingdom**. Startup of Unit 1 of Hinkley Point C is now planned for 2029–2031, with the price tag for the two units estimated at US$52.5–59.2 billion.

→ **United States**. After 11 years of construction, Vogtle-4 was connected to the grid in March 2024 with all-in costs for Vogtle-3 and -4 estimated at US$36 billion. No more reactors are under construction in the U.S.

Decommissioning

Of 213 closed power reactors only 23 have been fully decommissioned with only 9 units released from regulatory control as greenfield sites.

Russia Nuclear Dependencies

Russia is also playing a key role in the supply of fuel services, involving uranium mining, conversion, and fuel assembly manufacturing for Soviet-designed VVER pressurized water reactors, of which there are 19 in the E.U. and 15 in Ukraine. International sanctions have had little effect on the business. On the contrary, the share of Russian supply of natural uranium, conversion, and enrichment services to the E.U. all increased between pre-war year 2021 and 2023; VVER fuel imports doubled.

Potential Newcomer Countries

Africa Focus. Of 18 African countries analyzed, only four—Algeria, Libya, Morocco, and Nigeria—would have grid systems large enough to meet minimum capacity criteria to host a large nuclear reactor.

Civil-Military Cross-Financing in the U.K. Nuclear Sector

New analysis suggests that the overall undeclared excess costs to the U.K. economy of keeping the national nuclear complex—civil and military—in operation, may be estimated conservatively at £5 billion (US$6.3 billion) per year.

Militarization of Civil Nuclear Reactors: Tritium for Nuclear Weapons

The planned militarization of two French civil nuclear power reactors to produce tritium for nuclear weapons has a precedent in the U.S. showing operational, environmental, and non-proliferation issues.

Power Firming and Competitive Pressure on Nuclear

At the end of 2022, the U.S. had 374 operating hybrid power plants—e.g. renewables plus storage—excluding hydro pumped storage. These comprised more than 40 GW of generating capacity, of which more than half were solar plus storage. Costs of utility scale storage continue to decline, and installations are surging. A recent OECD-IEA study concluded:

→ Solar plus storage is already more competitive than coal in India.

→ Due to carbon pricing witxfhin the E.U. solar plus battery storage already easily outcompetes natural-gas-fired power.

→ The cost of solar plus storage is already "significantly lower than nuclear power in most markets today," as well as "highly competitive with other low-emissions sources of electricity that are commercially available today."

Small Modular Reactors (SMRs)

The gap between hype about SMRs and industrial reality continues to grow. The nuclear industry and multiple governments are doubling down on their financial and political investments into SMRs. So far, reality on the ground does not reflect those efforts: with no design certifications, no constructions in the west, SMR projects continue to be delayed or canceled.

Solar and Wind Add Hundreds of Gigawatts, Nuclear Shrinks

In 2023, total investment in non-hydro renewable electricity capacity reached a record US$623 billion, 27 times the reported global investment decisions for the construction of nuclear power plants. Solar and wind power capacities grew by 73 percent and 51 percent, respectively, resulting in 460 GW of combined new capacity versus a decline of 1 GW in nuclear capacity. Global wind and solar facilities generated 50 percent more electricity than nuclear plants.

China added over 200 GW of solar capacity and just 1 GW of nuclear; solar produced a total of 578 TWh overtaking nuclear power by 40 percent. Adding wind and other non-hydro renewables like biomass, net total generation was four times more than nuclear output.

The European Union achieved its largest renewable capacity additions ever, and the renewable share in total electricity generation reached 44 percent, exceeding 40 percent for the first time. Solar and wind plants together produced 721 TWh, almost a quarter more than nuclear energy with 588 TWh. Also for the first time ever, non-hydro renewables generated more power than all fossil fuels combined, and wind alone surpassed fossil gas. Fossil fuel production dropped by a record 19 percent, reaching its lowest level ever.

Overall Conclusion

Contrary to widespread perception, nuclear power remains irrelevant in the international market for electricity generating technologies. Solar plus storage might be the game changer for the adaptation of policy decisions to current industrial realities.

EXECUTIVE SUMMARY AND CONCLUSIONS

The World Nuclear Industry Status Report 2024 (*WNISR2024*) provides a comprehensive overview of nuclear power plant data, including information on age, operation, production, and construction of reactors. WNISR2024 includes various topical focus chapters. Russia Nuclear Dependencies looks at the global nuclear industry's relationship with Russian companies with a particular focus on nuclear fuel supplies. Civil-Military Cross-Financing in the U.K. Nuclear Sector presents the result of an independent study that assesses the undeclared financing streams by tax- and ratepayers to the civil and military nuclear sectors. Militarization of Civil Nuclear Reactors: Tritium for Nuclear Weapons looks at the U.S. precedent for a recent, similar decision in France.

The Focus Countries chapter includes a detailed overview of developments in 14 of the 32 nuclear countries and on potential newcomer countries Poland and Türkiye. The chapter on Potential Newcomer Countries includes an Africa Focus that assesses the status of planning in selected countries and raises some feasibility issues.

The situation of Small Modular Reactor (SMR) development is analyzed in a dedicated chapter. The status of onsite and offsite challenges is discussed in the Fukushima Status Report. The Decommissioning Status Report provides an overview of the current state of nuclear plants that have been permanently closed. The chapter on Nuclear Power vs. Renewable Energy Deployment offers comparative data on investment, capacity, and generation from nuclear, wind, and solar energy, as well as other renewables around the world. That overview is complemented by a new analysis on Power Firming and Competitive Pressure on Nuclear that assesses the increasing implementation of hybrid systems—especially solar plus storage—that are falling in cost, already less expensive than new nuclear, increasingly competitive with existing nuclear and fossil fuel plants and could rapidly become game changers in the energy-system landscape.

Finally, Annex 1 presents overviews of nuclear power programs in the countries not covered in the Focus Countries chapter.

PRODUCTION AND ROLE OF NUCLEAR POWER

Reactor Operation and Capacity. As of 1 July 2024, a total of 408 reactors—excluding Long-Term Outages (LTOs)—were operating in 32 countries, one unit more than in WNISR2023,[7] ten less than in 1989, and 30 below the 2002-peak of 438. At the end of 2023, the operating nominal net nuclear electricity generating capacity stood at 365 GW. As of mid-2024, operating nominal capacity reached 367.3 GW, 0.2 GW more than the previous 2006 end-of-year record of 367.1 GW.

IAEA versus WNISR Assessment. Between September 2022 and April 2023, the International Atomic Energy Agency (IAEA) significantly modified its statistics—including retroactively—in its online-Power Reactor Information System (PRIS). This in turn impacts the perception

7 - Difference WNISR2023–WNIR2024: 5 reactor startups +5 restarts –8 new LTOs –1 closure = +1

of nuclear industry trends. Until September 2022, PRIS showed a historic peak in officially operating reactors, both in terms of number (449) and capacity (396.5 GW), in 2018.

In July 2024, PRIS showed the peak in the number of units occurring as early as 2005 at a maximum of 440 and the maximum end-of-year capacity still in 2018 at 374 GW. PRIS showed 416 units as operating with 374.7 GW of capacity as of mid-2024, just, slightly exceeding the 2018 peak. It is also likely that a new, record end-of-year capacity will be reached in 2024.

Until September 2022, the IAEA had included 33 units in Japan in its total number of reactors "in operation" in the world while only 10 of these units had effectively restarted and 23 have not produced electricity at least since 2010–2013 (of which, three since 2007). As of mid-2023, the IAEA had pulled those 23 units, together with four reactors in India, from the list of operating reactors retroactively since shutdown and added them to a new category labeled "Suspended Operation". As of mid-2024, the IAEA classified 21 reactors in Japan and four units in India as suspended.

As of mid-2024, WNISR classified 34 units as in LTO, of which 21 were in Japan, six in Ukraine, four in India, and one each in Canada, China and South Korea—the number increased by three compared to WNISR2023.

Nuclear Electricity Generation. In 2023, the world nuclear fleet generated 2,602 net terawatt-hours (TWh or billion kilowatt-hours) of electricity. Production increased by 2.2 percent compared to 2022—still below the levels of 2021 and 2019. China continued to generate more nuclear electricity than France for the fourth year in a row. Considering the continued difficulties of the ageing French fleet and the continuous expansion of the Chinese program, it seems now impossible for France to catch up, making China second only to the United States (U.S.) in nuclear generation for the foreseeable future. Outside China, nuclear production increased by 2.1 percent in 2023, remaining at a level last seen in the mid-1990s.

Share in Electricity/Energy Mix. Nuclear energy's share of global commercial gross electricity generation declined slightly to 9.15 percent in 2023 compared to 9.18 percent in 2022, down from the peak of 17.5 percent in 1996.

REACTOR STARTUPS AND CLOSURES[8]

Startups. In 2023, five reactors were connected to the grid, one each in Belarus, China, Slovakia, South Korea, and the U.S. In the first half of 2024, four units were connected to the grid, one each in China, India, United Arab Emirates (UAE), and the U.S.

Closures.[9] In 2023, five reactors were closed, three in Germany and one each in Belgium and Taiwan. In the first half of 2024, one unit was closed in Russia.

Over the two decades 2004–2023, there were 102 startups and 104 closures. Of these, 49 startups were in China which did not close any reactors. As a result, outside China, there

8 - See Focus Countries and Annex 1 for a country-by-country overview.

9 - WNISR accounts for closures in the respective years of last electricity generation and adjusts statistics retroactively if units have not generated power in the year in review.

has been a drastic net decline by 51 units over the same period, and net capacity declined by 26.4 GW.

CONSTRUCTION DATA[10]

As of 1 July 2024, 59 reactors (60 GW) were under construction, that is one more (1.2 GW) than in WNISR2023, but 10 fewer than in 2013 (five of which have subsequently been abandoned).

Thirteen countries are building nuclear plants, three less than in WNISR2023. The UAE and the U.S. completed their last construction projects and Brazil suspending (again) its only building project. Only three countries—China, India, and Russia—have construction ongoing at more than one site.

Building vs. Vendor Countries

- As of mid-2024, China had by far the most reactors under construction with 27 units or 46 percent of the total. However, China is currently not building anywhere outside the country.
- Russia is the dominant supplier on the international market with 26 units under construction in the world as of mid-2024. Six of these are being built domestically. The remaining 20 units are being constructed in seven countries, including four each in China, Egypt, India, and Türkiye.[11] It remains uncertain to what extent these projects have been or will be impacted by sanctions imposed on Russia and other consequential geopolitical developments following Russia's invasion of Ukraine.
- Besides Russia's Rosatom, only France's EDF is acting as lead-contractor building a nuclear power plant abroad (two units in the U.K.).

Construction Times

- For the 59 reactors being built, on average 5.9 years have passed since construction start—almost identical to the mid-2023 average of 6 years—but many remain far from completion.
- All reactors under construction in at least nine of the 13 builder-countries have experienced, often year-long, delays.
- Of the 23 reactors documented as behind schedule, at least 10 have reported *increased* delays and two were reported as delayed for the first time over the past year.
- WNISR2022 noted a total of 12 reactors scheduled for startup in 2023. At the beginning of 2023, nine were still planned to be connected to the grid within the year (including three pushed back from 2022 to 2023) but only five of these generated first power; the other four were delayed at least into 2024.
- Grid connection of the Mochovce-4 reactor in Slovakia has been further delayed, currently to 2025, that is 40 years after its initial construction start. Bushehr-2 in Iran originally started construction in 1976, over 48 years ago, and resumed construction in 2019 after a

10 - See Annex 5 for a detailed overview of the 59 reactors under construction in the world as of mid-2024.

11 - Two units are under construction in Bangladesh and one each in Iran and Slovakia where a Czech-led consortium is completing a Russian-designed reactor (Mochovce-4).

40-year-long suspension. Grid connection is currently scheduled for 2028, 52 years after construction started initially.

- Six additional reactors have been listed as "under construction" for a decade or more: the Prototype Fast Breeder Reactor (PFBR) and Rajasthan-7 & -8 in India, Shimane-3 in Japan, Flamanville-3 (FL3) in France, and CAREM in Argentina[12].

Construction Starts

- Construction started on six reactors in 2023, down from 10 in 2022, both included five in China. Russia began work on one more reactor in Egypt.
- Construction of four reactors started in the first half of 2024, two of them in China, and one each in Russia and Egypt, both implemented by the Russian industry.
- Chinese and Russian government-owned or -controlled companies launched all 35 reactor constructions in the world over the 54-month period from the beginning of 2020 to mid-2024.

OPERATING AGE

- The average age (from grid connection) of the 408 operating nuclear reactors has been increasing since 1984 and stands at 32 years as of mid-2024, up from 31.4 years in mid-2023.
- A total of 269 reactors—four more than mid-2023—two-thirds of the world's operating fleet, have operated for 31 or more years; of these, 127—more than a quarter of the world's operating fleet—have operated for at least 41 years.
- If all currently licensed lifetime extensions were maintained, all construction sites completed as planned, and all other units operated for a 40-year lifetime (unless a firm earlier or later closure date has been authorized), in the years to 2030, the net balance of operating reactors would turn negative as soon as 2025, and slightly positive for the years 2026–2027. Overall, an *additional* 65 new reactors (43 GW)—almost one unit or 1 GW per month—would have to start up or restart to replace closures. This would necessitate almost doubling the annual startup rate of the past decade from six to eleven until 2030 just to maintain the current number of reactors in the world. Considering the long lead times, this is a highly unrealistic scenario. However, it is increasingly likely that at least one third of the 126 reactors slated for closure under this scenario will secure lifetime extension beyond 2030. Only further lifetime extension will avoid the world nuclear fleet to decline by 2030 and thereafter.

FOCUS COUNTRIES

The following 16 Focus Countries include 14 of the current 32 nuclear countries as well as potential newcomer countries Poland and Türkiye. Some key developments in 2023 and the first half of 2024:

12 - In 2022, the IAEA modified the construction-start date in the PRIS database from 2 February 2014 to 29 August 2016. WNISR does not take that modification into account.

Belgium. Nuclear generation dropped by 25 percent in 2023. Under the 2003-phaseout policy, one reactor was closed in September 2022 and another one in January 2023. Five reactors remain operational. The current plan is to close three by 2025 and extend operation by 10 years for the two most recent ones to 2035 or up to end of 2037 at the latest depending on the restart date following major upgrading. A legally binding agreement between the government and operator was signed and the Parliament passed a legislative amendment; implementation is awaiting European Commission approval and the final green light of the national safety authorities.

China. Nuclear power generation increased by 2.8 percent—a modest development compared to the 11-percent boost in 2021—and provided a stable 4.9 percent of total electricity generation, marginally lower than the 5 percent in 2022. While nuclear capacity grew by 1 GW, solar capacity alone grew by over 200 GW. Non-hydro renewables produced 17.6 percent of national gross power generation, 3.6 times more than the nuclear contribution.

Czech Republic. Czech nuclear production was stable. Newbuild projects remain embroiled in legal battles without any final decisions on builders for either large reactors or small modular reactors.

France. Following 2022, "annus horribilis", in the words of an EDF director, nuclear power generation recovered by 15 percent, but at 320 TWh remained still far from the 400 TWh considered normal a decade ago. Nuclear power represented 65 percent of the total power generation but only 16.3 percent of final energy. While the declared "planned" outage-days at zero-production dropped significantly in 2023 to (still remarkable) 127 days or four months per reactor, the declared "forced" outages have increased by 43 percent from 278 to 399 days exceeding any of the four previous years.

Hungary. The four Russian-designed VVERs generated almost 49 percent of the country's power, the fourth highest share in the world. The country is highly dependent on Russia for its energy supplies and has been instrumental in blocking E.U. attempts to include the nuclear sector in sanction packages. Construction start of a newbuild project, Paks II, implemented by Rosatom, could happen before the end of the year 2024.

Japan. Two additional reactors were restarted in the second half of 2023 bringing the total to 12 operating units while 21 reactors remain in LTO. Nuclear power generation surged by 49 percent, but the nuclear share in total electricity nevertheless dropped again slightly, from 6.1 percent to 5.6 percent. The Noto Peninsula earthquake (1 January 2024), of recorded magnitude 7.6, caused damage to the Shika nuclear power station, shut down since 2011, and raised concerns in the local community.

Netherlands. The country operates one over 50-year-old reactor, the oldest in the E.U., that provided 3.4 percent of total electricity. The incoming government envisages the construction of two to four large reactors and has invited South Korean KEPCO's subsidiary KHNP, Westinghouse, and EDF to carry out feasibility studies. The lower house of the Dutch Parliament voted a resolution to allow for the extension from two to four units. Meanwhile, the Netherlands has built up the largest installed per-capita solar capacity in the E.U.

Poland. In December 2023, a new administration was sworn in that, while in favor of the nuclear program, had previously expressed skepticism as to its feasibility, considering it was "not based on a robust economic analysis and lacks a business plan." A first startup is thought possible by 2035 with construction starting in 2028. Meanwhile, over the year, solar capacity grew by 30 percent to 15.8 GW and contributed 7.25 percent to the national power consumption, a 17-fold increase in four years.

Russia. Seventy years ago, in 1954, the Soviet Union/Russia became the first country to connect a nuclear power plant to the grid. Today, Russia's Rosatom is the leading nuclear power plant builder in the world with 26 units under construction in eight countries (including six in Russia) as of mid-2024. Rosatom also maintains its pro-active role in the hostile military occupation of Europe's largest nuclear power plant, Zaporizhzhia, in Ukraine.

South Korea. The country operates the fifth largest nuclear power program (by capacity and production) in the world. Its 25 operating reactors generated a record 171.6 TWh in 2023. The national nuclear utility is responding to calls for tender for reactor construction in various countries but has refused to reveal financial records on the sole previous foreign deal with the UAE. By mid-2024, KEPCO's debt load stood at an unparalleled US$147 billion.

Sweden. Nuclear power generation decreased by 6.7 percent, reaching 47 TWh accounting for just under 29 percent of national power production. The current government is determined to relaunch a nuclear newbuild program that should lead to at least 2.5 GW new capacity on the grid by 2035. However, so far, no design, provider, or site have been selected, and no financial package has been developed.

Taiwan. As of mid-2024, the country had two remaining reactors operating.[13] Four others had been closed in the framework of a national nuclear phaseout plan. The last unit is planned to close by May 2025. So far, the buildup of other power-generation options has been slow but picked up speed in 2022 when renewables' output outpaced nuclear for the first time. In 2023, solar power generation jumped by almost three quarters, while natural gas more than quintupled its 2020 production.

Türkiye. Russia's Rosatom started building four units at the Akkuyu site between 2018 and 2022. Turkish authorities had hoped to connect Unit 1 to the grid in 2023, to coincide with the 100th anniversary of the foundation of the Republic of Türkiye. That target was missed, and startup of the first unit was delayed to 2024, and then delayed again to 2025. Reportedly, one reason for the latest delay is that equipment from Germany had not been delivered, likely due to current geopolitical circumstances. The project has also been troubled by a series of technical problems, e.g. parts of the foundation had to be redone, and worker health and safety issues, including a deadly meningitis outbreak.

Ukraine. Of 15 operating or operable reactors, six are at the Russian occupied Zaporizhzhia site; shut down for nearly two years, they entered the LTO category as of mid-2024. The remaining operating reactors are a constant cause of concern in a country engaged in a full-blown war. At 51 percent, Ukraine is nevertheless the country with the third highest nuclear share in total electricity generation in the world. Westinghouse is partnering with Ukrainian companies in a project to build two AP-1000 at the Khmelnytskyi site. However, the licensing and financing aspects remain unclear.

13 - On 27 July 2024, one of the two units at Maanshan closed.

United Kingdom. There are only nine reactors with a combined capacity of 5.8 GW left operating in the country. Nuclear power generation dropped again by 14.5 percent to 37.3 TWh representing 12.5 percent of total electricity production (down from 28 percent in 1997). Meanwhile, further delays and cost increases for the two reactors under construction at Hinkley Point C have been announced; grid connection for the first unit is now planned between 2029 and 2031, and the price tag for the two units is estimated at US$52.5–59.2 billion.

United States. Nuclear output increased slightly (+0.9 percent) to 775 TWh. The nuclear share of commercial electricity generation increased accordingly by 0.4 percentage points to 18.6 percent. The U.S. nuclear fleet is still the largest in the world, with 93 units, as well as one of the oldest with a mean age 42.7 years. After 11 years of construction, the second of two new reactors at Plant Vogtle was connected to the grid in March 2024. All-in cost estimates for the two units have reached almost US$36 billion. In November 2023, SMR developer NuScale canceled its flagship Carbon Free Power Project (CFPP), after cost estimates soared and subscriptions hardly exceeded a quarter of the planned power generating capacity.

FUKUSHIMA STATUS REPORT

Thirteen years have passed since the Fukushima Daiichi nuclear power plant disaster began, triggered by the East Japan Great Earthquake on 11 March 2011 (also referred to as 3/11 throughout the report). The situation is still far from having been stabilized.

Overview of Onsite and Offsite Challenges

Onsite Challenges

Spent Fuel Removal. All spent fuel from the pool of Unit 3 had been removed by February 2021. Preparatory work is still underway on Units 1 and 2, with removal to begin in FY2027–2028 and to be completed by the end of 2031, more than 20 years after the disaster began.

Fuel Debris Removal. Due to technical challenges, operations have been postponed several times. Preparatory work for the trial debris removal at Unit 2 has made some progress. However, more detailed engineering studies on various retrieval options are needed.

Contaminated Water Management. As water injection continues to cool the fuel debris, highly contaminated water continues to run out of the cracked containments into the basements mixing with water from an underground river that has penetrated the basements. Various measures have reduced the influx of water from up to 540 m^3/day in 2015 to about 80 m^3/day in 2024. Nonetheless, an equivalent amount of water is partially decontaminated and stored in 1,000-m^3 tanks daily, with a new tank filling up in less than two weeks.

As of 31 March 2024, about 1.2 million m^3 of contaminated water were stored.

The safety authority have allowed operator TEPCO to release contaminated water into the ocean. As of the end of March 2023, about two thirds of the water needed to be treated again, and all of the water had to be diluted by a factor of 100 or more in order to meet licensed standards before being released into the ocean. TEPCO released approximately 31,200 tons of contaminated water in four rounds during the fiscal year through March 2024. The plan remains widely contested, including overseas.

Offsite Challenges

Offsite, the future of tens of thousands of evacuees, the contamination of food, and the management of decontamination wastes, all remain major challenges.

Evacuees. Although down from a peak of nearly 165,000 in May 2012, nearly 26,000 residents of Fukushima Prefecture remained living as evacuees as of 1 May 2024. In 2022, evacuation orders for some parts of the so-called "difficult to return areas" were lifted for the first time, but 2.2 percent of the Fukushima Prefecture surface continues to be designated as "difficult to return areas". These areas continue to have significant exposure levels.

Food Contamination. According to official statistics, of a total of 43,643 samples that were analyzed in financial year up to end of March 2023, 162 samples from twelve prefectures, of which over half from wild animal meat, exceeded the radionuclide concentration limits. Whether the testing program provides an adequate picture of the situation remains open, considering that e.g. 12.5 percent of the wild animal samples from Fukushima exceeded contamination limits. As of the end of May 2024, six countries and regions—down from a peak of 54—still had import restrictions for Japanese food items in place. In July 2023, the European Commission lifted its remaining import restrictions for the E.U.

Decontamination and Contaminated Soil Management. The effectiveness of the decontamination operations remains uncertain. Decontamination is carried out only for areas within 20 meters of the so-called "living areas". Around 71 percent of the Fukushima Prefecture is forested, so unsurprisingly only 2 percent of the area designated for decontamination was decontaminated. The contaminated soil is transferred to intermediate storage facilities in eight areas. As of the end of mid-2024, about 90 percent of total storage capacity was filled. The government is legally responsible for the final disposal of the contaminated soil.

DECOMMISSIONING STATUS REPORT

As an increasing number of nuclear facilities either reach the end of their pre-determined operational lifetime or close due to deteriorating economic conditions, timely decommissioning is becoming a key challenge.[14]

- The number of closed power reactors reached 213 units by mid-2024—one more than a year earlier and almost one third of the 655 reactors connected to the grid in the past 70 years have been closed. These had a total operating capacity of 106 GW.
- 190 units are awaiting or are in various stages of decommissioning.
- Only 23 units, or 11 percent of the closed reactors, have been fully decommissioned, one more than a year ago: 17 in the U.S., four in Germany, and one each in Japan and Spain (added over the past year). Of these, only nine, or 4 percent of all closed reactors, have been released from regulatory oversight as greenfield sites.

14 - Note that the status of radioactive waste management is not part of this analysis.

- The average duration of the decommissioning process is about 20 years, with a large range of 6–45 years (both extremes are for reactors with very low power ratings of 22 MW and 63 MW, respectively).
- The analysis of 11 major nuclear countries hosting 85 percent of all closed reactors shows that progress in decommissioning remains slow: of 159 units in various stages of advancement, 77 are in the "warm-up stage", 31 (+4 compared to one year earlier) are in the "hot-zone stage", 13 (+1) are in the "ease-off stage", while 38 (-1) are in "long-term enclosure" (45 globally).
- To date, four of the early nuclear states— Canada, France, Russia, and U.K.—have not fully decommissioned a single reactor.

POTENTIAL NEWCOMER COUNTRIES

Africa Focus

For the first time, a dedicated Africa Focus section looks at a selection of countries and the status of nuclear aspirations on the continent. Only South Africa operates two ageing reactors in continental Africa (see South Africa in Annex 1). China and especially Russia have been the most aggressive promoters of nuclear power. While China has cooperation agreements with Kenya and Sudan with no concrete follow-up yet, Russia has inked agreements with about 20 countries and is in the course of building one plant in Egypt, the only nuclear construction site in Africa.

As a rule of thumb, the largest unit in a grid system should not exceed 10 percent of total available capacity in the system. There needs to be sufficient reserve production and transmission capacity to keep the grid stable, even if the largest unit is not available. A typical large modern reactor has 1 GW. The analysis of 18 African countries shows that only four of these—Algeria, Libya, Morocco, and Nigeria—would meet the production capacity criteria with more than 10 GW in the grid. Even there, adequate transmission capacity is uncertain. These constraints have led some countries to consider SMRs instead of large units. Below is a status overview for selected countries:

Egypt. Construction of the first (Russian-designed) nuclear power plant was launched at the El Dabaa site on 20 July 2022, even as the war in Ukraine was ongoing. Building of Units 2, 3, and 4 began in November 2022, May 2023, and January 2024, respectively.

Ghana. The country has set up a Nuclear Regulatory Authority, the Ghana Atomic Energy Commission, and Nuclear Power Ghana to develop the first nuclear power plant project. The U.S. considers Ghana an important ally in the region and a U.S.-Japanese initiative aims at establishing Ghana as an African leader in SMR rollouts. The country's total installed capacity of around 5 GW would not allow for the integration of a large reactor.

Nigeria. The country signed nuclear cooperation agreements with several countries and considered the option of developing up to 4 GW of nuclear capacity. However, when in early 2023 Nigeria launched its Energy Transition Plan (ETP) with the goal of carbon neutrality by 2060, nuclear power did not feature amongst the options outlined for electricity generation.

Rwanda. The government signed an agreement with Canadian-German Company Dual Fluid in September 2023 to build and operate a demonstration unit by 2026. The capacity has not been specified in the announcement and it says "about 300 MW" on the company website. The innovative, untested design has not been licensed anywhere. The target date for startup seems unrealistic.

Uganda. The country offers a striking illustration of the disconnect between reality and plans for nuclear development: the Ugandan Government envisages the buildup of 24 GW of nuclear capacity, 18 times the country's total installed capacity.

Other Potential Newcomer Countries

Besides Egypt, two other potential newcomer countries had nuclear reactors under construction as of mid-2024: Bangladesh and Türkiye. Both of these projects are implemented by the Russian nuclear industry. The full impact of sanctions and potentially other geopolitical developments on the future of these projects remains uncertain albeit some effects have already been documented.

Bangladesh. Two reactors of Russian design have been under construction since 2017–2018. They were scheduled to start up in 2023 and 2024. Sanctions have reportedly led to delays in the delivery of some equipment and the commissioning of Unit 1 has been pushed back at least until December 2024. The impact of the recent turmoil in the country remains to be seen.

Jordan. Attention has shifted from large reactors to SMRs. In October 2023, the government had submitted plans for SMR deployment to the IAEA. No precise construction plans have been communicated.

Kazakhstan. Several potential suppliers had been considered for the construction of small or large reactors, but no technology has been chosen, no site selected, and no financing package announced. The government has announced the organization of a national referendum prior to the launch of a nuclear power program.

Saudi Arabia. The government has issued a call for "best and final offers" from China, France, Russia, and South Korea for the construction of two large reactors. But the deadline has been extended twice, to July 2024 the last time. The government has also explicitly invited the U.S. to provide an offer; however, that is at least delayed due to a number of non-proliferation concerns.

Uzbekistan. In May 2022, officials announced that a site for the construction of two Russian-designed VVER-1200 reactors had been chosen. Subsequently, the plan was apparently abandoned in favor of an SMR project. Reportedly, in May 2024 the government signed an agreement with Russia's Rosatom to build six 55-MW Small Modular Reactors (SMRs) in the eastern Jizzakh region. Should this materialize, it would be the first export agreement for an SMR anywhere in the world.

RUSSIA NUCLEAR DEPENDENCIES

Russia has not only developed into the dominant international vendor of nuclear power plants. Further, the country is also playing a key role in the supply of fuel services, including uranium mining, conversion, and fuel assembly manufacturing for Soviet-designed VVER pressurized water reactors, of which there are 19 in the E.U. and 15 in Ukraine. The U.S. introduced sanctions on some subsidiaries of Russian government-controlled company Rosatom in April 2023 and banned the import of uranium products from Russia in May 2024. Since the invasion of Ukraine in February 2022, the E.U. has passed 14 sanctions packages against Russia as of mid-2024. Despite repeated calls—notably by the European Parliament—the nuclear sector remained exempt from sanctions—a clear indication of dependency on Russia in the field.

Surprisingly, the share of Russian supply of natural uranium, conversion, and enrichment services to the E.U. all *increased* between pre-war year 2021 and 2023. E.U. imports of fuel assemblies "shot up in 2023" (*The Wall Street Journal*), in fact at least doubling in total (data for Bulgaria unavailable), with Slovakia more than quadrupling and Hungary more than doubling imports compared to 2021.

Efforts to reduce or eliminate Russia dependencies in natural uranium, conversion, and enrichment services will likely increase costs.

The quasi-monopoly of Rosatom and its subsidiary TVEL constituted a technical dependency. Westinghouse provided an alternative, but only for some clients, some fuel, and some periods of time. Since the Russian invasion of Ukraine, things are starting to change. Westinghouse has greatly expanded its client-base in Europe beyond Ukraine and is increasing manufacturing capacity. Concurrently, VVER-operating utilities accelerated fuel assembly deliveries, apparently due to concerns about potential sanctions on Russian fuel. Competitor Framatome is also entering the market.

Westinghouse has apparently reverse-engineered VVER fuel assemblies. Perhaps to avoid an expensive learning curve, Framatome decided to expand its long-term cooperation with Rosatom for the manufacturing of VVER fuel elements instead. The company chose its Lingen site in Germany to plan for a VVER-dedicated fuel assembly production line, which created political problems with the German authorities that have yet to be resolved.

Interdependence between Russia and its western partners remains significant. With Rosatom implementing all 13 nuclear power reactor construction sites started outside China over the past five years, providers of parts, e.g. France's Arabelle turbines, do not have any other foreign customer besides Rosatom. Germany's Instrumentation & Control technology has a similar problem.

The close mutual industrial and market interdependencies between the Russian nuclear industry and its western counterparts at least partially explain European hesitations to impose sanctions on the nuclear sector.

CIVIL-MILITARY CROSS-FINANCING IN THE U.K. NUCLEAR SECTOR

This chapter follows up directly on work discussed in WNISR2018 that examined interdependencies between civil and military nuclear infrastructures around the world. It summarizes an academic study, carried out in the framework of a wider U.K. Government project, that assesses the overall flows of money and other resources that deeply interlink supposedly separate civilian and military nuclear activities.

The study also provides a rough estimate of the opportunity costs of civil nuclear power use in the U.K., identifies revenues from 'civil' taxpayer and consumer budgets to cover costs of military nuclear activities that fall outside existing levels of defense spending, and assesses the costs of an expensive array of nuclear-specific policy, regulatory, research and industrial bodies that are unnecessary for non-nuclear strategies.

Subject to considerable uncertainties, the analysis suggests that the overall excess costs to the U.K. economy of keeping the national nuclear complex in operation, may be estimated conservatively to exceed £5 billion (US$6.3 billion) per year.

MILITARIZATION OF CIVIL NUCLEAR REACTORS: TRITIUM FOR NUCLEAR WEAPONS

In March 2024, the French Government announced that, following the closure of its dedicated tritium production reactors, it was partnering with the utility EDF to produce tritium for its nuclear weapons program at the Civaux dual-reactor nuclear power plant. Though the program has not yet been approved by the regulator, a first test is already planned for 2025. Virtually no information has been released on the project other than a one-page Defense Ministry press statement.

The chapter provides an overview of the purpose of tritium production and the precedent in the U.S. where the two Watts Bar reactors in Tennessee serve the same purpose. The first 18-month production cycle was started at Watts Bar-1 in 2003. It was discovered that the tritium permeation rate into the reactor coolant was nearly ten times higher than predicted, leading it to exceed the regulatory limit for tritium release in wastewater. This led the Nuclear Regulatory Commission (NRC) to impose a limit of the so-called Tritium-Producing Burnable Absorber Rods (TPBARs) per irradiation cycle significantly below the originally envisaged number. As the Department of Energy raised its tritium requirements (for unknown reasons), it applied for permission to increase absorber rods. NRC authorized an increase by a factor of 2.5 to a maximum of 1,792 absorber rods. The maximum amount was loaded in 2023 into Watts Bar-1 and 1,104 in Watts Bar-2. The effects of these changes to the tritium content in wastewater are not known yet.

SMALL MODULAR REACTORS (SMRs)

The gap between hype about Small Modular Reactors (SMRs) and industrial reality continues to grow. The nuclear industry and multiple governments are doubling down on their investments into SMRs, both in monetary and political terms. So far, reality on the ground does not reflect those efforts. SMR projects continue to be delayed or canceled. Costs for nuclear projects in general and SMRs in particular are surging. The few available cost estimates for SMRs, especially when weighted by their electrical power generation capacities, show how expensive these are.

The country-by-country status:

Argentina. The CAREM-25 project had been under construction since 2014. Reportedly, construction was halted in spring 2024 due to budget cuts (WNISR retains it 'under construction' for the time being). The National Atomic Energy Commission (CNEA), builder-owner of the reactor, decided to carry out a "critical design review" prior to construction restart. The estimated date for startup has been pushed back to 2028. Recent estimates suggest the reactor will cost at least US$800 million or US$32,000/kW, much more on a per kilowatt basis than the most expensive large Generation-III reactors.

Canada. Strong federal and provincial government support for the promotion of SMRs continues. The Canadian Nuclear Safety Commission (CNSC) also promotes SMRs. Several designs have gone through a "pre-licensing vendor design review" but none has yet been certified.

China. It took ten years between construction start and first full power in December 2022 for two high-temperature reactor modules, twice as long as anticipated. Since then, the operational record appears disappointing. Nominal capacity has been downrated for unknown reasons by 25 percent from 200 MW to 150 MW for the two units. A second design, the ACP100 or Linglong One, has been under construction since July 2021 with scheduled startup by May 2026.

France. In February 2022, President Macron announced a $\text{US\$}_{2022}$1.1 billion contribution to finance the development of the Nuward SMR design and other "innovative reactors". "Basic design" studies were to be completed by 2026 and construction was scheduled to start in 2030. But in mid-2024, EDF confirmed that it had suspended the development and reoriented the project "to a design based on proven technological building blocks". Consequences on timeline and costs are uncertain yet.

India. An Advanced Heavy Water Reactor (AHWR) design has been under development since the 1990s, but its construction has been continuously delayed. There have been no reports about progress over the past three years, which raises the possibility that the design has been shelved. Meanwhile, the government has announced the start of a new Bharat SMR program and talks continue about potential cooperation on SMRs with various countries including France and Russia.

Russia. Russia has a special focus on barge-mounted SMRs, and two 30-MW "floating reactors", the Akademik Lomonosov, were started up in December 2019, nine years later than planned. Since then, their performance has been mediocre. Two more barge-mounted projects are underway. Construction on a different, land-based SMR project, a lead-cooled fast reactor design called BREST-300, started in June 2021. The project has been discussed for a decade and was originally to be deployed by 2018.

South Korea. In 2012, the System-Integrated Modular Advanced Reactor (SMART) design received approval by the safety authority, but there have been no orders since. Several other designs are reportedly in early stages of development, in particular the "i-SMR". The regulator has yet to receive an application for standard design approval, not expected before 2026, with plans to start construction in 2029.

United Kingdom. Since 2014, Rolls Royce has been developing the "UK SMR", a (now) 470 MW reactor (exceeding the size-limit of 300 MW for the generally adopted SMR definition). The regulator is currently carrying out a Generic Design Assessment (GDA) that is scheduled to be completed by August 2026. Six other SMR designs were submitted for review of which four have been rejected for failing the GDA entry criteria and only Holtec's SMR-160 and GE-Hitachi's BWRX-300 were accepted for review. The government aims for a final investment decision by 2029.

United States. The Department of Energy (DOE) continues to offer large amounts of funding for SMR development. In June 2024, DOE announced it would provide US$0.8 billion for "up to two first-mover teams of utility, reactor vendor, constructor, and end-users or power off-takers committed to deploying a first plant". In other words, there is still not a single reactor under construction.

Only one design, NuScale, had received a (conditional) final safety evaluation report. However, since then, the design capacity has been increased from 50 MW to 77 MW per module, and many issues remain unresolved. By January 2023, cost estimates had ballooned to US$9.3 billion, and in early November 2023, the entire investment project was terminated.

In June 2024, the ground-breaking ceremony was held in Wyoming for TerraPower's Natrium fast reactor. The nuclear regulator has not yet licensed the design of the 345-MW fast reactor—exceeding the size-limit of the SMR-definition—nor has it issued a construction license.

NUCLEAR POWER VS. RENEWABLE ENERGY DEPLOYMENT

In 2023-24, the global energy landscape continued being reshaped by national, continental, and global climate ambitions in the face of persistent economic pressures, including inflation and geopolitical tensions. There is no doubt, however, that the renewable energy sector got another significant boost over the period. The Global Renewables and Energy Efficiency Pledge, launched at COP28 in Dubai in December 2023 and endorsed by about 130 national governments and the E.U., aims to triple global renewable energy capacity to 11,000 GW (11 TW) and double the annual rate of energy efficiency improvements to over four percent by 2030.

Investment. Total investment in non-hydro renewable electricity capacity in 2023 was estimated by Bloomberg New Energy Finance (BNEF) at US$623 billion, up 8 percent compared to the previous year. According to a WNISR estimate, this represents 27 times the reported global investment decisions for the construction of nuclear power plants of about

US$23 billion for 6.7 GW. According to BNEF, investment in solar increased by 12 percent to reach US$393 billion. Investments in wind power plants followed at US$217 billion seeing a slight reduction in investments for onshore wind more than offset by a record US$77 billion for offshore wind plants. BNEF estimated investments in stationary storage capacity at around US$36 billion, which, for the first time, exceeded investments into new nuclear.

Installed Capacity. Annual additions of solar and wind power grew by 73 percent and 51 percent, respectively, resulting in nearly 460 GW of combined new capacity, according to the International Renewable Energy Agency (IRENA). The solar PV market saw China alone adding around 217 GW—a 150-percent increase over 2022-additions—and the rest of the world 129 GW for a total of 346 GW or about 1 GW *per day*. The Global Wind Energy Council (GWEC) reported a record of 117 GW of new wind installations, a 50 percent year-on-year increase, with China accounting for 65 percent of total added onshore capacity and 58 percent of total added offshore capacity. These numbers compare with a net addition of 1 GW nuclear capacity in China and -1 GW globally between new startups and closures.

Electricity Generation. In 2021, the combined output of solar and wind plants surpassed nuclear power generation for the first time. In 2023, wind and solar facilities generated 50 percent more electricity than nuclear plants. Wind power alone generated 2,300 TWh and is getting close to nuclear's 2,600 TWh. Since 2013, non-hydro renewables added 3,500 TWh to the world's power generation, 14 times more than nuclear's roughly 250 TWh, and generated 80 percent more power than nuclear in 2023.

China. Solar PV produced a total of 578 TWh of electricity in 2023, for the second year in a row, overtaking nuclear power that generated 413 TWh by 40 percent. Wind outpaced nuclear in 2012 and has stayed ahead every year since. Wind power plants produced 877 TWh, more than twice the nuclear power generation. Adding other non-hydro renewables like biomass to solar and wind, the net total generation of 1,643 TWh represents four times the nuclear output, or more than three times the total power consumption of Germany, the world's fourth largest economy (by GDP in 2022).

European Union. In 2023, the E.U. achieved its largest renewable capacity additions ever and the renewable share in total electricity generation reached 44 percent, exceeding 40 percent for the first time. Solar and wind plants together produced 721 TWh—almost a quarter more than nuclear energy with 588 TWh—accounting for 27 percent of the E.U.'s gross electricity production. Notably, in 2023, for the first time ever, non-hydro renewables generated more power than all fossil fuels combined, and wind alone surpassed fossil gas. Fossil fuels generally dropped by a record 19 percent, reaching their lowest level ever and accounting for less than one-third of the E.U.'s electricity generation.

India. Over the period 2000–2023, electricity generation from wind power grew 50-fold. Solar power capacity surged by 85 percent in the short period between 2020 and 2023, while nuclear added nothing in operational capacity. Solar power generation soared by 19 percent in 2023 and India overtook Japan as the third largest solar electricity generator. Solar and wind individually generated 2.4 times and 1.8 times respectively more electricity than nuclear.

United States. According to the Solar Energy Industries Association (SEIA), solar power experienced remarkable growth in 2023 with a record 31 GW of new solar capacity installed—55 percent more than 2022 additions. Wind capacity increased by 8 GW. On-grid solar power output increased from virtually nothing in 2000 to 238 TWh in 2023. Over the same period, installed nuclear capacity has remained almost stable at 96–100 GW and production has fluctuated roughly between 750–810 TWh.

POWER FIRMING AND COMPETITIVE PRESSURE ON NUCLEAR

What is firming? Asset level firming pairs variable renewables with another power resource via co-located or hybrid plants to backfill hours when solar and wind are not available. Battery storage is increasingly used for firming, boosting reliability and availability for variable producers while also providing some additional market power to store and later sell electricity when prices are higher.

Power firming is already an important and growing complement to variable renewables. Within the United States, there were 374 hybrid power plants operating at the end of 2022, excluding hydro pumped storage. These comprised more than 40 GW of generating capacity, of which more than half were PV plus storage. Most of these installations have occurred since 2020, which is indicative of the rapid improvements in the viability and market attractiveness of utility scale batteries. In recent months, battery storage in the U.S. state of California has sometimes met more than 20 percent of peak power demand, contributing around 7 GW, the equivalent of seven large nuclear reactors, to the grid.

Multiple sources of value from utility-scale storage support continued rapid growth. Grid services and renewable firming dominate the use cases for wind while peak shaving is an additional area of importance for PV. These additional sources of value help to propel and accelerate storage installations.

Globally, utility-scale storage additions jumped from just over 10 GW added in 2022 to more than 25 GW in 2023 (net nuclear additions were -1 GW).

The OECD's International Energy Agency (IEA) has concluded in a recent study that, even if taking into account the increased need for reserve margin, spinning reserve, part-load penalties, and cycling costs, solar plus storage is on the winning stretch:

- Costs are expected to fall below those of coal-fired and nuclear power plants by around 2025 in China.
- Solar plus storage is already more competitive than coal in India and remains so going forward.
- Costs are expected to drop below those of new efficient gas-fired power plants before 2025 in the U.S., and "substantially extends its lead by 2030."
- Carbon pricing within the E.U. means that solar PV plus battery storage already easily outcompetes natural gas-fired power.
- Solar plus storage is already "significantly lower than nuclear power in most markets today," as well as "highly competitive with other low-emissions sources of electricity that are commercially available today."

Estimates by investment bank Lazard also conclude that solar hybrids are often cheaper than gas peaking and new nuclear, while wind plus storage turned out even less expensive than coal in many circumstances. The competitive cost and large-scale availability of variable renewable energy sources combined with firming options—especially storage—could well turn out to be the game-changer of energy policy in the years to come.

INTRODUCTION

The global geopolitical situation remains tense in 2024. The nuclear power issue is still linked to a full-scale war, with the largest European nuclear power plant by installed capacity, Zaporizhzhia in Ukraine, still under hostile military occupation, assisted by engineers of Russian state-owned company Rosatom. The six reactors of the site have not generated power since 2022. But, as Russia steps up attacks against power generating or transport facilities and is seeking to cause disruption to the power system especially during the coming winter, the other nine operational nuclear reactors also come under increasing threat.

In the summer of 2024, an additional nuclear risk zone was opened by Ukraine's surprise attack—which turned out to be much more significant than originally interpreted by international observers—in the Russian Kursk region, which houses another large nuclear power plant with two operating reactors, two closed ones, and two units under construction. The risk of a nuclear disaster has increased again.

WNISR2022's chapter on Nuclear Power and War detailed why a nuclear reactor needs a functioning cooling system at all times, meaning it also needs reliable electricity supply at all times, during operation and after shutdown.

WNISR2024 has a chapter on Russia Nuclear Dependencies analyzing the question of dependencies of many countries on Russia as nuclear service and hardware provider, but also the other way around. Of the 35 reactor construction-starts in the world in the five years between December 2019 and mid-2024, 22 took place in China and the remaining 13 were implemented by the Russian nuclear industry in eight countries (including Russia). Nothing else. Nowhere. As Chinese companies do not need foreign components, who will buy, for example, French Arabelle turbines if not Rosatom? At the same time, as the chapter demonstrates, the share of Russian supplies in natural uranium, enriched uranium, and fuel assembly deliveries to the European Union *went up* in 2023 if compared with pre-war year 2021.

Two International Atomic Energy Agency (IAEA) General Assemblies have passed since the beginning of the all-out war in Ukraine, yet nothing has been reported on the potential discussions about establishing basic conditions for prospective newcomer countries to receive technical assistance and by whom, now and in the future. Russia continues to implement by far the most newbuild projects around the world—20 outside Russia in seven countries—many of them, if not all, with the assistance of the IAEA. Still, neither political decision-makers nor the international media have addressed the issue.

In addition to the usual overview of potential nuclear newcomer countries, WNISR2024 features a section on developments in Africa where a lot of noise is being made around potential nuclear projects, conferences are being held, and countless memoranda being signed, most of them with little chances of concrete activities on the ground.[15] Not only are the costs out of reach for many countries, but the grid systems are too small for a large nuclear reactor of 1 gigawatt (GW) or more. As a rule of thumb, used by the IAEA and others, the largest unit in a grid should not exceed 10 percent of the total installed capacity. Only four out of

15 - See Melissa Chemam, "Africa's nuclear dreams a fusion of high hopes and high hurdles", *RFI*, 29 August 2024.

18 assessed African countries with nuclear ambitions have grids that exceed 10 GW (Algeria, Libya, Morocco, and Nigeria). However, on 29 August 2024, the U.S. State Department announced the "signing of a commercial agreement between Nuclear Power Ghana (NPG) and Regnum Technology Group, the U.S. developer for a Small Modular Reactor (SMR) project using NuScale Power technology."[16] The goal is the deployment of a single NuScale VOYGR-12 reactor module. The VOYGR-12 design is not yet licensed anywhere, and no information is available on timelines or the financial package.

Many international media outlets continue to provide large-scale coverage of early, often vague developments of SMR designs, politicians take policy decisions and make plans for the near future, investors speculate, despite the lack of major progress to report on the ground (see chapter on SMRs)—"at least not outside China and Russia—with no startups, no construction starts, not even a design certification" (no change from WNISR2023). The once most advanced scheme in the western world, a NuScale project with a conglomerate of Utah municipalities, was terminated in early November 2023 following a significant rise in cost estimates and the subsequent failure to line up enough potential clients.

While effective action on the climate emergency is needed across all sectors and societies, one of the highest profile initiatives is the pledge for a trebling of the current renewables' capacity and the doubling in energy efficiency by 2030. These targets were embraced by 133 countries at COP 28 in Dubai in December 2023. Beyond the traditional Nuclear Power vs. Renewable Energy Deployment chapter, this report presents a first analysis of Power Firming and Competitive Pressure on Nuclear, looking at the potentially game-changing developments in hybrid systems that aim to provide the same grid service and reliability as dispatchable sources like nuclear and fossil fuels. These systems are growing quickly and becoming increasingly competitive with conventional power supply options, including winning capacity auctions and alleviating demand peaks.

An assessment released by the International Renewable Energy Agency (IRENA) in July 2024 confirms that "renewables are the fastest-growing source of power worldwide, with new global renewable capacity in 2023 representing a record 14% increase from 2022", but that is not enough. The annual growth rate would need to be at least 16.4 percent to get on track of tripling capacity by 2030.[17] In comparison, nuclear power has become irrelevant in the international market for electricity generating capacity, with more nuclear capacity closing than being newly added to the world's grids.[18]

A pledge to triple nuclear generating capacity by 2050, was also launched during COP28—considering the lack of industrial capacity, low building rates, long lead-times, and high costs involved in nuclear construction—seems highly unrealistic and has attracted comparatively little support with 25 countries signing up, including major nuclear players like France, Japan,

16 - U.S. Department of State, "U.S. and Ghana Nuclear Firms Sign Landmark Commercial Agreement for Small Modular Reactor Project in Ghana", 29 August 2024, see https://www.state.gov/u-s-and-ghana-nuclear-firms-sign-landmark-commercial-agreement-for-small-modular-reactor-project-in-ghana/, accessed 31 August 2024.

17 - IRENA, "Tripling Renewables by 2030 Requires a Minimum of 16.4% Annual Growth Rate", Press Release, 11 July 2024, see https://www.irena.org/News/pressreleases/2024/Jul/Tripling-Renewables-by-2030-Requires-a-Minimum-of-16-point-4-pc-Annual-Growth-Rate, accessed 31 August 2024.

18 - Aaron Larson, "Analyst Says Nuclear Industry Is 'Totally Irrelevant' in the Market for New Power Capacity", *POWER*, 8 July 2024, see https://www.powermag.com/analyst-says-nuclear-industry-is-totally-irrelevant-in-the-market-for-new-power-capacity/, accessed 31 August 2024.

the U.K., and the U.S., but also non-nuclear countries like Jamaica, Moldova, Mongolia, and Morocco.[19] Significantly, the pledge does not include the two major nuclear builders China and Russia. The annual global reactor building rate would have to almost double from five in the past two decades to ten simply to replace aging units that can be expected to close by 2050 (see Lifetime Projections). In order to triple the installed capacity an additional 1,000+ reactors would need to be built. This is impossible considering there are only a handful of nuclear builders around the world that can respond to calls for tenders for large units, and all of them have considerable limitations: the French Electricité de France (EDF) and Korea's Korea Electric Power Corporation (KEPCO) have very large debt loads (US$60 billion and over US$140 billion, respectively) and face technical and manpower challenges with their existing ageing nuclear fleets and ongoing construction projects; the Chinese China General Nuclear Power Group (CGN) and China Natinal Nuclear Corporation (CNNC) have been blacklisted by the U.S. Government; Russian Rosatom is suffering from international sanctions; and Westinghouse has made it clear that it will only supply technology and engineering but not act as a builder anymore.[20] Who is supposed to build hundreds of nuclear power reactors around the world over the coming two and a half decades?

In 2023–2024, the gap has widened again between media attention, political announcements, and public perception of the nuclear sector on one side and the industrial reality on the other side. The comprehensive documentation and analysis that WNISR2024—just as earlier editions—provides on the status and trends of the nuclear industry shows a sector that struggles to maintain ageing operating fleets, accumulates significant delays and cost overruns at construction projects, and fails to timely develop competitive new designs.

One question remains: in the absence of a convincing economic, energy- or climate-policy argument, what are the drivers for policy decisions in favor of plant lifetime extension or nuclear newbuild? This is a complex question and there is not one answer that fits all situations. In most cases, it is a combination of various drivers such as the powerful, long-term lock-in effect of a nuclear power project that binds two or more countries together for decades and untransparent package deals involving strategic interests outside the nuclear sector be it fossil fuels, raw materials, defense related issues or items seen as strategic by the protagonists that are never made public. In a concerning number of cases, corruption has proven to be another powerful driver in many countries, including Brazil, China, Russia, and the U.S. (see also Nuclear Power and Criminal Energy in WNISR2021).

The multi-layer connection between nuclear power and the military sector is particularly interesting. Of 59 reactors under construction in the world as of mid-2024, 55 (93 percent) are either built in nuclear weapon states or by a nuclear weapon state-controlled company—e.g. Rosatom—in other countries.

WNISR2018 carried a first analysis of Interdependencies Between Civil and Military Nuclear Infrastructures in various countries. WNISR2024 presents a short update on the matter and

19 - U.S. Department of Energy, "At COP28, Countries Launch Declaration to Triple Nuclear Energy Capacity by 2050, Recognizing the Key Role of Nuclear Energy in Reaching Net Zero", United States Government, 1 December 2024, see https://www.energy.gov/articles/cop28-countries-launch-declaration-triple-nuclear-energy-capacity-2050-recognizing-key, accessed 31 August 2024.

20 - Kim Mackrael, James Marson Nikita Nikolaienko and Jennifer Hiller, "The American Company Trying to Keep Ukraine's Nuclear Reactors Online", *The Wall Street Journal*, 7 June 2024, see https://www.wsj.com/world/the-american-company-trying-to-keep-ukraines-nuclear-reactors-online-e636917a?mod=world_lead_story, accessed 31 August 2024.

deeper analysis of the U.K. case that provides for the first time an estimate of undeclared taxpayer and ratepayer financing flows to the civil and military nuclear sectors (see Civil-Military Cross-Financing in the U.K. Nuclear Sector).

Another example is dual-use of specific facilities. Following the French Government's decision to militarize the two most recent French power reactors at Civaux and start tritium production for its nuclear weapons program, this edition provides a short overview of the issue on the basis of the U.S. precedent at the Watts Bar plant (see Militarization of Civil Nuclear Reactors: Tritium for Nuclear Weapons).

Understanding the political and other motivations is essential to grounding the debate on the nuclear power option finally on fact-based analysis. The WNISR provides a contribution to that goal.

GENERAL OVERVIEW WORLDWIDE

ROLE OF NUCLEAR POWER – NUCLEAR POWER GENERATION

For the past five years, Russia has been the dominating global reactor builder outside China and, even after the full-scale invasion of Ukraine and a hostile takeover of Europe's largest nuclear power plant, Zaporizhzhia, it continues to work closely with the International Atomic Energy Agency (IAEA), especially in potential newcomer countries. In its introductory statement to the First Session of the Preparatory Committee for the 11th Review Conference of the Parties to the Non-Proliferation Treaty (NPT) in August 2023, the Russian Ministry of Foreign Affairs stressed:

> Russia considers the efforts to promote the nuclear energy development central to the IAEA work. We cooperate with the Agency in implementing the initiative launched in 2017 to develop the nuclear energy infrastructure of newcomer countries. Russia is the initiator and leading donor of the IAEA International Project on Innovative Reactors and Fuel Cycles, in which 43 countries and the European Commission participate. (…)
>
> We note that all NPT-compliant countries should have access to peaceful nuclear energy without any additional conditions.[21]

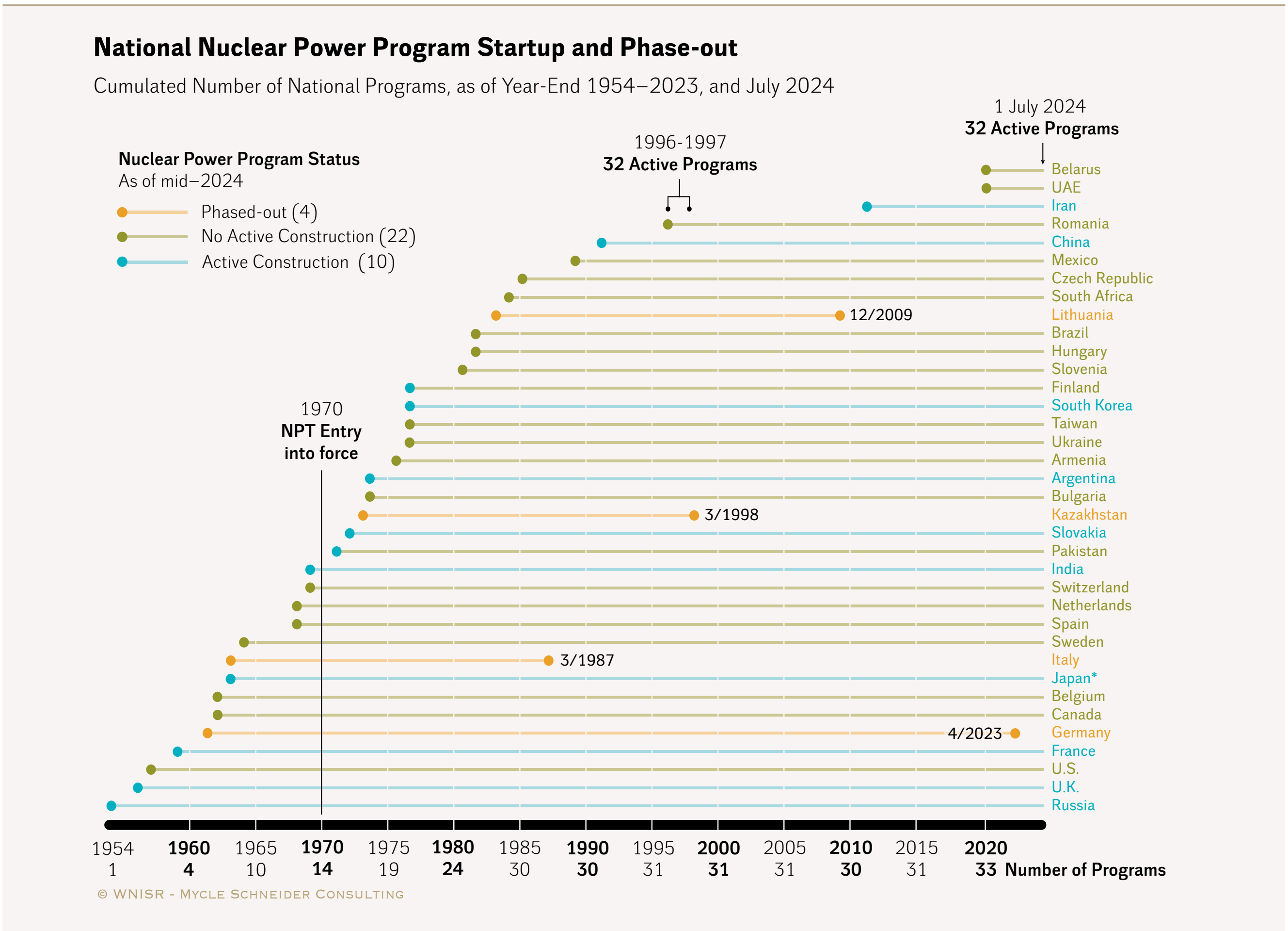
As of mid-2024, 32 countries operated nuclear power programs. Figure 1 illustrates how the spread of nuclear power throughout the world took place at a significantly slower pace and smaller scope than anticipated in the early 1970s:

- Fourteen countries had operating nuclear power reactors (grid connected) when the Treaty on the Non-Proliferation of Nuclear Weapons (commonly known as the nuclear Non-Proliferation Treaty, or NPT) entered into force in 1970.
- Sixteen additional countries were operating power plants by 1985, the year when reactor startups peaked.
- Four countries (Romania, Iran, United Arab Emirates, and Belarus) have started up power reactors for the first time over the past 30 years, of which two in 2020.
- The number of countries operating power reactors in 1996–1997 reached 32. It took another 23 years to reach a new peak at 33 countries.
- Four countries (Germany, Italy, Kazakhstan and Lithuania) abandoned their nuclear power programs.
- Ten of the 32 nuclear countries have active reactor construction programs.
- Twenty-two nuclear countries are not currently constructing any reactors (or construction is suspended); of these, four have either nuclear phaseout, no-newbuild, or no-program-

21 - Russian Ministry of Foreign Affairs, "Statement by the Head of the Delegation of the Russian Federation at the First Session of the Preparatory Committee for the 11th Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (General debate)", Government of Russia, 1 August 2023, see https://mid.ru/en/foreign_policy/news/1899782/, accessed 11 August 2023.

extension policies in place (Belgium, Spain, Switzerland and Taiwan). Some of these program-limitation policies, such as in the Netherlands and Sweden, have been revised only recently. However, while policy changes in some countries reopen the door for nuclear newbuild, actual work on the ground remains many years away.

Figure 1 • National Nuclear Power Programs Development, 1954–2024



Sources: compiled by WNISR, with IAEA-PRIS, 2024

In 2023, the world nuclear fleet generated 2,602 net terawatt-hours (TWh or billion kilowatt-hours) of electricity[22], (see Figure 2). After a decline in 2020, nuclear production increased by 3.9 percent in 2021, dropped by 4 percent in 2022 and increased again by 2.2 percent in 2023. As in 2021, it stayed below the 2019 level. China, with a 2.8-percent increase (compared to 11 percent in 2021 and 3.2 percent in 2022), produced more nuclear electricity than France for the fourth year in a row, and remains in second place—behind the U.S.—of the top nuclear power generators. Nuclear production outside China increased by 2.1 percent, to reach the equivalent of the global production of 1995.

22 - If not otherwise noted, all nuclear capacity and electricity generation figures throughout the report are based on International Atomic Energy Agency (IAEA), Power Reactor Information System (PRIS) online database, see https://prisweb.iaea.org/Home/Pris.asp. Production figures are net of the plant's own consumption unless otherwise noted, from IAEA-PRIS, "World Statistics—Nuclear Share of Electricity Generation in 2023", Power Reactor Information System, International Atomic Energy Agency, 2024, see https://pris.iaea.org/PRIS/WorldStatistics/NuclearShareofElectricityGeneration.aspx. However, as global nuclear production for 2022 and 2023 provided by IAEA-PRIS does not contain production for Ukraine, net production includes data for Ukraine from Energy Institute, "Statistical Review of World Energy", 2024.

Nuclear energy's share of global commercial gross electricity generation in 2023 was almost stable at 9.15 percent—the lowest value in four decades—and over 45 percent below the peak of 17.5 percent in 1996.[23]

Non-hydro renewables continued their growth, with a 13-percent increase, to reach a share of 7.5 percent in primary energy. While the share of non-hydro renewables is now 1.9 times larger than the nuclear share, both figures illustrate how modest the current contribution of both technologies remains in the global context.

Nuclear's main competitors, non-hydro renewables (primarily solar and wind) grew their gross output by 12.9 percent and their share in global gross power generation increased by 1.5 percentage points to 15.9 percent.

Non-hydro renewables continued their growth, with a 13-percent increase, to reach a share of 7.5 percent in primary energy. While the share of non-hydro renewables is now 1.9 times larger than the nuclear share, both figures illustrate how modest the current contribution of both technologies remains in the global context.

In 2023, there were ten countries—compared to six in 2022—that increased the nuclear share in their respective electricity mix, including two "newcomer countries", the United Arab Emirates (UAE) and Belarus, which generated nuclear power for the first time in 2020, while eight decreased, and 15 remained at a constant level (change of less than 1 percentage point). Besides the UAE and Belarus, six countries (China, Finland, India, South Korea, Pakistan, Slovakia) achieved their largest ever nuclear production. Belarus, China, and Slovakia started up new reactors during the year, as well as South Korea, but only in December, so with little effect on overall output which increased by modest 2.5 percent.

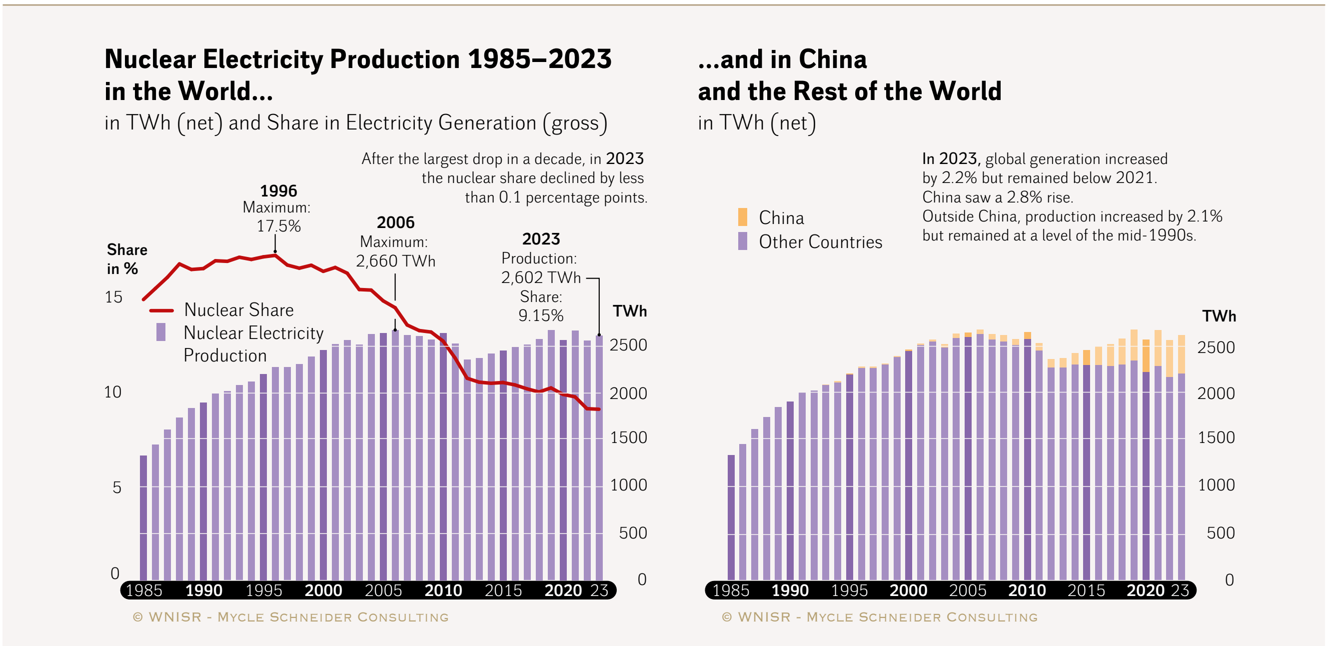
The following noteworthy developments for the year 2023 illustrate the volatile operational situation of the individual national reactor fleets (see country-specific sections for details):

- **Argentina**'s nuclear production increased by nearly 20 percent following a drop of 26.5 percent, primarily due to months-long—planned and unplanned—maintenance and reparation outages at one of its three reactors.
- **Belarus** has seen a spectacular, close to 150-percent increase in nuclear generation mainly due to the startup of its second unit.
- **Belgium,** following an exceptional 2021 and a drop of 13 percent output in 2022, nuclear power production declined again by 25 percent partially due to the closure of one unit in February 2023.
- **China** started up only one unit following three startups in both 2022 and 2021, with nuclear generation increasing a modest 2.8 percent following increases in 2022 and 2021 of respectively 3.2 percent and 11.2 percent.
- **Finland** saw a significant 35 percent increase in nuclear generation due to the beginning of the commercial operation of the largest nuclear reactor in the country, Olkiluoto-3, 18 years after construction start.

23 - This and the following paragraphs are based on Energy Institute, "Statistical Review of World Energy 2024 - Consolidated Dataset", 2024, see https://www.energyinst.org/__data/assets/excel_doc/0004/1540552/merged_narrow.xlsx.

- **France**'s nuclear generation picked up by close to 15 percent following a record 22.7 percent drop to below 300 TWh for the first time since 1990 but remained below 400 TWh for the eighth year in a row.
- **Germany** completed its nuclear phaseout in mid-April 2023 and therefore nuclear power output declined by 79 percent compared to 2022.
- **Japan** has boosted nuclear electricity generation by almost half following the restart of two additional units—12 reactors are now in operation—and improved productivity of the remaining fleet.
- **South Africa** once again has experienced a highly volatile nuclear generation pattern. Output dropped again by close to 20 percent following a 17-percent decline in 2022.
- The **UAE** reached a logical all-time high in nuclear power generation after connecting to the grid the third of four nuclear units that were under construction. Output increased by 31 percent.
- In the **U.K.**, after decreasing steadily between 2016 and 2021, nuclear generation increased by 4.3 percent in 2022. However, as two reactors closed in the second half of 2022, output dropped by 14.5 percent in 2023.

Figure 2 • Nuclear Electricity Generation in the World... and China



Sources: WNISR, with IAEA-PRIS and Energy Institute, 2024

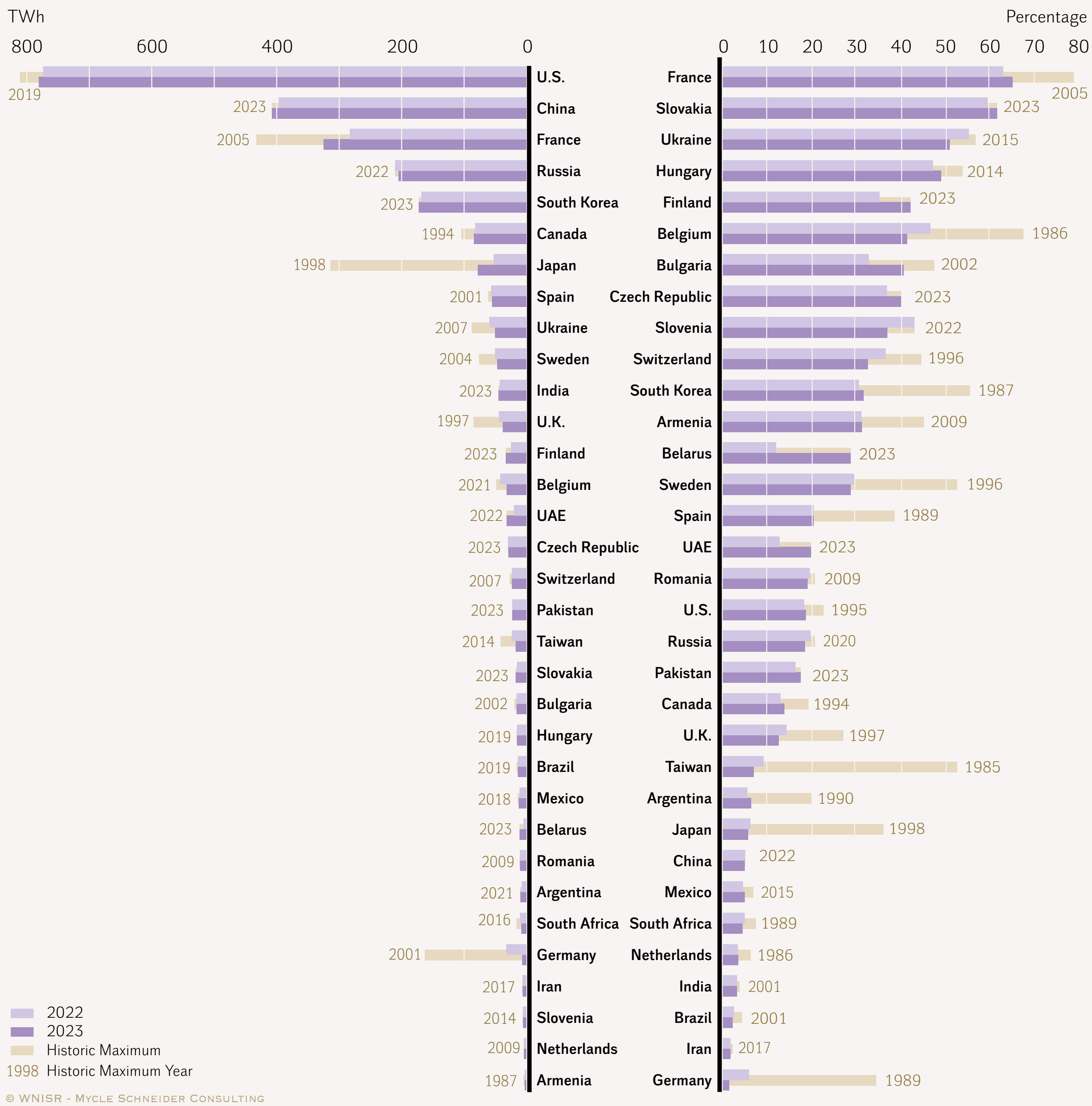
Note: IAEA-PRIS production data for the years 2022 and 2023 does not include Ukraine (data unavailable). Net nuclear production for Ukraine for those years represented 59 TWh and 49 TWh respectively according to the Energy Institute's "Statistical Review of World Energy" dataset.[24] The total number is thus based on IAEA-PRIS plus the production figure for Ukraine from the Energy Institute.

Similar to previous years, in 2023, the "big five" nuclear generating countries—the U.S., China, France, Russia, and South Korea, in that order—generated 72.4 percent of all nuclear electricity in the world (see Figure 3, left side).

24 - Energy Institute, "Statistical Review of World Energy 2024 - Consolidated Dataset", 2024, op. cit.

In 2002, China was 15th in terms of global production levels; in 2007, it was tenth, and it reached third place in 2016. In 2020—earlier than anticipated due to the mediocre performance of the French fleet—China became the second largest nuclear generator in the world, a position that France held since the early 1980s. That has not changed since.

Figure 3 · Nuclear Electricity Generation and Share in National Power Generation



Sources: IAEA-PRIS, and Energy Institute data for Ukraine, compiled by WNISR, 2024

Note: For comparison reasons, data used in this graphic are IAEA-PRIS data, except for Ukraine, and may differ from data used in the country sections.

In 2023, the top three countries, the U.S., China, and France, remained at around 58 percent of global nuclear output, underscoring the concentration of nuclear power generation in a very small number of countries.

In many cases, even where nuclear power generation increased, the addition is not keeping pace with overall increases in electricity production, leading to a nuclear share below the respective historic maximum (see Figure 3, right side). Six of the current 32 nuclear countries achieved their historically largest nuclear shares in the 1980s, seven in the 1990s, six in the 2000s, four in the 2010s, nine in the short 2020s with a remarkable eight for the single year of 2023.

STARTUPS/CLOSURES, OPERATION, AGE DISTRIBUTION

Since the first nuclear power reactor was connected to the Soviet power grid at Obninsk in 1954, there have been two major waves of startups. The first peaked in 1974, with 26 grid connections. The second reached a historic maximum in 1984 and 1985, just before the Chornobyl accident in 1986, reaching 33 grid connections in each year. By the end of the 1980s, the uninterrupted net increase of operating units had ceased, and in 1990, the number of reactor closures[25] outweighed the number of startups for the first time.

The 1994–2003 decade globally produced almost a third more startups than closures (44/33), while in the decade 2004–2013, startups compensated for only about 60 percent of the closures (35/59) (see Figure 4).

In the past decade 2014–2023, 67 reactors were started-up, that is 60 percent more than in the previous decade—of which 37 (55 percent) in China—and 45 were closed (none in China).

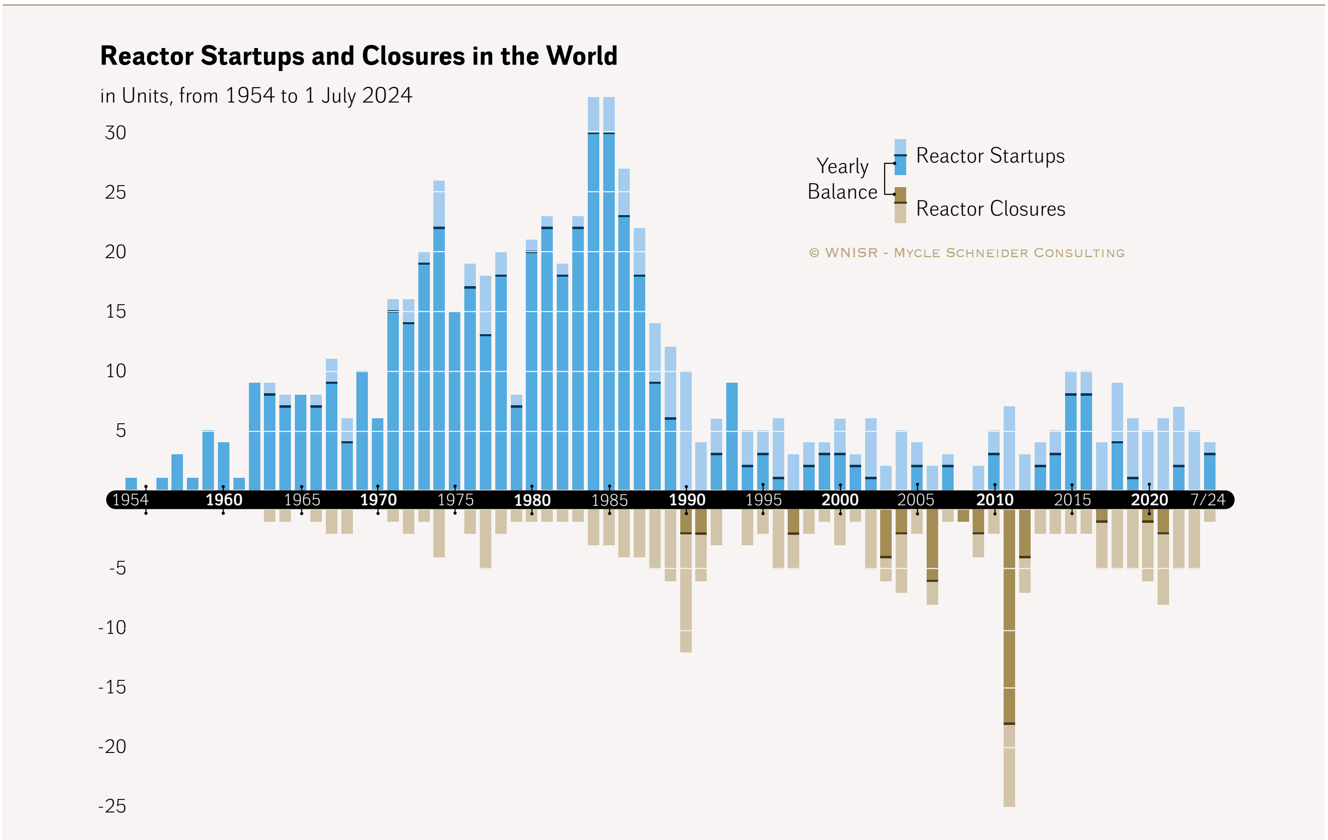
Over the past two decades 2004–2023, there were 102 startups and 104 closures. Of these, 49 startups were in China which did not close any reactors. As a result, outside China, there has been a drastic net decline of 51 units (see Figure 5). As larger units were started up (totaling 94 GW) than closed (totaling 73.3 GW) the net nuclear capacity added worldwide over the 20-year period was 20.7 GW. However, since China alone added half of the capacity (47 GW), the net capacity outside China declined by almost 26.5 GW.

In 2023, five reactors were connected to the grid, one each in Belarus, China, Slovakia, South Korea, and the U.S., and five were closed, three in Germany and one each in Belgium and Taiwan.

In the first half of 2024, four units were connected to the grid, one each in China, India, the UAE, and the U.S., and one was closed in Russia. (See Figure 5).

25 - WNISR considers closure from the moment of grid disconnection—and not from the moment of the industrial, political, or economic decision—and as the units have not generated power for several years, in WNISR statistics, they are closed in the year of their last power generation.

Figure 4 · Nuclear Power Reactor Grid Connections and Closures in the World



Sources: WNISR, with IAEA-PRIS, 2024

Notes: WNISR considers reactors closed as of the date of their last electricity production, and not as of their closure announcement (which can be made years after the reactor ceased production).

As of 1 July 2024, a total of 408 nuclear reactors were operating in 32 countries, one more than reported for mid-2023.[26] The current world fleet has a total electric net operating capacity of 367.3 GW. As the annual statistics always reflect the status at year-end, the situation might change again by the end of 2024.

The number of operating reactors remains ten below the fleet size already reached in 1989 and 30 below the 2002-peak (see Figure 6).

Usually, the capacity of new reactors is larger than the ones that are closed. The year 2023 was an exception: while five reactors closed and five reactors started up, the capacity of those closed at 6 GW exceeded the new ones by 1 GW, mainly because of the retirement of three large German units totaling over 4 GW.

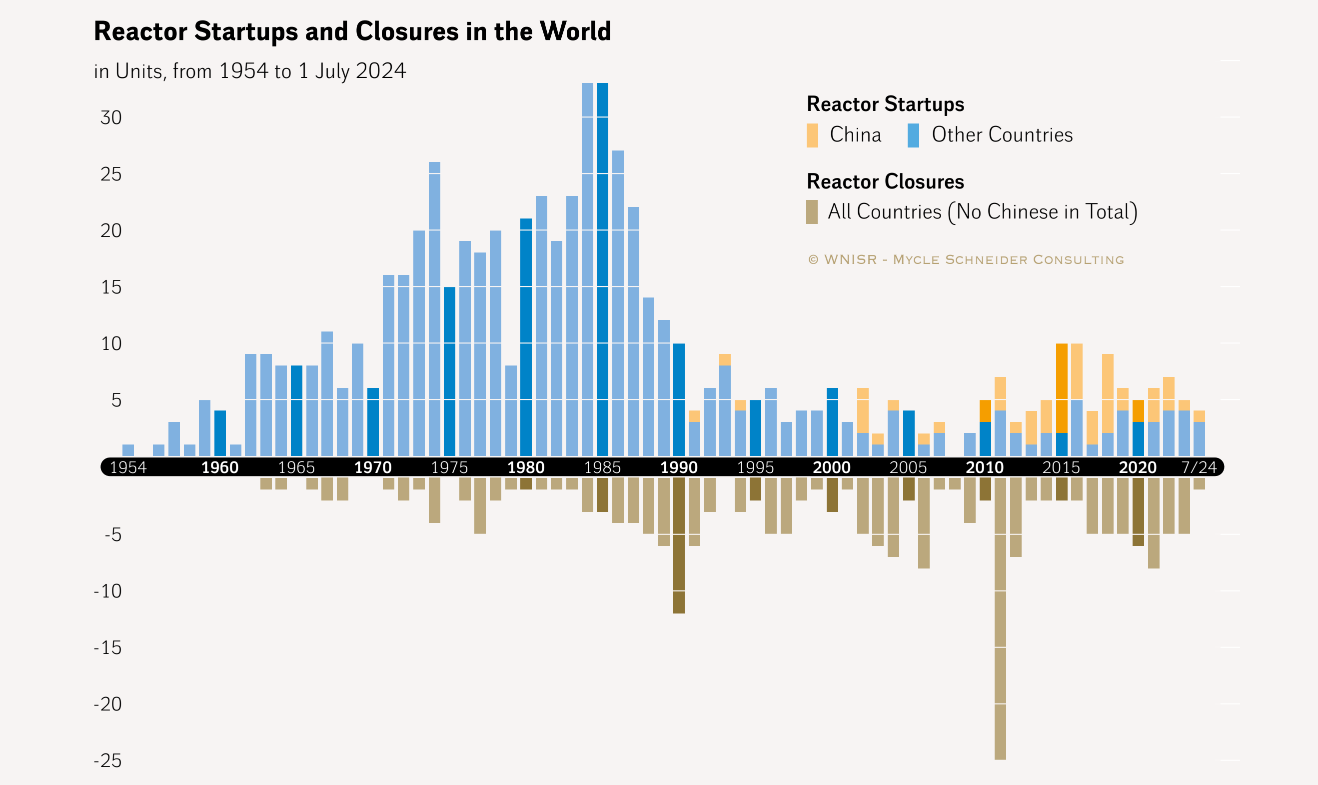
For many years, the capacity increased more than the number of reactors as a result of the combined effects of larger units replacing smaller ones and "uprating". In 1989, the average size of an operational nuclear reactor was about 740 MW, in 2023 it was almost 900 MW. Technical alterations raised capacity at existing plants resulting in larger electricity output, a process known as uprating.[27] In the U.S. alone, the Nuclear Regulatory Commission (U.S. NRC) has

26 - Balance since WNISR2023: +5 startups +5 restarts –8 new LTO –1 closure = +1 operating unit.

27 - Increasing the capacity of nuclear reactors by equipment upgrades e.g. more powerful steam generators or turbines.

approved 172 uprates since 1977. The cumulative approved uprates in the U.S. total 8 GW, the equivalent of eight large reactors. These include seven minor uprates (<2 percent of reactor capacity) approved since mid-2020, of which only one since mid-2021.[28] So this is a program that is pretty much completed in the U.S.

Figure 5 · Nuclear Power Reactor Grid Connections and Closures – China Effect Pausing?

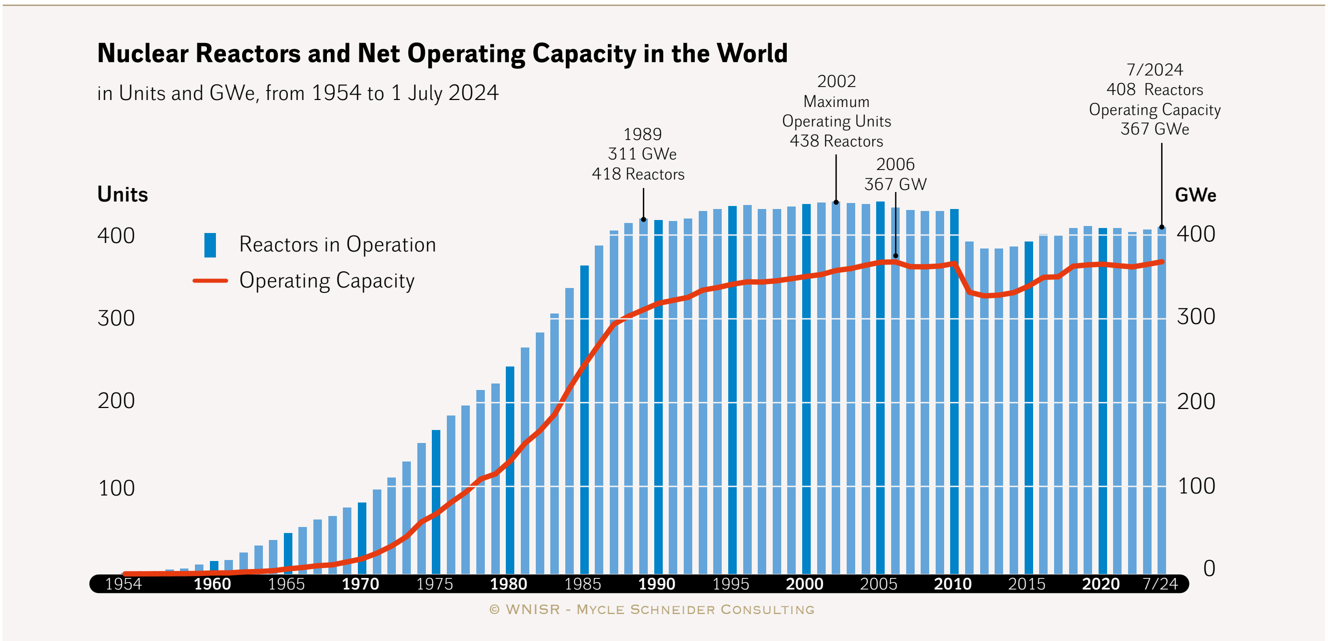


Sources: WNISR, with IAEA-PRIS, 2024

A similar trend of uprates and major overhauls in view of lifetime extensions of existing reactors has been seen in Europe. The main incentive for lifetime extensions is economic but this argument is being increasingly challenged as refurbishment costs soar and alternatives become cheaper.

28 - U.S. NRC, "Approved Applications for Power Uprates", United States Nuclear Regulatory Commission, Updated 20 October 2023, see http://www.nrc.gov/reactors/operating/licensing/power-uprates/status-power-apps/approved-applications.html, accessed 7 July 2024.

Figure 6 · World Nuclear Reactor Fleet, 1954–mid-2024



Sources: WNISR, with IAEA-PRIS, 2024

IAEA's Operating Reactor Data Revisions

Until September 2022, the IAEA's online Power Reactor Information System (PRIS) database counted 33 reactors as operational/operating in Japan, whereas 20 of these had not produced power since 2010–2012, and an additional three units had been shut down even since the Niigata Earthquake in 2007.

For almost a decade, WNISR has been calling for an appropriate reflection in world nuclear statistics of the unique situation in Japan. The approach taken by the IAEA, the Japanese Government, utilities, industry, and many research bodies as well as other governments and organizations to continue classifying the entire stranded reactor fleet in the country as "in operation" or "operational" was misleading.

Faced with this dilemma, the WNISR team in 2014 decided to create a new category with a simple definition, based on empirical fact, without room for speculation: "Long-Term Outage" or LTO. Its definition:

> A nuclear reactor is considered in Long-Term Outage or LTO if it has not generated any electricity in the previous calendar year and in the first half of the current calendar year. It is withdrawn from operational status retroactively from the day it was disconnected from the grid.

When subsequently the decision is taken to close a reactor, the closure status starts with the day of the last electricity generation, and the WNISR statistics are retroactively modified accordingly.

IAEA's Category "Suspended Operation"

On 16 January 2013, the IAEA moved 47 reactors in Japan, most of them shut down in the aftermath of the Fukushima events in 2011, from the category "In Operation" into "Long-term Shutdown"[29] that existed in the IAEA statistical system until October 2022. Only two days later, the move was labelled a "clerical error" and the action was reversed at the request of the Japanese Government.[30]

It was only in September 2022, that in the IAEA-PRIS database, twelve Japanese reactors[31] were gradually withdrawn from the list of "operating" or "operational" reactors, and their status changed to "Long-term Shutdown" (LTS). By mid-October 2022, the category title was changed to "Suspended Operation" on the PRIS website[32], and in November 2022, four more Japanese units[33] joined the new category as well as one Indian reactor (Rajastan-1) that has not generated any power since 2004 and is considered closed by WNISR.

As of the end of 2022, the PRIS database still counted 17 Japanese reactors as "in Operation". Whereas ten had effectively restarted since the beginning of the Fukushima disaster (also referred to as 3/11), the remaining seven had not produced any electricity since 2010–2012. Then, in April 2023, those seven units also joined the "Suspended Operation" category, followed by three additional Indian reactors in May 2023, that have not produced power since 2018 (Madras-1) and 2020 (Tarapur-1 & -2).

The definition of the new category is as follows:

> A reactor is considered in the suspended operations status, if it has been shut down for an extended period (usually more than one year) and there is the intention to re-start the unit but:
>
> 1. restart is not being aggressively pursued (there is no vigorous onsite activity to restart the unit) or
>
> 2. no firm restart date or recovery schedule has been established when unit was shutdown [shut down].
>
> Suspended operations may be due to [~~due to~~] technical, economical, strategic or political reasons. This status does not apply to long-term maintenance outages, including unit refurbishment, if the outage schedule is consistently followed, or to long-term outages due to regulatory restrictions (licence suspension), if restart (licence recovery) term and conditions have been established. Such units are still considered "operational" (in a long-term outage). If

29 - WNISR, "Historic Move: IAEA Shifts 47 Japanese Reactors Into "Long-Term Shutdown" Category", 16 January 2013, see https://www.worldnuclearreport.org/Historic-Move-IAEA-Shifts-47.html, accessed 14 November 2023.

30 - WNISR, "IAEA-Japan Reactor Status Incident: "Clerical Error" Explanation Not Credible", 20 January 2023, see https://www.worldnuclearreport.org/IAEA-Japan-Reactor-Status-Incident.html, accessed 14 November 2023.

31 - Kashiwazaki Kariwa 1–5, then Tomari 1–3, then Hamaoka 3–5, followed by Tsuruga-2.

32 - In fact, this category was already mentioned in the IAEA's "Nuclear Power in the World" booklet in July 2015, but never used in the Agency's online resources. It said: under "Long term shutdown (suspended operation)": "A unit is considered to be in long term shutdown if it has been shut down for an extended period (usually several years) initially without any firm recovery schedule, but with the intention to restart the unit eventually. Suspended operation is a new term for this status.

33 - Higashi Dori-1, Onagawa-3 and Shika-1 & -2.

> an intention not to restart the shutdown unit has been officially announced by the owner, the unit is considered "permanently shutdown [shut down]".[34]

It is important to understand that the application of this new rule modifies retroactively *all of* the IAEA's statistics on operating reactors—in most cases as of day of last production—back to 2007. This dramatically modifies the IAEA's representation of the Japanese nuclear reactor fleet's evolution. The changes obviously also impact the IAEA's representation of the long-term evolution of the entire global nuclear power-reactor fleet (see a detailed discussion in WNISR2023).

The differences with WNISR statistics are greatly reduced, and the remaining ones mostly relate to official closure dates, as WNISR statistics consider the end of electricity production as reference for dating closures, and not the "announcement" or "political decision" to permanently withdraw a reactor from the grid.

IAEA vs. WNISR Assessment

WNISR's assessment of "operating" reactors has shown significant differences with IAEA statistics since the beginning of the Fukushima disaster in 2011. However, after major changes in the PRIS statistics (see above), those differences were reduced to minor disparities during the period September 2022 to May 2023.

The following section provides a detailed explanation and justification of the differences.

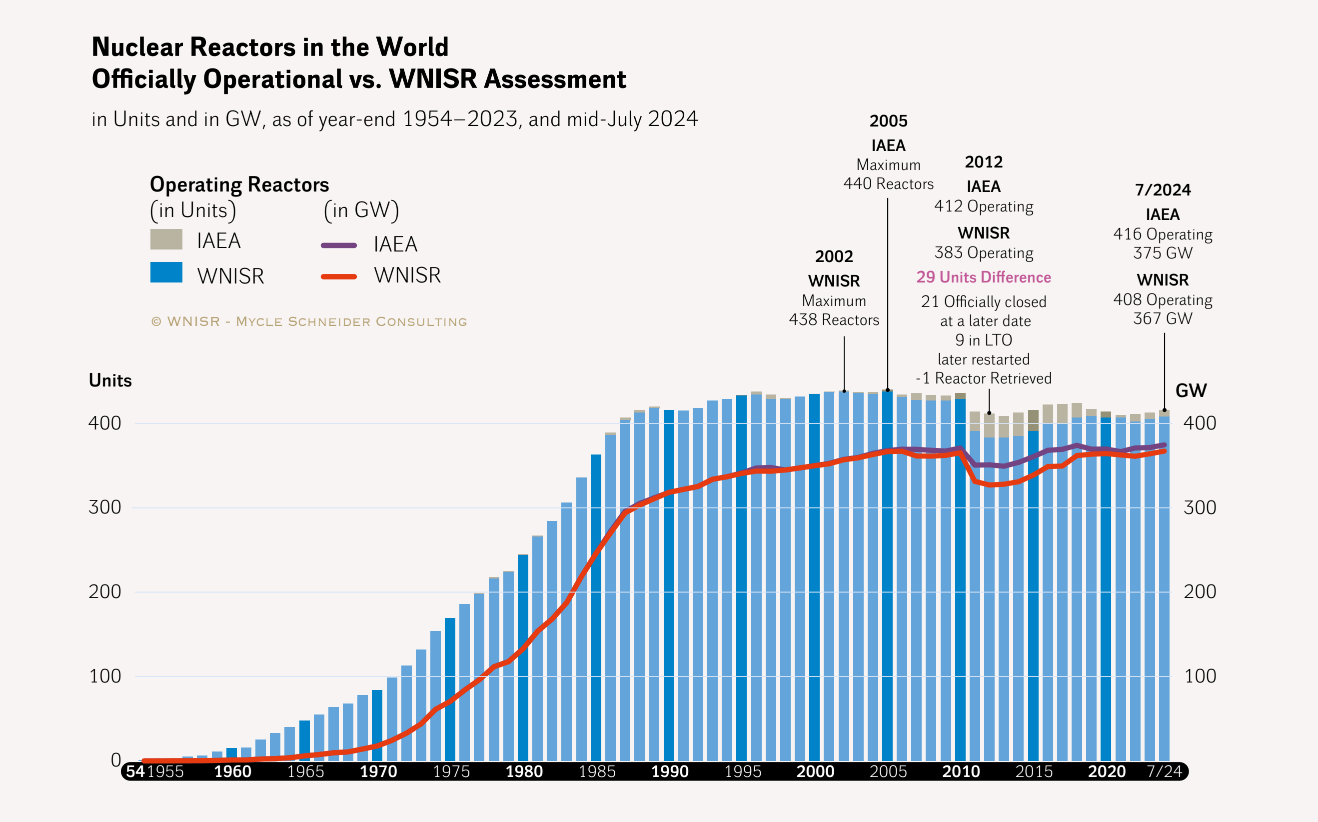
Figure 7 presents the evolution of the number and capacity of the world reactor fleet "in operation" as reported by the IAEA vs. WNISR.

As of July 2024, the evolution of the world nuclear fleet in the IAEA-PRIS statistics shows a peak of 440 reactors operating in 2005, whereas the operating capacity reached 374.7 GW, marginally over the previous peak of 374 GW reached in 2018; as of the end of 2023, the operating capacity was 371.5 GW.

In the WNISR statistics, which consider reactors closed from the day they stop producing electricity, and systematically apply the LTO status to reactors not operating for a certain period, a maximum number of 438 *operating reactors* was reached as soon as 2002, and again in 2005. At the end of 2023, with a balance of minus 1 GW between closed and newly started-up reactors and a balance of three additional reactors in LTO, the *operating capacity* stayed at 364.7 GW below the previous peak of 367.1 GW in 2006 but in July 2024, with 367.3 GW, just exceeded the previous record.

34 - IAEA-PRIS, "Glossary of Terms in PRIS Reports", Power Reactor Information System, International Atomic Energy Agency, 2023, see https://pris.iaea.org/PRIS/Glossary.aspx, accessed 14 November 2023.

Figure 7 • World Nuclear Reactor Fleet – IAEA vs WNISR, 1954–July 2024



Sources: IAEA-PRIS and WNISR, 2024

Notes: The IAEA data used for this graph includes at least three reactors that have been later withdrawn from the PRIS statistics for operating reactors (Niederaichbach, VAK-Kahl and HDR Großwelzheim, in Germany, now only appearing as "Decommissioning Completed"). On the other hand, the Swiss research reactor in Lucens is not included. Reactors classified as in "Suspended Operation" by the IAEA are not represented here.
Although the total number of reactors in operation according to WNISR statistics has always remained, albeit slightly, inferior to IAEA-PRIS data, it contains Chinese reactors not accounted for in PRIS (see below).

Although not the only case, the Japanese fleet still provides the main and most visible differences between the two datasets, especially over the past decade. This applies both to reactors that did not produce electricity for many years before they returned to service (designated as "LTO later restarted" or "Restarted from LTO"), or which were declared permanently closed years after they stopped producing electricity ("Closed at a later date").

Applying this definition to the world nuclear reactor fleet, as of 1 July 2024, leads to classifying nine units considered "in operation" by the IAEA as in LTO:

- Darlington-1, under refurbishment since February 2022 (see Canada in Annex 1).
- Kori-2 in South Korea, shut down in April 2023, after 40 years of operation, expected to be restarted at an unknown date, and therefore considered in LTO (see South Korea Focus).
- Rajasthan-3 in India, shut down for repairs since October 2022 (see India in Annex 1).[35]
- The six reactors at Zaporizhzhia in Ukraine that did not produce any electricity in 2023, and are considered in LTO as of the end of 2022.

35 - The reactor met the LTO criteria by the end of June 2024 but was reconnected to the grid in July 2024.

But on the other hand, WNISR statistics do include additional reactors in China:

- Shidao-Bay-1: The IAEA considers the two 100-MW modules as one reactor as they drive a single 200-MW turbine. WNISR considers that each module is a separate reactor.
- China Experimental Fast Reactor (CEFR): The IAEA has simply deleted the file for the reactor without any indication of reasons. Chinese sources have argued it should have never been in the IAEA's PRIS database in the first place as it is to be considered an experimental reactor. However, as this is a nuclear power reactor, it is considered as such by WNISR. Its current operational status is uncertain. In the absence of operational data, WNISR considers it in LTO as of May 2023 (but still operating as of December 2022).[36]

The biggest difference between IAEA-PRIS and WNISR is found as of the end of 2012, with 29 units less operating according to WNISR criteria: the IAEA-PRIS counts 30 reactors (detailed in Table 1) that are not considered operating according to WNISR, but on the other hand has retrieved the Chinese CEFR it previously considered operational at this date.

Table 1 · WNISR Rationale for the Classification of 30 Reactors as Non-Operational as of end 2012

Countries	Officially Closed at a Later Date 21 Reactors		Restarted from LTO 9 Reactors
	Reactors that last produced electricity in (or prior to) 2012, officially closed after 2012 (either considered closed by WNISR as early as 2012, or after a certain period in LTO). Most of those reactors were considered "in operation" for many years before their official closure date.		
	Reactors considered closed in 2012	*Reactors in LTO prior to closure*	*Reactors in LTO as of December 2012* *Restarted prior to 1 July 2023*
Japan	6 Reactors Fukushima Daiichi 5–6 Fukushima Daini 1–4 *Officially Closed in 2013 and 2019*	11 Reactors Last production in 2010–2012 *Officially closed 2015–2019*	8 Reactors Restarted 2015–2021
South Korea			1 Reactor Wolsong-1, Restarted in 2015
Spain	1 Reactor Santa Maria de Garoña Last production in 2012 *Officially Closed in 2017**		
U.S.	3 Reactors San Onofre-2 & -3 Last production in 2012 *Officially closed in 2013* Crystal River-3 Last production in 2009 *Officially closed in 2013*		

Sources: IAEA-PRIS and WNISR, 2024

Note: *Garoña was subsequently considered in "Suspended Operation" during 2013–2016 by the IAEA until its official closure.

The differences between the IAEA and WNISR are not limited to the effects of the Fukushima disaster. Even prior to 3/11, WNISR and IAEA-PRIS data had differences, reaching up to 10 units at the end of some years. These differences were mainly due to the definition of the closure

36 - CEFR was considered in LTO in WNISR statistics from 2017 to 2020, until it was reconnected to the grid in February 2021; see *WNN*, "Chinese fast reactor begins high-power operation", 19 February 2021, see https://www.world-nuclear-news.org/Articles/Chinese-fast-reactor-begins-high-power-operation, accessed 8 November 2023.

date that the IAEA either sets at last production or at closure-decision date while WNISR systematically applies the day of last electricity generation (when available). Another reason for differences lies in the IAEA's delays to classify reactors in "suspended operation".

OVERVIEW OF CURRENT NEWBUILD

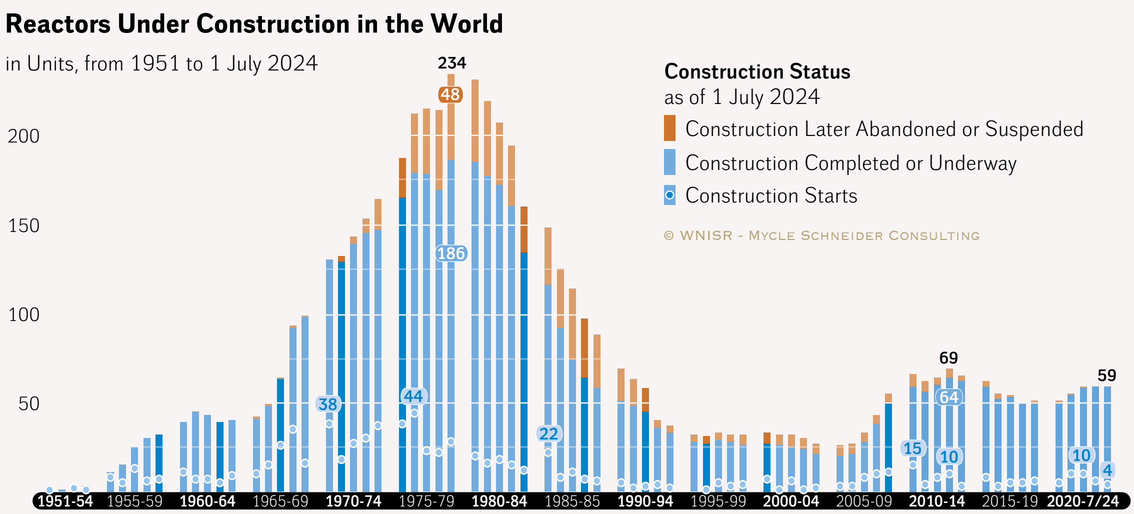
As of 1 July 2024, 59 reactors were considered as under construction—including 27 units in China—one more than the WNISR reported a year ago and 10 fewer than in 2013 (see Figure 9). Of the 69 reactors under construction at the end of 2013, five projects have subsequently been abandoned or suspended.

Eighty-five percent of the reactors are being built in Asia or Eastern Europe (see Building vs. Vendor Countries). In total, 13 countries are building nuclear plants, with the UAE and U.S. having started up their last units under construction, and work was suspended (again) on a reactor in Brazil, that is three countries less building than as of mid-2023.

However, only three countries—China, India, and Russia—have construction ongoing at more than one site, and five countries only have a single reactor under construction (see Table 2 and Annex 5 for details). Between mid-2023 and mid-2024, construction of seven units was launched worldwide, five in China and one each in Egypt and Russia.

The 59 reactors that are listed as under construction by mid-2024 represent a quarter of the 234 units—totaling more than 200 GW—listed in 1979. However, 48 of those projects listed at the time were never finished (see Figure 8). The year 2005, with 26 units listed as under construction, was the lowest since the early nuclear age in the 1950s.

Figure 8 · Nuclear Reactors "Under Construction" in the World

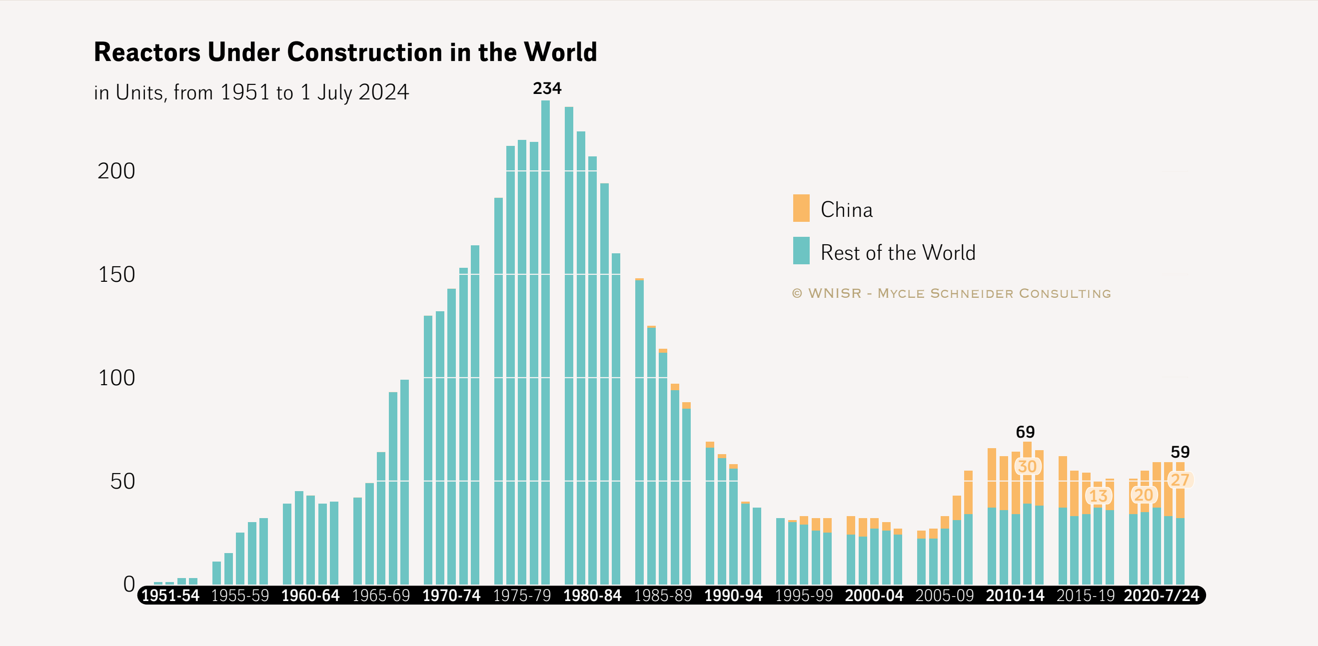


Sources: WNISR, with IAEA-PRIS, 2024

Notes: This figure includes construction of two CAP1400 reactors at Rongcheng/Shidaowan, although their construction has not been officially announced (see China Focus). This figure considers the Ohma project in Japan as suspended, as it remains unclear whether active construction has resumed.

Compared to the year before, the total capacity of the 59 units under construction in the world in mid-2024 increased by 1.2 GW to 59.8 GW, with an average unit size of 1 GW.

Figure 9 · Nuclear Reactors "Under Construction" – China and the World



Sources: WNISR, with IAEA-PRIS, 2024

BUILDING VS. VENDOR COUNTRIES

As of mid-2024, China has by far the most reactors under construction in the world. However, it is currently not building anywhere outside the country and, so far, has only exported to Pakistan. Although the official construction start of a barge which China is building for a Russian client occurred in China, it is considered a Russian domestic project as installation of the two "floating reactors" will be carried out in Russia where they will operate.

Russia is in fact largely dominating the international market as a technology supplier with 26 units under construction in the world, as of mid-2024, of which only six are domestic and 20 in seven different countries, including four each in China, Egypt, India, and Türkiye, two in Bangladesh and one each in Iran and Slovakia (Russian design, completed by Czech-led consortium). It is uncertain to what extent these projects are impacted by the various layers of sanctions imposed on Russia following its invasion of Ukraine.

Besides Russia's Rosatom, there is only France's EDF presently building abroad (see Table 2 and Figure 10).

Table 2 · Nuclear Reactors "Under Construction" (as of 1 July 2024)[37]

Country	Units (Domestic Design)	Other Vendor	Capacity (MW net)	Construction Start	Grid Connection	Units Behind Schedule
China	27 (23)	Russia: 4	29 101	2017 – 2024	2024 – 2029	1
India	7 (3)	Russia: 4	5 398	2004 – 2021	2024 – 2027	5[(a)]
Russia	6 (6)	–	3 960	2018 – 2024	2025 – 2030	2
Türkiye	4 (0)	Russia: 4	4 456	2018 – 2022	2025 – 2028	4
Egypt	4 (0)	Russia: 4	4 400	2022 – 2024	2028 – 2031	-
South Korea	2 (2)	–	2 680	2017 – 2018	2024 – 2025	2
Bangladesh	2 (0)	Russia: 2	2 160	2017 – 2018	2024 – 2025	2
U.K.	2 (0)	France: 2	3 260	2018 – 2019	2030 – 2031	2
Argentina	1 (1)	–	25	2014	2028	1
France	1 (1)	–	1 630	2007	2024	1
Iran	1 (0)	Russia: 1	974	1976	2028	1
Japan	1 (1)	–	1 325	2007	2030	1
Slovakia	1 (0)	Russia: 1[(b)]	440	1985	2025	1
Total	59		59 809	1976 – 2024	2024 – 2031	23
Total per Vendor Country: Russia: 26 - China: 23 - India: 3 – South Korea: 2 - France: 3 - Argentina: 1 - Japan: 1						

Sources: Various, Compiled by WNISR, 2024

Notes:

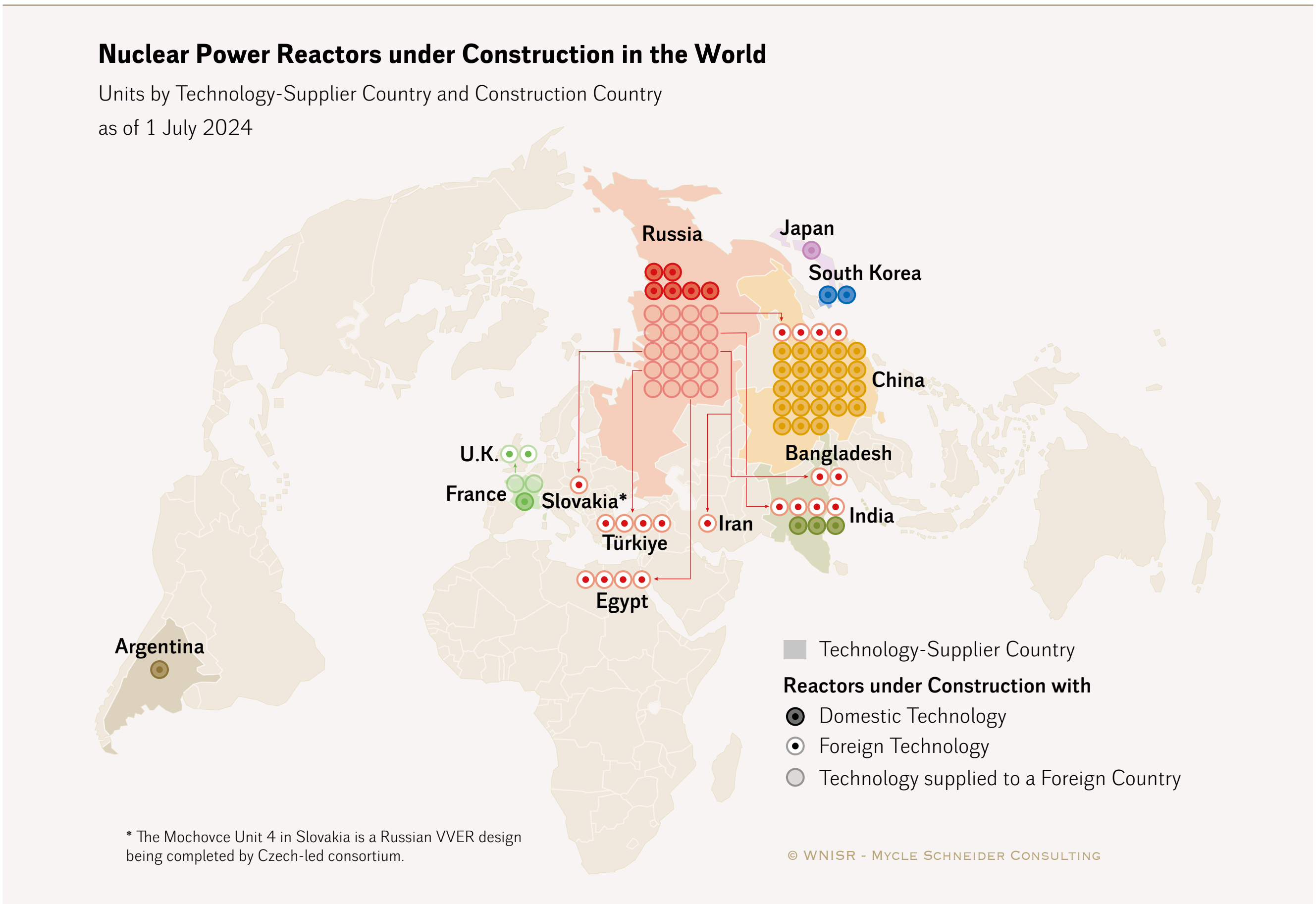
(a) - Of the seven reactor projects under construction, all are delayed or likely to be delayed, with all Kudankulam reactors under construction "likely to be impacted" by the war in Ukraine. Five is the number of reactors "formally" delayed. See India (in Annex 1) and Annex 5.

(b) - Mochovce -4 is a Russian VVER design being completed by a Czech-led consortium.

This table does not contain suspended or abandoned constructions. It does include construction of two CAP1400 reactors at Rongcheng/Shidaowan, although that has not been officially announced (see China Focus) as well as two floating reactors of Russian design to be deployed in Russia—thus counted under Country-Russia, but with a barge built in China.

37 - For further details, see Annex 5.

Figure 10 • Nuclear Reactors "Under Construction" by Technology-Supplier Country



Sources: WNISR, with IAEA-PRIS, 2024

CONSTRUCTION TIMES

Construction Times of Reactors *Currently Under Construction*

A closer look at projects listed as "under construction" as of 1 July 2024 illustrates the level of uncertainty and problems associated with many of these projects, especially given that most builders still claim a five-year construction period in their project proposals:

- For the 59 reactors being built, an average of 5.9 years has passed since construction start—slightly lower than the mid-2023 average of 6 years—and many remain far from completion.
- *All* reactors under construction in at least nine countries—of which five have only one unit in work—of the 13 builder-countries have experienced often year-long delays. Almost forty percent (23) of the building projects are documented to be delayed. Most of the units which are nominally being built on-time (yet)—23 of the 36 are in China—were begun within the past three years, making it difficult to assess whether they are on schedule. Significant uncertainty remains over construction in China because of lack of access to information.

- It remains also unclear what will happen with Russian designed and/or implemented projects in six other countries, as sanctions have or will likely have an impact on supply chains. Russian projects in five of the seven countries are already documented to be delayed (Bangladesh, India, Iran, Slovakia, Türkiye).
- Of the 23 constructions clearly documented as behind schedule, at least ten—in Argentina, Bangladesh, France, India, Iran, Slovakia, South Korea, and the U.K.—have reported *increased* delays, and two have reported a delay for the first time over the past year.
- WNISR2022 noted a total of 12 reactors scheduled for startup in 2023. At the beginning of 2023, nine were still planned to be connected to the grid (including three pushed back from 2022 to 2023) but only five of these made it to generate first power, while the other four were delayed at least into 2024.
- The initial construction start of the Mochovce-4 reactor in Slovakia dates back 39 years and its grid connection has been further delayed, currently to 2025. Bushehr-2 in Iran originally started construction in 1976, over 48 years ago, and resumed construction in 2019 after a 40-year-long suspension. Grid connection is currently scheduled for 2028.
- Six additional reactors have been listed as "under construction" for a decade or more: the Prototype Fast Breeder Reactor (PFBR) and Rajasthan-7 & -8 in India, Shimane-3 in Japan, Flamanville-3 (FL3) in France and CAREM in Argentina38. Angra-3 construction, which initially started in 2010, was halted in 2015, apparently resumed in 2022, with an expected startup date of 2028. However, construction activities have been interrupted again in 2023 and WNISR considers the project currently as suspended.

The actual lead time for nuclear plant projects includes not only the construction itself but, in most countries, also lengthy political and legal processes, licensing procedures, complex financing negotiations, site preparation, and other infrastructure development.

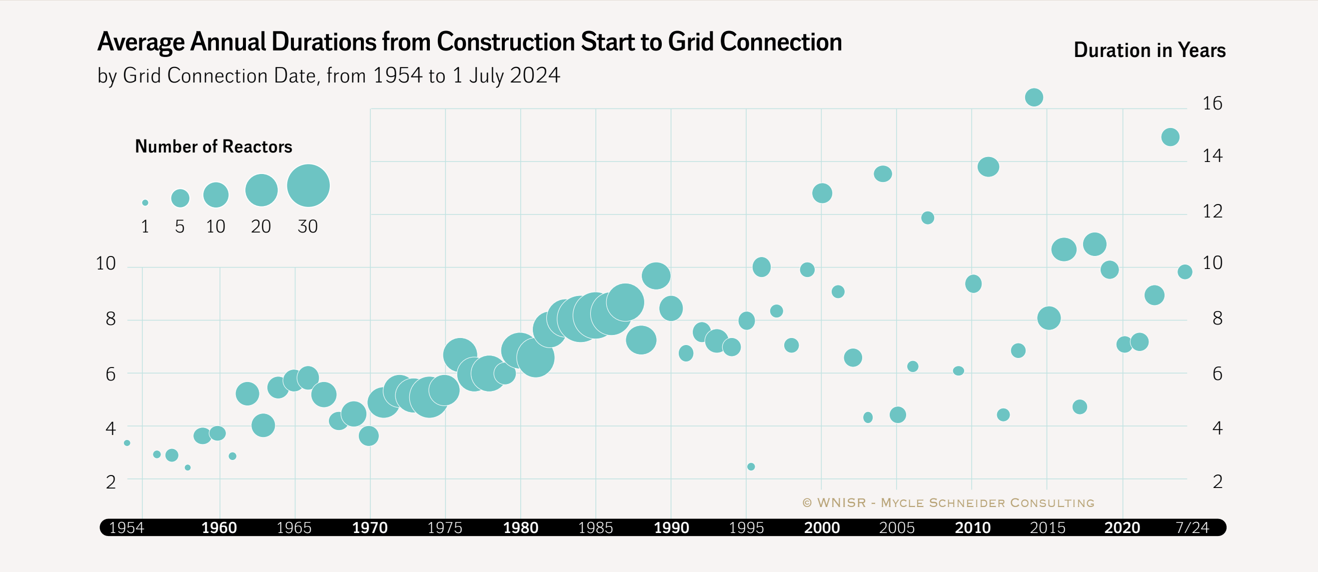
Construction Times of *Past and Currently Operating* Reactors

Since the beginning of the nuclear power age, there has been a clear global trend towards increasing construction times. National building programs were faster in the early years of nuclear power, when units were smaller, and safety and environmental regulations were less stringent. As Figure 11 illustrates, average times between construction start and grid connection of reactors completed in the 1970s and 1980s were quite homogenous, while in the past two decades they have varied widely.

As Figure 12 shows for the period 2021–2023, the longest construction time was for Mochovce-3, even taking into account the suspension construction (38 years in total, of which over 16 years of suspension), followed by the Olkiluoto-3 (OL3) reactor (16.6 years), a Franco-German project, the first European Pressurized Water Reactor (EPR) to start up in Europe, twelve years later than planned. The longest construction times in China were seen for the two HTR modules at Shidao Bay (between 9 and 10 years). The seven units completed in 2021–2023 in China took on average 7.1 years to build.

38 - In 2022, the IAEA modified the construction-start date in the PRIS database for unknown reasons from 2 February 2014 to 29 August 2016. WNISR does not take that modification into account.

Figure 11 • Average Annual Construction Times in the World



Sources: WNISR, with IAEA-PRIS, 2024

The mean time from construction start to grid connection for the five reactors started up in 2023 was 14.9 years, almost six years more on average than construction times of units started up in 2022 (9 years). This includes Mochovce-3 in Slovakia, with construction starting first in 1985.

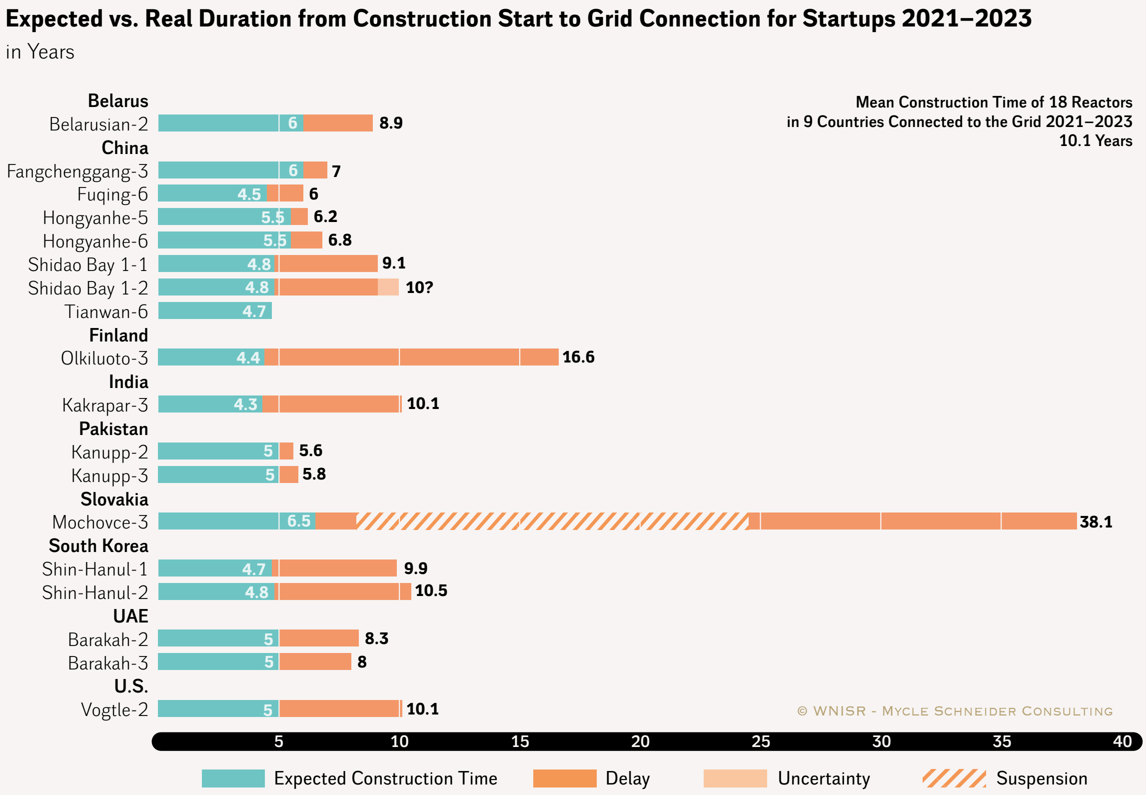
Four units began power generation in the first half of 2024 in a diverse selection of countries including China, India, UAE, and the U.S., after an average time between construction start to grid connection of 9.9 years.

Over the three years 2021–2023, only one of 18 units connected to the grid in nine countries started up on-time, the Chinese-designed and -built CNP-1000 Tianwan-6.[39] The average duration between construction start and first grid connection of these 18 units was 10.1 years (see Figure 12).

The longer-term perspective confirms that short construction times remain the exceptions. Eleven countries completed 67 reactors over the decade 2014–2023—of which 37 in China alone—with an average construction time of 9.9 years (see Table 3), higher than the 9.4 years of mean construction time in the decade 2013–2022. The construction durations from the beginning of concreting of the foundations of the reactor building to first grid connection have been stable around 10 years for over a decade with a broad range between countries and between projects inside individual countries as can be seen in Table 3.

39 - In previous, WNISR editions, Tianwan-5 and -6 have been erroneously labelled VVER-designs built with major Chinese input.

Figure 12 · Delays for Units Started Up, 2021–2023



Sources: Various, Compiled by WNISR, 2024

Notes: Expected construction time is based on grid connection data provided at construction start when available; alternatively, best estimates are used, based on commercial operation, completion, or commissioning information.

At Shidao Bay, the HTR plant, where construction started in 2012, has two reactor modules on the site and is therefore counted as two units as of WNISR2020. Grid connection of the first unit of the twin reactors officially took place on 20 December 2021. No date was provided for startup of the second reactor, which is considered as operating in WNISR2023 as of end-2022, and total construction time set at 10 years.

Table 3 · Duration from Construction Start to Grid Connection, 2014–2023

Construction Times of 67 Units Started Up 2014–2023				
Country	Units	Construction Time (in Years)		
		Mean Time	Minimum	Maximum
China	37	6.3	4.1	10.0
Russia	9	17.9	8.1	35.1
South Korea	5	8.7	6.4	10.5
Pakistan	4	5.6	5.5	5.8
UAE	3	8.1	8.0	8.3
Belarus	2	8.0	7.0	8.9
India	2	12.2	10.1	14.2
U.S.	2	26.5	10.1	42.8
Argentina	1	33.0	33.0	
Finland	1	16.6	16.6	
Slovakia	1	38.1	38.1	
World	67	9.9	4.1	42.8

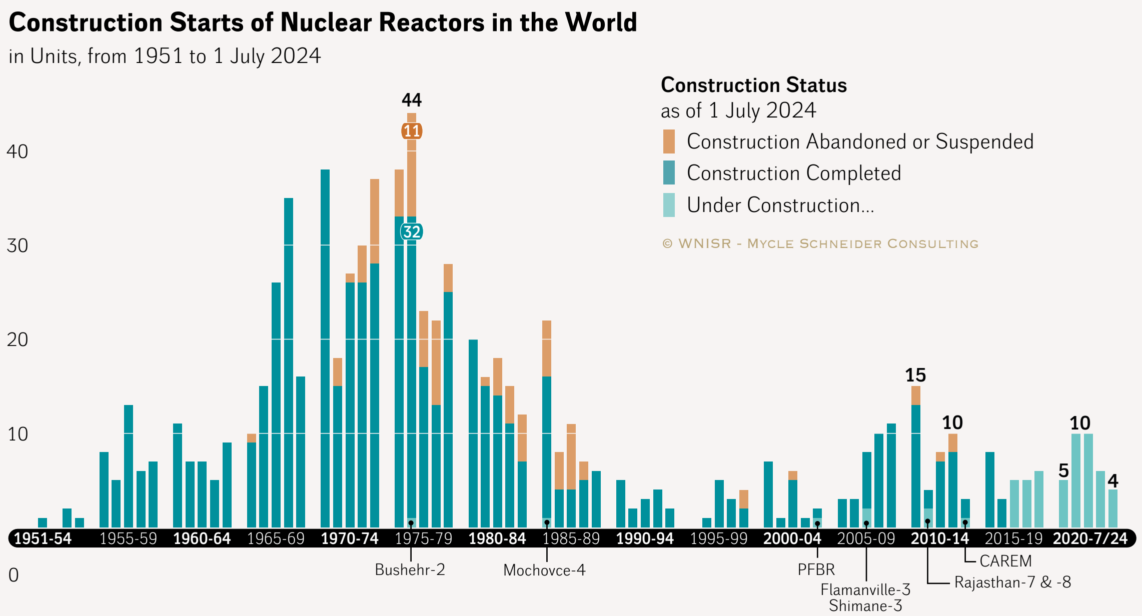
Sources: WNISR, with IAEA-PRIS, 2024

CONSTRUCTION STARTS AND CANCELLATIONS

The number of annual construction starts[40] in the world peaked in 1976 at 44, of which 11 projects were later abandoned. In 2010, there were 15 construction starts—including 10 in China—the highest level since 1985 (see Figure 13 and Figure 14). That number dropped to five in 2020 (including four in China), while building started on ten units in 2021 (including six in China), as well as in 2022 (including five in China). Six constructions started in 2023, of which five in China and one in Egypt implemented by the Russian nuclear industry.

Four reactors got underway in the world in the first half of 2024, two of them in China, one in Russia, and one built by the Russian industry in Egypt. Chinese and Russian government-owned or -controlled companies launched all 35 reactor constructions in the world over the 54-month period from the beginning of 2020 to mid-2024.

Figure 13 · Construction Starts in the World



Sources: WNISR, with IAEA-PRIS, 2024

Notes: Construction of Bushehr-2 in Iran started in 1976, was considered abandoned in earlier versions of this figure. As construction was restarted in 2019, it now appears as "Under Construction". Albeit of uncertain future, construction of Angra-3 in Brazil (2010) was considered restarted in WNISR2023, but construction has been suspended again.

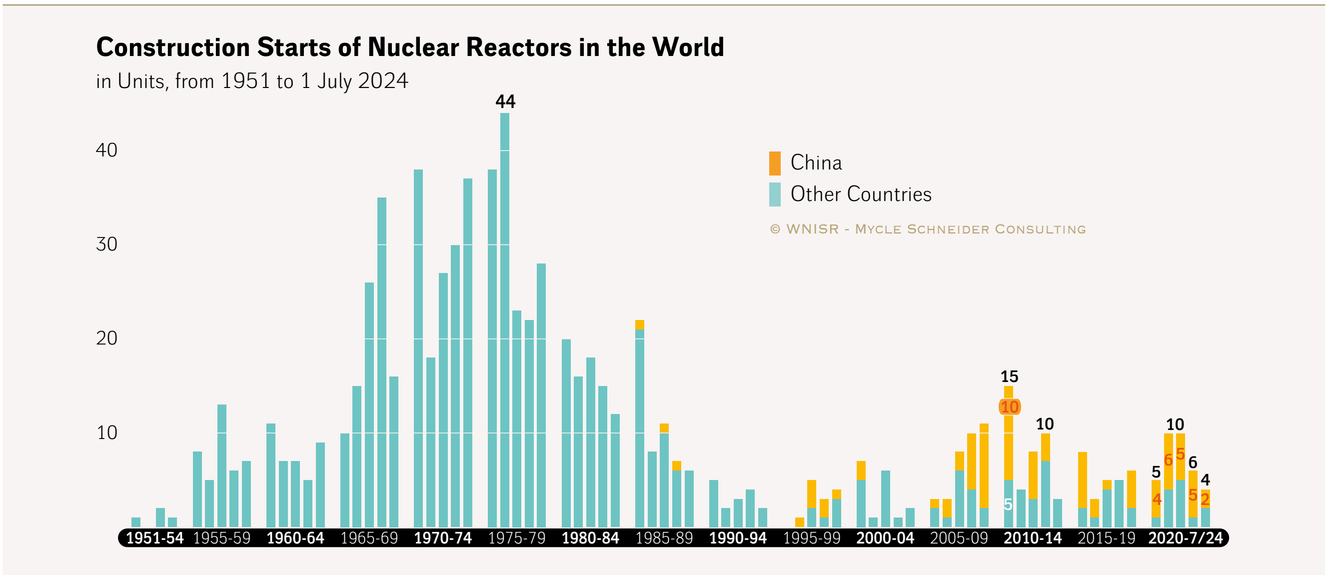
Over the decade 2014–2023, construction began on 61 reactors in the world, of which over half (33) in China. As of mid-2024, 13 of those units had started up, while 48 remain under construction.

Seriously affected by the Fukushima events, China did not start any construction in 2011 and 2014 and began work only on eight units in total in 2012 and 2013. While Chinese utilities started building six more units in 2015, the number shrank to two in 2016, only a demonstration

40 - Generally, a reactor is considered under construction with the beginning of the concreting of the base slab of the reactor building. Site preparation work, excavation and other infrastructure developments are not included.

fast reactor in 2017, none in 2018, but four each in 2019 and 2020, six in 2021, five each in 2022 and 2023 and two in the first half of 2024 (see Figure 14). While this increase represents a sign of the restart of commercial reactor building in China, the level continues to remain below expectations. The five-year plan 2016–2020 had fixed a target of 58 GW operating and 30 GW under construction by 2020. As of the end of 2020, China had 49 units with 47.5 GW operating, one reactor in LTO (CEFR), and 17 units (16 GW) under construction, much lower than the original target. At the end of 2023, 56 reactors with a total capacity of 53.1 GW were operating and 26 units (27.7 GW) were under construction (for details, see China Focus).

Figure 14 • Construction Starts in the World/China



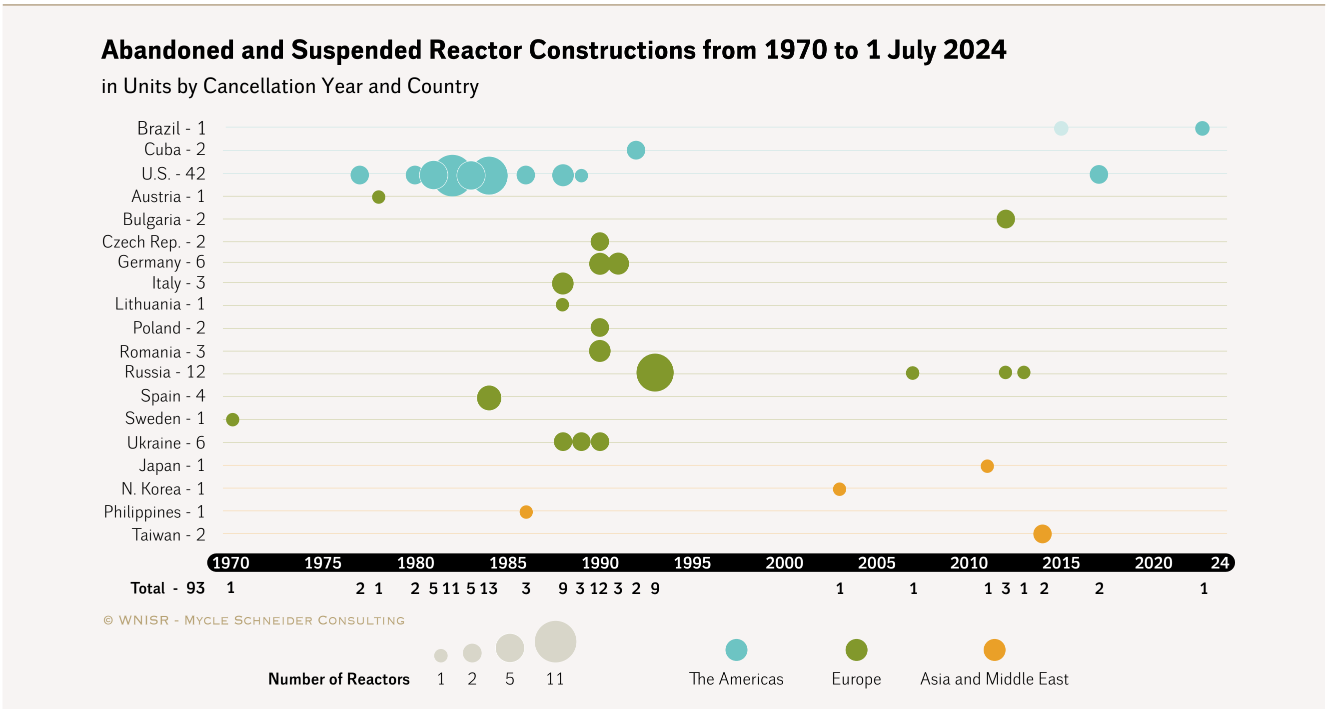
Sources: WNISR, with IAEA-PRIS, 2024

Experience shows that having an order for a reactor, or even having a nuclear plant at an advanced stage of construction, is no guarantee of ultimate grid connection and power production. The two V.C. Summer units in the U.S., abandoned in July 2017 after four years of construction and following multi-billion-dollar investment, are only the latest in a long list of failed significantly advanced nuclear power plant projects.

French Alternative Energies & Atomic Energy Commission (CEA) statistics through 2002 indicate 253 "cancelled orders" in 31 countries, many of them at an advanced construction stage (see also Figure 15). The United States alone accounted for 138 of these order cancellations.[41]

41 - CEA, "Elecnuc—Nuclear Power Plants in the World", Commissariat à l'énergie atomique et aux énergies alternatives/French Alternatives Energies and Atomic Energy Commission, 2002. The section "cancelled orders" has disappeared after the 2002 edition.

Figure 15 • Cancelled or Suspended Reactor Constructions



Sources: Various, compiled by WNISR, 2024

Note: This graph only includes constructions that had officially started with the concreting of the base slab of the reactor building. Many more projects have been cancelled at earlier stages of construction/site preparation.

Of the 807 reactor constructions launched since 1951, at least 93 units in 19 countries had been abandoned or suspended, as of 1 July 2024. This means that 11.5 percent—or one in nine—of nuclear constructions have been abandoned.

Close to three-quarters (66 units) of all cancelled projects were in four countries alone—the U.S. (42), Russia (12), Germany and Ukraine (six each). Some units were 100-percent completed—including Kalkar in Germany and Zwentendorf in Austria—before it was decided not to operate them.

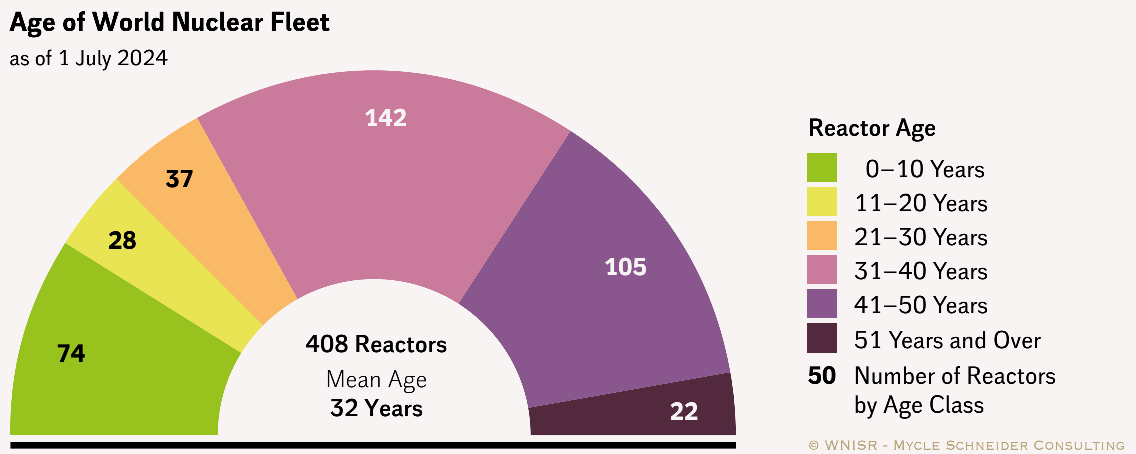
OPERATING AGE

In the absence of significant, successful newbuild over many years, the average age (from grid connection) of operating nuclear power plants has been increasing since 1984, and as of mid-2024 is 32, up from 31.4 years in mid-2023 (see Figure 16).[42]

A total of 269 reactors—four more than mid-2023—two-thirds of the world's operating fleet, have operated for 31 or more years, including 127—almost one in three—for at least 41 years.

42 - WNISR calculates reactor age from grid connection to final disconnection from the grid. In WNISR statistics, "startup" is synonymous with grid connection and "closure" with withdrawal from the grid. In order to have a better image of the fleet and ease calculations, the age of a reactor is considered to be 1 between the first and second grid connection anniversaries. For some calculations, we also use operating years: the reactor is in its first operating year until the first grid connection anniversary, when it enters the second operating year.

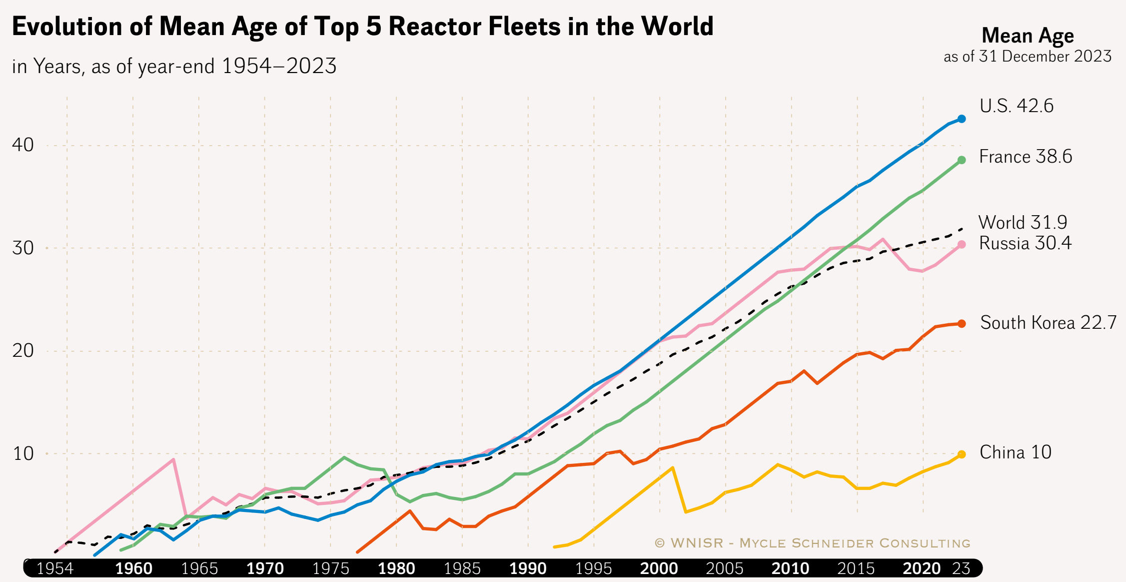
Figure 16 • Age Distribution of Operating Reactors in the World



Sources: WNISR, with IAEA-PRIS, 2024

In 1990, the average age of the operating reactors in the world was 11.3 years; in 2000, it was 18.8 years, and it stood at 26.3 years in 2010. The leading nuclear nation also has the oldest reactor fleet of the top-five nuclear generators. The average age of reactors in the U.S. passed 40-years in 2020 and reached 42.6 years as of the end of 2023. France's fleet exceeded 38.5 years. Russia's fleet age peaked in 2017 and declined for a few years before increasing again starting in 2020, and its average fleet age of 30.4 years, as of the end of 2023, almost caught up with that of 2017. South Korea's reactors at 22.7 years remained almost half as old as the U.S. fleet, and China had an average fleet age of just 10 years. (See Figure 17).

Figure 17 • Reactor-Fleet Age of Top 5 Nuclear Generators



Sources: WNISR, with IAEA-PRIS, 2024

Many nuclear utilities envisage average reactor lifetimes of beyond 40 years up to 60 and even 80 years. In the U.S., reactors are initially licensed to operate for 40 years, but nuclear operators can request a license renewal from the Nuclear Regulatory Commission (NRC) for an additional 20 years. An initiative to allow for 40-year license extensions in one step was terminated in June 2021 after NRC staff recommended that the Commission "discontinue the activity to consider regulatory and other changes to enable license renewal for 40 years."[43]

As of mid-2024, 84 of the 94 operating U.S. units had received a 20-year license extension, applications for six further reactors were under NRC review. The Initial License Renewal application for the Diablo Canyon units, scheduled to close when their current licenses expire in 2024–2025, is under review.[44]

As of July 2024, the NRC had granted Subsequent Renewed Operating Licenses to six reactors, which permit operation from 60 to 80 years. A further sixteen reactors have their applications still under review, and owners have notified of their intentions to submit applications for a further 29 reactors between 2025 and 2034. See Extended Reactor Licenses in United States Focus for details and references.

Only nine of the 41 units that have been closed in the U.S. had reached 40 years on the grid. All nine had obtained licenses to operate up to 60 years but were closed long before mainly for economic reasons. In other words, almost one quarter of the 136 reactors connected to the grid in the U.S. never reached their initial design lifetime of 40 years. Only one of those already closed had just reached 50 years of operation (Palisades, closed after 50.4 years). The mean age at closure of those 41 units was 22.8 years.

On the other hand, of the 94 currently operating plants, 54 units have already operated for 41 years or more, of which 15 have been on the grid for 51 years or more; thus, almost two thirds of the units with license renewals have entered the lifetime extension period, and that share is growing rapidly with the mid-2024 mean age of the U.S. operational fleet exceeding 42.7 years (see Figure 47).

Many countries have no specific time limits on operating licenses. In France, for example, reactors must undergo in-depth inspection and testing every decade against reinforced safety requirements. The French reactors have operated for 39 years on average. The Nuclear Safety Authority (ASN) has evaluated each reactor, and most have been permitted to operate for up to 40 years, which is considered the limit of their initial design. For economic reasons, the French state-controlled utility Électricité de France (EDF) prioritizes lifetime extension to at least 50 years over large-scale new-build. ASN's fourth decennial assessments are years behind schedule.

EDF's approach to lifetime extension has been reviewed by ASN and its Technical Support Organization. In February 2021, ASN granted a conditional generic agreement to lifetime extensions of the 32 reactors of the 900-MW series. However, lifetime extensions beyond 40 years require reactor-specific licensing procedures involving public inquiries in France and

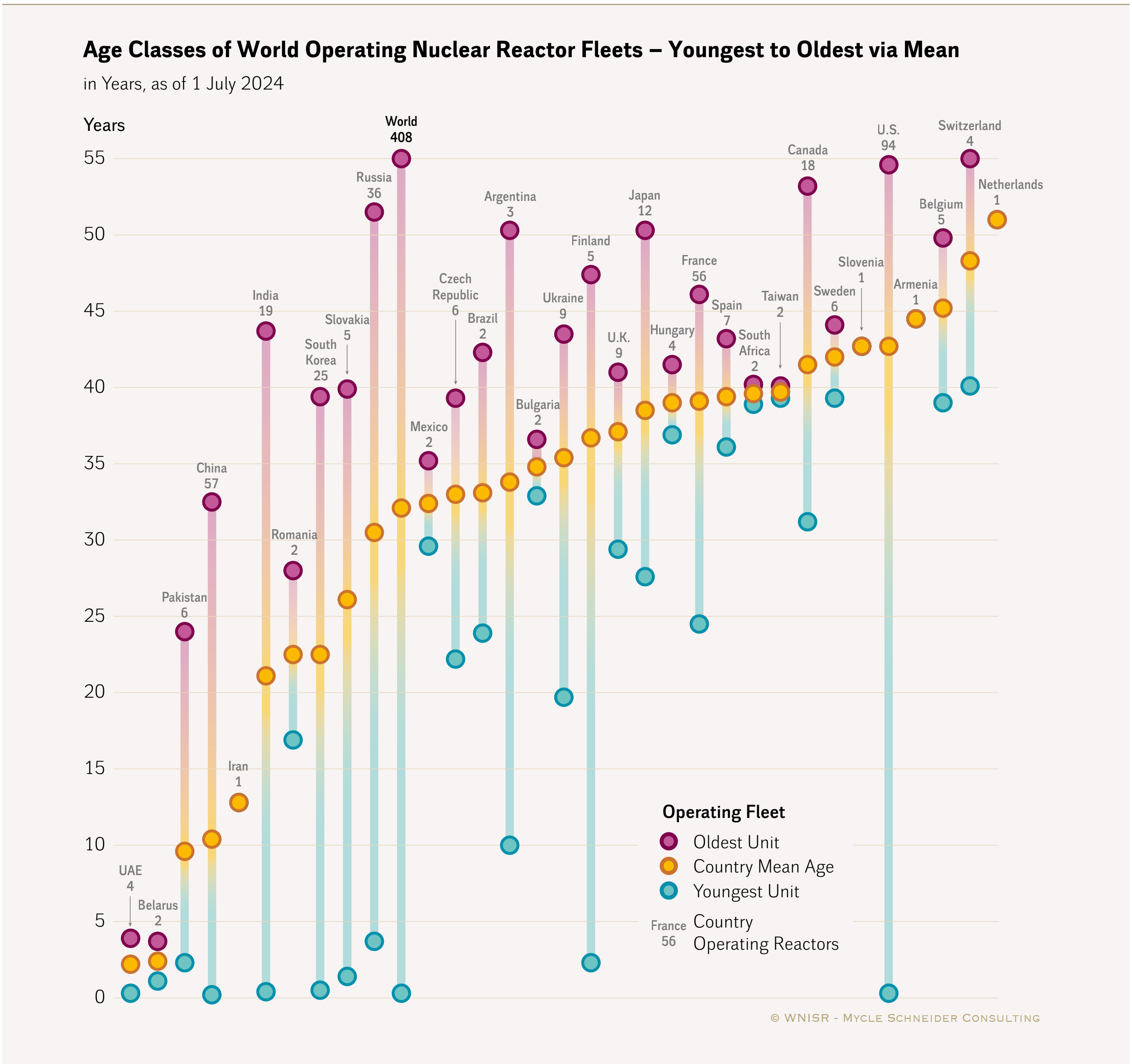
43 - Division of New and Renewed Licenses, "Closure of Activity to Consider License Renewal for 40 Years of Additional Nuclear Power Plant Operation", Office of Nuclear Reactor Regulation, United States Nuclear Regulatory Commission, 22 June 2021, see https://www.nrc.gov/docs/ML2111/ML21117A007.pdf, accessed 11 August 2021.

44 - U.S. NRC, "Status of License Renewal Applications and Industry Activities", United States Nuclear Regulatory Commission, Updated 8 May 2024, see http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html, accessed 11 July 2024.

transborder consultations. For an assessment of the status of fourth decennial inspections see France Focus: Lifetime Extension – Fact Before License in WNISR2023.

Recently commissioned reactors and the ones under construction—including in France, South Korea, and the U.K.—have or will seek a 60-year operating license from the start.

Figure 18 · Age of World Nuclear Fleets



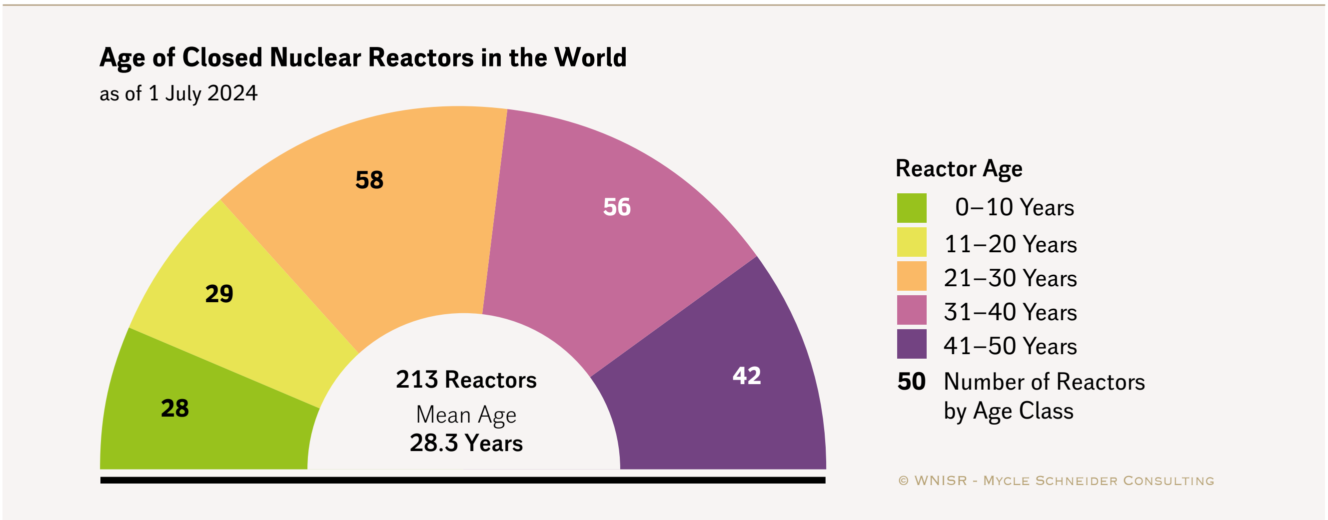
Sources: WNISR, with IAEA-PRIS, 2024

Note: This figure only takes into account reactors operating as of 1 July 2024, thus excluding reactors in LTO, in particular Tarapur-1 & -2 in India, that have passed 50 years.

Figure 18 shows that the average fleet age in 23 of the 32 countries that operate nuclear reactors as of mid-2024 is over 30 years, and in eight countries over 40. Two in three, that is 21 of the countries have been operating one or more reactors for more than 40 years, but, as of mid-2024, only seven countries operate reactors that are over 50 years.

In assessing the likelihood of reactor fleets being able to operate for 50 or 60 years, it is useful to compare the age distribution of reactors that are currently operating with the 213 units that have already closed (see Figure 16 and Figure 19). In total, 98 of these units operated for 31 years or more, of which 42 reactors operated for 41 years or more. Many units of the first-generation designs only operated for a few years. The mean age of the closed units is about 28 years.

Figure 19 • Age Distribution of Closed Nuclear Power Reactors

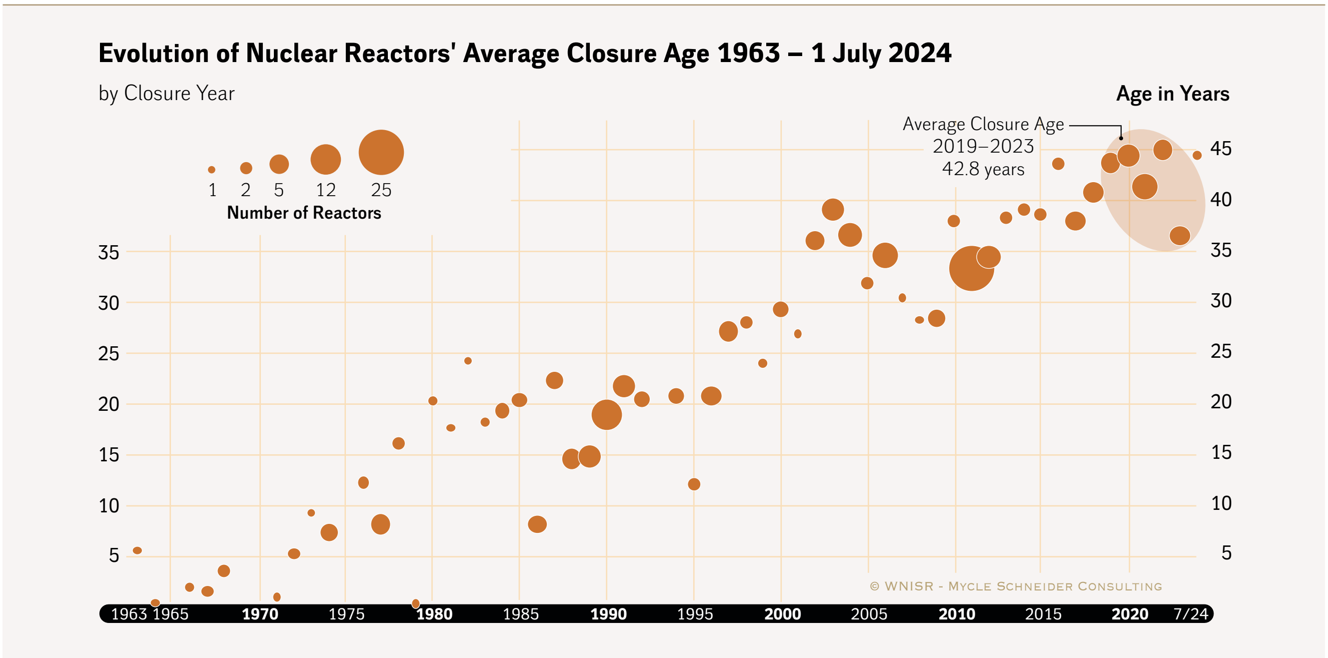


Sources: WNISR, with IAEA-PRIS, 2024

While the operating time prior to closure has clearly increased continuously, the mean age at closure of the 29 units taken off the grids in the five-year period between 2019 and 2023 was 42.8 years (see Figure 20).

As a result of the Fukushima nuclear disaster (elsewhere also referred to as 3/11), many analysts have questioned the wisdom of operating older reactors. The Fukushima Daiichi units (1 to 4) were connected to the grid between 1971 and 1974. The license for Unit 1 had been extended for another 10 years in February 2011, just one month before the catastrophe began. Four days after the initial events in Japan, the German Government ordered the closure of eight reactors that had started up before 1981, two of which were already closed at the time and never restarted. The sole selection criterion was operational age—30 years or more. Other countries did not adopt the same approach, but clearly the 3/11 events in Japan had an impact on previously assumed extended lifetimes in other countries. Some of the main nuclear countries closed their oldest units, at the time, before or long before age 50, including Germany at age 37, South Korea at 40, Sweden at 46. France closed its two oldest units in spring 2020 at age 43. The U.S. closed its oldest unit, Palisades, at age 50 in 2022, but is now considering reopening it.

Figure 20 · Nuclear Reactor Closure Age



Sources: WNISR, with IAEA-PRIS, 2024

LIFETIME PROJECTIONS

Nuclear operators in many countries continue to implement or prepare for lifetime extensions. As in previous years, WNISR has created two lifetime projections. A first scenario (40-Year Lifetime Projection, see Figure 21), assumes a general lifetime of 40 years for worldwide operating reactors—not including reactors in Long-Term Outage (LTO).

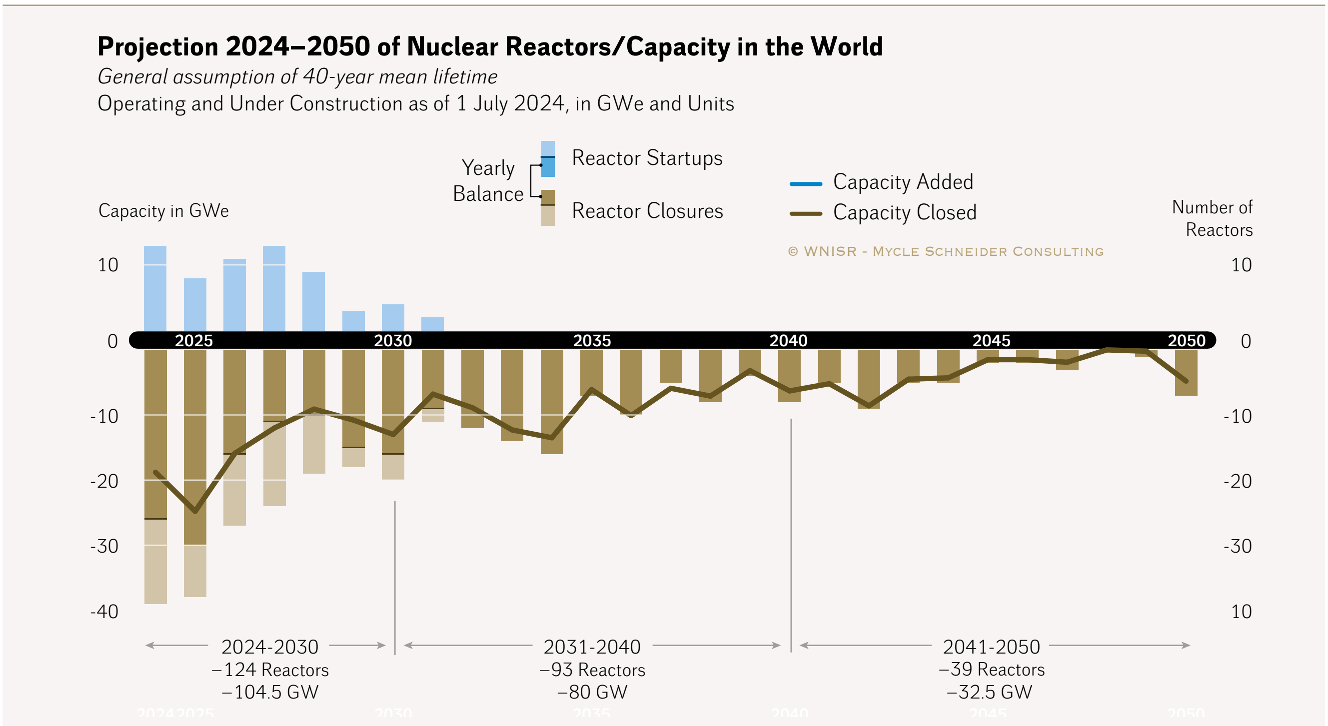
Forty years, explicitly or implicitly, corresponds to the design lifetimes of most operating reactors. Some countries have legislation or policy in place—including Belgium (even if the currently debated lifetime extension for two units was implemented), or Taiwan—that limit operating lifetime, for all or part of the fleet, to 40 or 50 years. Recent designs, mostly reactors under construction, have often a design lifetime of 60 years (e.g. APR-1400, EPR). For the 136 reactors that have passed the 40-year lifetime as of end-2023, we assume they will operate to the end of their licensed, extended operating time.

A second scenario (Plant Life Extension or PLEX Projection, see Figure 22) takes into account all *already-authorized* lifetime extensions as of mid-2024 and assumes that the respective reactors will operate until the expiration of their license—a very conservative assumption considering empirical evidence from the past.

The lifetime projections allow for an evaluation of the number of reactors and respective power generating capacity that would have to come online over the next decades to offset closures and simply maintain the same number of operating reactors and level of capacity, if all units were closed after a lifetime of 40 years (60 years for the very few units that hold such initial licenses) or after their licensed lifetime extension.

Considering all units under construction scheduled to have started up, 26 additional reactors would have to be commissioned or restarted prior to the end of 2024 to maintain the status quo of operating units (compared to the end of 2023 status). Without additional startups, installed nuclear capacity would decrease by 19 GW by the end of 2024.

Figure 21 • The 40-Year Lifetime Projection



Sources: Various sources, compiled by WNISR, 2024

Notes pertaining to Figure 21, Figure 22 and Figure 23:

Those figures include two Chinese 1400 MW-units at Shidao Bay and two Russian 55 MW RITM reactors, for which the startup dates were arbitrarily set to 2024 and 2027, as there are no official dates.

Restarts or closures amongst the 34 reactors in LTO as of 1 July 2024 are not represented in Figure 21 and Figure 22; however, at least some are expected to be restarted (and later closed, after 2050 in some cases)

In the case of reactors that have reached 40 years of operation prior to 2024, the 40-year projection also uses the end of their licensed lifetime. (including 80 years for 6 reactors in the U.S, where the Subsequent License Renewal Applications have been approved for a further 20 years of operation, despite the fact that their new expiration dates will be incorporated when NRC adopts the new Generic Environmental Impact Statement (GEIS) for license renewal.) See United States Focus.

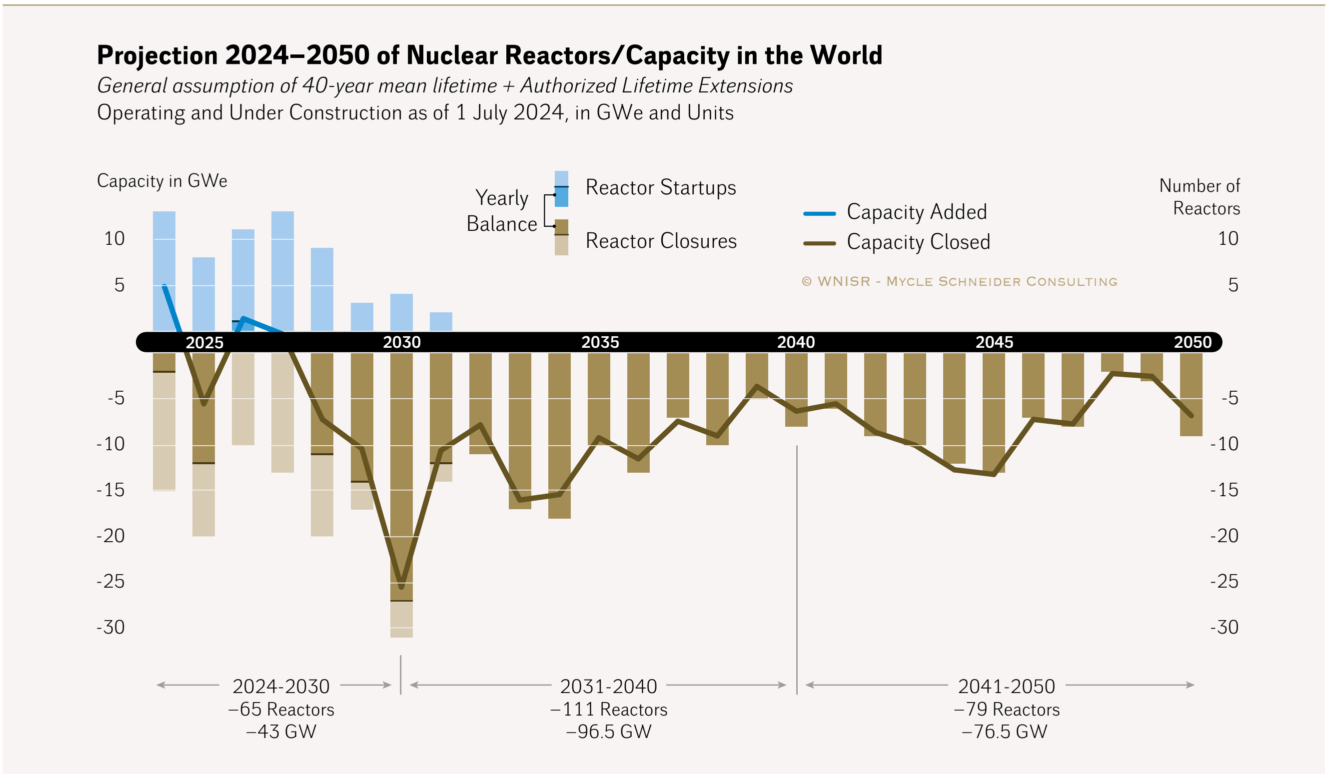
In the case of French reactors that have reached 40 years of operation prior to 2024 (startup before 1984), we use the deadline for their 4th periodic safety review (visite décennale) as closing date in the 40-year projection. In case this deadline is or will be passed by the end of 2024, we use a 10-year extension, although no licensing procedure has yet been completed for this extension besides Tricastin-1. For all those that have already passed their 3rd periodic safety review, the scheduled date of their 4th periodic safety review is used in the PLEX projection, regardless of their startup date.

In total, over the period 2024–2030, in addition to the units currently under construction, 124 new reactors (104.5 GW)—over 18 units or 15 GW per year—would have to be connected to the grid to maintain the status quo, almost three times the rate achieved over the past decade (67 startups between 2014 and 2023, that is 6.7 units or 6.7 GW per year).

The relative stabilization of the situation by the end of 2024 is only possible because most reactors will not actually close, regardless of their age. The number of reactors in operation will probably more or less continue to stagnate in spite of lifetime extensions becoming the rule worldwide. Such generalized lifetime extensions—far beyond 40 years—are clearly the objective of the international nuclear power industry, and, especially in the U.S., there are numerous, increasingly successful attempts to obtain subsidies for uneconomic nuclear plants in order to keep them on the grid (see Subsidies and Financing for Nuclear Power in United States Focus).

Developments in Asia, including in China, do not fundamentally change the global picture. Reported ambitions for China's targets for installed nuclear capacity have fluctuated in the past. While construction starts have picked up speed again since 2021, Chinese medium-term ambitions appear significantly lower than anticipated in the pre-3/11 era.[45]

Figure 22 • The PLEX Projection (not including LTOs)



Sources: Various sources, compiled by WNISR, 2024

Notes: see Figure 21.

Every year, WNISR also models a scenario in which all currently licensed lifetime extensions and license renewals are maintained, and all construction sites are completed. For all other units, a 40-year lifetime projection is maintained, unless a firm later closure date has been authorized. By the end of 2024, the net number of operating reactors would remain almost stable but the operating capacity would increase (-1 unit /+4.8 GW).

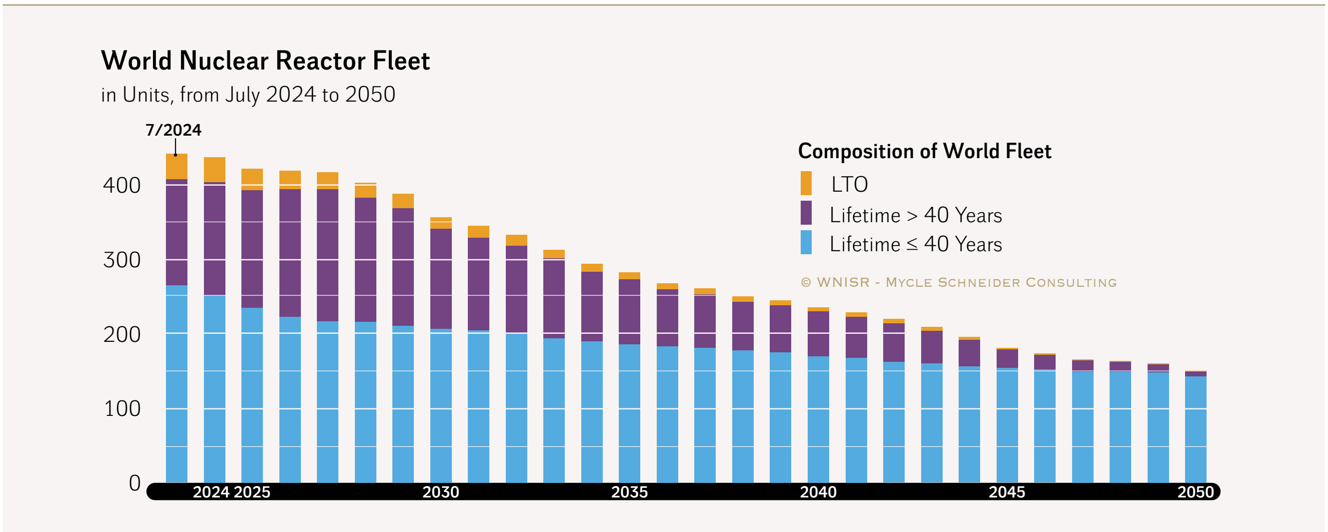
In the remaining years to 2030, the net balance would turn negative in 2025, slightly positive for the year 2026, stable in 2027, and would decrease sharply during 2028–2030; overall, over the period 2024–2030, an *additional* 65 new reactors (43 GW) would have to start up or restart to replace closures. Taking into account the already licensed lifetime extensions, the

45 - As of end of August 2024, five construction starts had taken place in China since the beginning of the year. Worldwide only one more reactor building started (in Egypt, implemented by Russia) in the first eight months of 2024.

PLEX-Projection still reveals for the remaining years to 2030 a need to almost triple the annual startup rate of the past decade from 6.7 to 18 units (see Figure 21, Figure 22 and the cumulated effect in Figure 23) only to maintain the status quo. However, probably at least a third of the 126 reactors projected to close between 2024 and 2030 are likely to secure a lifetime extension beyond 2030.

However, as documented in detail above, construction starts have not been picking up over the past decade. Between 2020 and mid-2024, a total of 35 constructions were launched around the world, of which 22 in China and 13 implemented by the Russian industry, thus an average of 7.8 units per year were launched. Based on empirical evidence, it is unlikely that any substantial number of reactors will come online by 2030 that are not yet under construction. In other words, newbuild will not be sufficient, only further lifetime extensions will allow for the world nuclear fleet not to decline by 2030 and after.

Figure 23 • Forty-Year Lifetime Projection versus PLEX Projection



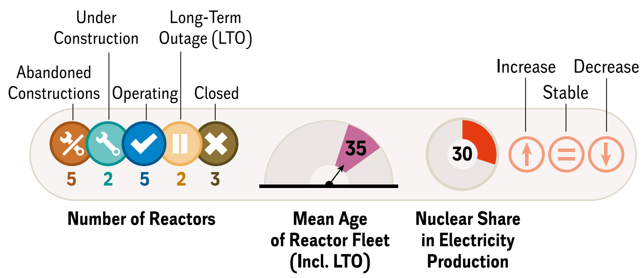
Sources: Various, compiled by WNISR, 2024

Note: This figure illustrates the trends, and the projected composition of the current world nuclear fleet, taking into account existing reactors (operating and in LTO) and their closure dates (40-years Lifetime vs authorized Lifetime Extension) as well as the 59 reactors under construction as of 1 July 2024. The graph does *not* represent a forecasting of the world nuclear fleet over the next three decades as it does not speculate about future constructions.

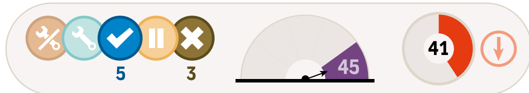
This figure takes into account the restarts of Rajasthan-3 during the second half-year of 2024, as well as Darlington-1 expected in 2025.

FOCUS COUNTRIES

These “quick view” indicators will be used in the country sections throughout the report.

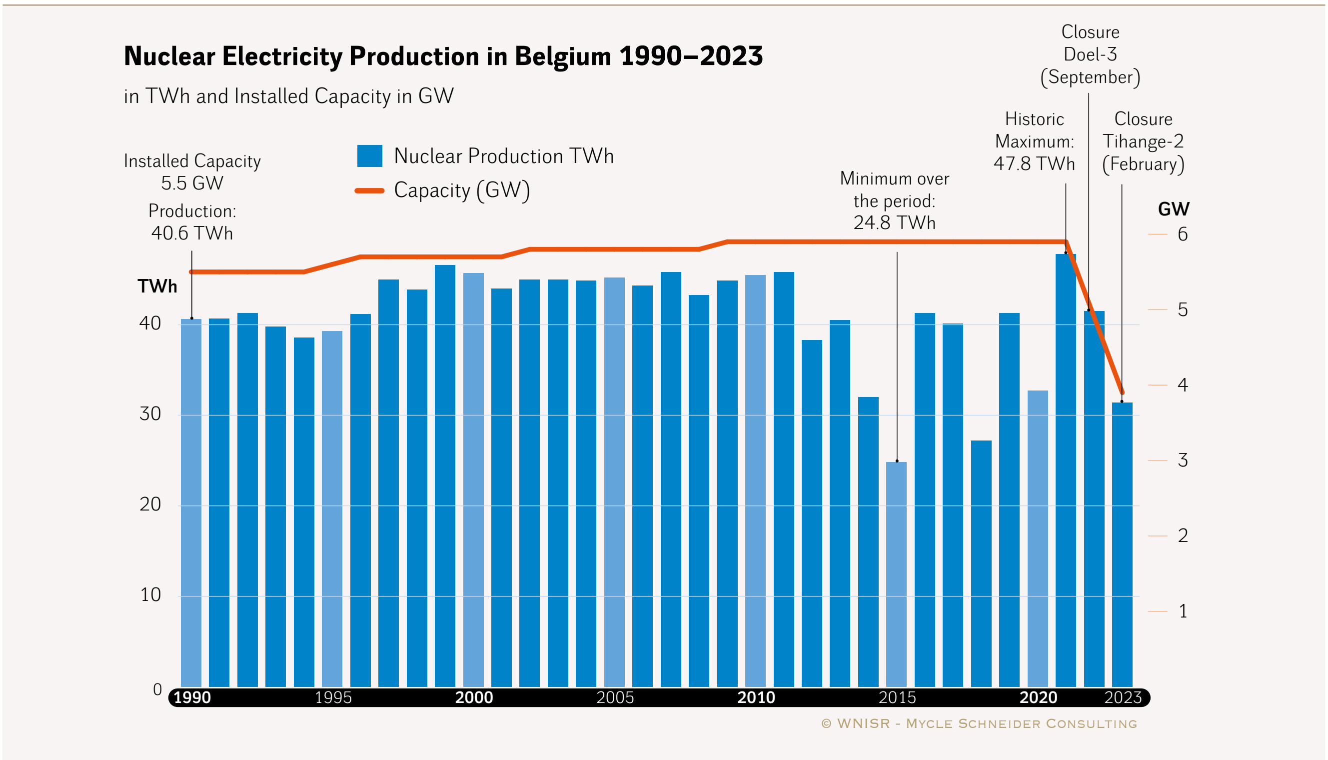


BELGIUM FOCUS



After a decade of ups and downs due to multiple technical issues and a record of 48 TWh in 2021, nuclear production dropped by 13 percent in 2022 to 41.7 TWh and another 25 percent in 2023 to 31.3 TWh partly due to the closure of two units in late 2022 and early (see Figure 24). The installed capacity, with negligeable changes in 30+ years, after a ramp-up period, delivered high levels of production for a period of 15 years, before generating erratic numbers of kilowatt-hours.

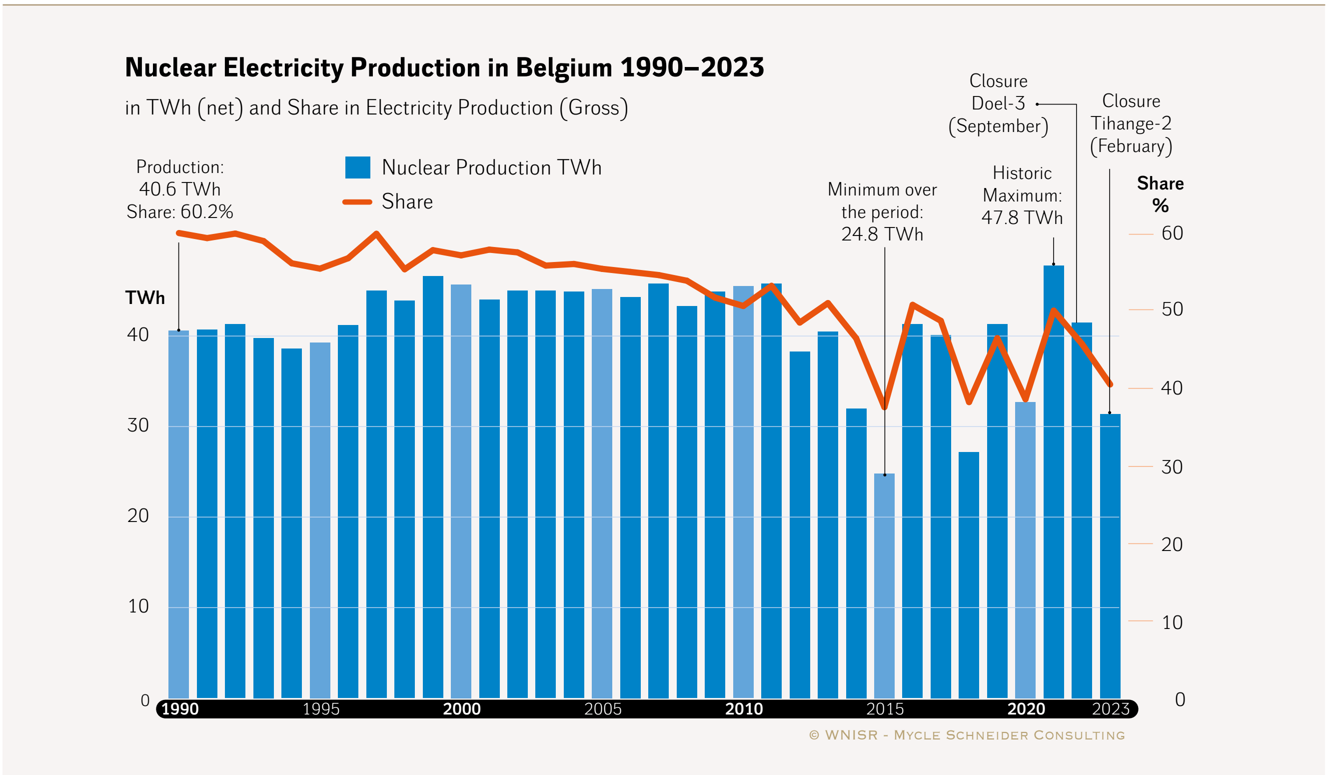
Figure 24 · Nuclear Power Generation in Belgium vs. Installed Nuclear Capacity



Sources: Energy Institute and IAEA-PRIS, 2024

Nuclear plants contributed 41.2 percent to Belgium's electricity generation in 2023, 5.2 percentage-points less than in 2022 which already saw a 4.4 percentage-point drop over 2021 (see Figure 25). The historic maximum nuclear share was 67.2 percent in 1986.

Figure 25 • Nuclear Power Generation in Belgium vs. Nuclear Share



Source: Energy Institute, 2024

Until 2022, Belgium operated seven commercial pressurized water reactors (PWRs) at the Doel (4) and Tihange (3) sites. In the framework of the Belgian nuclear phaseout legislation, the nuclear operator closed Doel-3 on 23 September 2022 and Tihange-2 on 31 January 2023. The average age of the remaining Belgian five-reactor fleet is 45.2 years, the third oldest nuclear fleet in the world behind the Netherlands (1 reactor) and Switzerland (4 reactors). See Figure 18.

Belgium remains highly dependent on fossil fuels as contributions to final energy consumption in 2023 represented 48.1 percent for oil, 24.6 percent of natural gas (together 72.7 percent) with nuclear at 6.9 percent and renewables at 12.8 percent. There has been a major surge in installations of solar capacity in 2023 with a jump of 25 percent, so that solar and wind together cumulate 14.2 GW of capacity, representing over half of the total installed capacity in the country. Two thirds of the solar capacity is decentralized with system sizes below 30 kW.[46]

The gas-price increase in the fall of 2021 and the war in Ukraine have reopened the debate about the possibility of lifetime extension of the two most recent units, Tihange-3 and Doel-4. The government has introduced a corresponding preliminary legislative proposal on

46 - SPF Economie, "Belgian Energy Data Overview", Service Public Fédéral Economie/Federal Public Service Economy, SMEs, Self-Employed and Energy, Updated 3 July 2024 (in French), see https://economie.fgov.be/fr/publications/belgian-energy-data-overview-1, accessed 24 August 2024.

1 April 2022. There is no debate about potential lifetime extensions of the remaining three of the seven Belgian reactors beyond the closure schedule specified by current law. Those three units are to be closed in 2025.

On 18 April 2024, the Belgian Parliament voted in favor of legislation that modifies the nuclear phaseout law from 31 January 2003, which originally required the closure of all of Belgium's nuclear plants after 40 years of operation. Based on their startup dates, plants would have been closed progressively between 2015 and 2025 (see Table 4). Practically, however, after a first amendment to the law in 2015, lifetime extension to 50 years was granted for three reactors, five of the seven units would have gone offline in the single year of 2025.

The new law was promulgated on 26 April 2024 and published on 5 June 2024.[47] It allows for the operation of Doel-4 and Tihange-3 "for a 10-year period from the restart date" it being understood that the reactors will be definitively closed at the end of this period or "at the latest on 31 December 2037." The text is formulated this way as it is unclear at this time when the units will be able to restart after the end of their current licensing period which expires in 2025.

Table 4 · Belgian Nuclear Fleet (as of 1 July 2024)

Reactor	Net Capacity (MW)	Grid Connection	Operating Age (as of 1 July 2024)	End of License (Planned or Actual Closure Date)
Doel-1	433	28/08/1974	48.8	10-year lifetime extension to 15 February 2025
Doel-2	433	21/08/1975	47.9	10-year lifetime extension to 1 December 2025
Doel-3	1 006	23/06/1982		1 October 2022 (Closed on 23 September 2022)
Doel-4	1 038	08/04/1985	38.2	10-year lifetime extension? (Closure date 2035–2037)
Tihange-1	962	07/03/1975	48.3	10-year lifetime extension to 1 October 2025
Tihange-2	1 008	13/10/1982		1 February 2023 (Closed on 31 January 2023
Tihange-3	1 038	15/06/1985	38.0	10-year lifetime extension? (Closure date 2035–2037)

Sources: Various, compiled by WNISR, with Belgian Laws of 28 June 2015[48] and 26 April 2024[49].

47 - Service public fédéral Economie, P.M.E., Classes moyennes et Énergie, "26 AVRIL 2024. - Loi modifiant la loi du 31 janvier 2003 sur la sortie progressive de l'énergie nucléaire à des fins de production industrielle d'électricité", Federal Public Service Justice, *Moniteur Belge*, 5 June 2024 (in French), see http://www.ejustice.just.fgov.be/eli/loi/2024/04/26/2024003971/moniteur, accessed 20 August 2024.

48 - *Moniteur Belge*, "Loi modifiant la loi du 31 janvier 2003 sur la sortie progressive de l'énergie nucléaire à des fins de production industrielle d'électricité afin de garantir la sécurité d'approvisionnement sur le plan énergétique", N.174, Second Edition, 6 July 2015 (in French and Dutch), see http://www.ejustice.just.fgov.be/mopdf/2015/07/06_2.pdf.
- For Doel-1&-2, see Electrabel, GDF Suez/Engie, "Note de Presse—Sécurité d'approvisionnement et transition énergétique—Accord sur la prolongation de Doel 1 et Doel 2", Press Release,1 December 2015 (in French) and Engie Electrabel, "Doel Nuclear Power Plant—Profile of the 4 units", Updated 7 August 2017, see http://corporate.engie-electrabel.be/local-player/nuclear-3/doel/;
- For Tihange-1, see Engie/Electrabel, "Tihange", Undated, see http://corporate.engie-electrabel.be/local-player/nuclear-3/tihange/; all accessed 23 June 2019.

49 - Federal Public Service Justice, "26 AVRIL 2024. - Loi modifiant la loi du 31 janvier 2003 sur la sortie progressive de l'énergie nucléaire à des fins de production industrielle d'électricité", *Moniteur Belge*, 5 June 2024, op. cit.

Lifetime Extension of Doel-4 and Tihange-3?

Operator Electrabel, a subsidiary of French energy group Engie, had previously signaled that it was interested in extending the lifetime of two or three units beyond 2025 but warned that it would need legislation to be adapted by the end of the year 2020.[50] This did not happen and Engie decided "to stop preparation works that would allow for the 20-year extension of two nuclear units beyond 2025."[51]

In July 2022, the Belgian Government inquired whether Tihange-2, slated for closure on 1 February 2023, could be kept operating until the end of March 2023. Engie stated that a lifetime extension of Tihange-2 "had never been on the table" and that on such short notice, without any preparatory work having been done, "it is not possible due to both technical and nuclear safety constraints."[52] In another reported statement Engie explained that any lifetime extension of Tihange-2 was "not an option" and pointed out that "taking into account the concrete situation, considering such a scenario in haste, without the necessary preliminary studies having been carried out, is not possible with regard to the imperatives of nuclear safety (...)"[53] Accordingly, Tihange-2 was closed on 31 January 2023.

In January 2022, the Federal Agency for Nuclear Control (FANC) issued a report commissioned by the government concluding a lifetime extension "would be possible from a nuclear safety point of view but only if the facilities were updated."[54]

On 9 January 2023, the government—represented by the Prime Minister and the Energy Minister (Green Party)—jointly announced the signature of a Heads of Terms and Commencement of LTO [Long-Term Operation] Studies Agreement with Engie, stating that

> This agreement in principle constitutes an important step, and paves the way for the conclusion of full agreements in the upcoming months. It also provides for the immediate start of environmental and technical studies prior to obtaining the authorizations related to this extension. (...)
>
> With this agreement, both parties confirm their objective to make reasonable endeavours to restart the Doel 4 and Tihange 3 nuclear units in November 2026.[55]

50 - Herman Moestue, "Electrabel réitère son appel à prolonger le nucléaire belge", *Montel*, 28 January 2020 (in French), see http://www.montelnews.com/fr/story/electrabel-ritre-son-appel-à-prolonger-le-nuclaire-belge/1082410, accessed 8 August 2020.

51 - Engie, "2020 Management Report and Annual Consolidated Financial Statements", March 2021, see https://www.engie.com/sites/default/files/assets/documents/2021-02/ENGIE_2020_Management_report_and_annual_consolidated_financial_statements.pdf, accessed 1 August 2021.

52 - *WNN*, "Belgium asks Engie to extend Tihange 2's life", 18 July 2022, see https://world-nuclear-news.org/Articles/Belgium-asks-Engie-to-extend-Tihange-2-s-life, accessed 24 July 2022.

53 - *RTBF*, "Sortie du nucléaire : prolonger Tihange 2 deux mois ? Engie dit non au gouvernement", 16 July 2022 (in French), see https://www.rtbf.be/article/sortie-du-nucleaire-prolonger-tihange-2-deux-mois-engie-dit-non-au-gouvernement-11032081, accessed 21 August 2022.

54 - AFCN/FANC, "Sortie du nucléaire : l'AFCN soumet son rapport au gouvernement fédéral—Possible prolongation d'exploitation en toute sûreté de Doel 4 et Tihange 3, sous conditions", Agence Fédérale de Contrôle Nucléaire/Federal Agency for Nuclear Control, Press Release (in French), 17 January 2022, see https://afcn.fgov.be/fr/actualites/sortie-du-nucleaire-lafcn-soumet-son-rapport-au-gouvernement-federal, accessed 3 August 2022.

55 - ENGIE, "ENGIE and the Belgian federal government set a frame for the extension nuclear reactors of Doel 4 and Tihange 3", Press Release, 9 January 2023, see https://nuclear.engie-electrabel.be/en/press/release/engie-and-belgian-federal-government-set-frame-extension-nuclear-reactors-doel-4-and, accessed 25 October 2023.

Green-Party Co-President Rajae Maouane commented: "I'm part of this new generation of environmentalists for whom nuclear power is no longer a taboo."[56]

Between 20 March and 20 June 2023, the Belgian Government held a transboundary public consultation on the basis of the "Environmental Impact Assessment in the context of postponing the deactivation of the Doel 4 and Tihange 3 nuclear power plants."[57]

According to Engie, the intermediate agreement signed with the Belgian Government on 29 June 2023, only nine days after the end of the public consultation, contained the following key points:[58]

- "The commitment from both parties to use their best efforts to restart the nuclear units of Doel 4 and Tihange 3 as early as November 2026, or, subject to the effective implementation of an announced relaxation of regulations, as early as November 2025, with the aim to strengthen the security of supply in Belgium."
- The Doel-4 and Tihange-3 reactors will be co-owned in a 50-50 percent partnership.
- The remuneration will be based on a Contract for Difference model.
- Engie will pay a lump sum of €15 billion (US$$_{2023}$16 billion)[59] for "the future costs of nuclear waste management" of all seven of Engie's nuclear reactors in Belgium. The amount is to be paid in two instalments, one at closing in the first semester 2024 for intermediate- and high-level nuclear waste, and a second payment in 2026 for low-level waste.
- Electrabel has already ordered fuel and the nuclear regulator has determined the scope of inspections and work to be carried out for the operation of ten additional years.

Another "intermediate agreement" was signed on 21 July 2023[60] and was to be followed by the final, legally binding agreement by the end of October 2023. Provided the European Commission approved the contract, closure of the deal was expected in the first half of 2024.[61]

56 - David Coppi, "'Dire que le contribuable paiera la prolongation du nucléaire, c'est totalement faux'", Interview with Jean-Marc Nollet and Rajae Maouane, Co-Presidents, Ecolo/Belgian Green Party (in French), *Le Soir*, 14 January 2023.

57 - FPS Economy, "Public consultation on the life extension of Doel 4 and Tihange 3", Federal Public Service Economy, May 2023, see https://economie.fgov.be/en/themes/energy/public-consultation-life, accessed 8 June 2023; and SCK CEN, "Non-technical summary of the Environmental Impact Assessment In the context of postponing the deactivation of the Doel 4 and Tihange 3 nuclear power plants", Studiecentrum voor kernenergie/Centre d'étude de l'énergie nucléaire/Belgian Nuclear Research Centre, 20 March 2023.

58 - ENGIE, "ENGIE signs an agreement with the Belgian government on the extension of Tihange 3 and Doel 4 nuclear reactors and all obligations related to nuclear waste", Press Release, 29 June 2023, see https://corporate.engie.be/en/press/release/engie-signs-agreement-belgian-government-extension-tihange-3-and-doel-4-nuclear, accessed 21 July 2023; and ENGIE Electrabel, "What was agreed between ENGIE and the Belgian government on the 10-year operating extension of Doel 4 and Tihange 3?", Undated, see https://nuclear.engie-electrabel.be/en/nuclear-energy/key-questions-about-nuclear-power-plants/what-was-agreed-between-engie-and-belgian, accessed 31 October 2023

59 - Throughout the report, to the best of our ability, amounts in foreign currencies that were allocated, estimated or spent during the ongoing year are translated into US$$_{2024}$ by applying the monthly exchange rate as of June 2024—unless the amount is explicitly based on the value of a different year, in which case the yearly exchange rate of the corresponding year is applied.
Amounts in foreign currencies that were allocated, estimated or spent in past years are converted to the corresponding value by applying the yearly average exchange rate.

60 - ENGIE Electrabel, "Signing of Framework Agreement with the Belgian state", 21 July 2023, see https://nuclear.engie-electrabel.be/en/news/signing-framework-agreement-belgian-state, accessed 1 November 2023.

61 - ENGIE Electrabel, "What was agreed between ENGIE and the Belgian government on the 10-year operating extension of Doel 4 and Tihange 3?", Undated, op. cit.; and ENGIE, "ENGIE signs an agreement with the Belgian government on the extension of Tihange 3 and Doel 4 nuclear reactors and all obligations related to nuclear waste", Press Release, 2023, op. cit.

On 13 December 2023, just two months later than scheduled, Engie and the Belgian Government signed the final, legally binding agreement that, according to Engie, "endorses the key principles of the framework agreement signed on 21 July 2023."[62]

Independent experts and the environmental movement have sharply criticized the agreement. Independent energy consultant Alex Polfliet lists as the "main critics":

- deficiencies in the democratic process (with lack of consultation, including with the energy regulator);
- the abandoning of the 'Polluter Pays Principle' (with the €15 billion [US$16 billion] capping of decommissioning and waste management coverage);
- high costs (as taxpayer would cover almost half of lifetime-extension costs and guaranteed price that might be well over market prices);
- state aid cuts out other options (as Doel-4/Tihange-3 reactors would "run even during negative price hours" and that "while renewables will be stopped."[63]

On 18 April 2024, the Belgian Parliament nevertheless voted not only to amend the 2003-nuclear phaseout legislation (see above) but also approved the following pieces of legislation:

- A law on the creation, organization and operation of a public institution whose purpose is to take over the financial responsibility for certain nuclear liabilities (called Hedera Law). Hedera is the public institution to be responsible for those capped liabilities linked to nuclear waste and spent fuel and manage the funds.[64]
- A law to guarantee security of supply in the energy sector and reforming the nuclear energy sector (called Phoenix Law).[65]
- A law on the creation, organization and operation of the administrative service with autonomous accounting (called BE-WATT Law). BE-WATT is to become the government's shareholder in BE-NUC.[66]

BE-NUC, a company with equal shares for Engie's subsidiary Electrabel, that remains the sole operator, and the Belgian state that would co-own the remaining two reactors and share the inherent commercial risks. So far, Electrabel held 89.807 percent of the plant ownership that will be shared now with the Belgian state with the remaining 10.193 percent remaining with Luminus, a 68.6 percent subsidiary of EDF-Belgium.

62 - Engie, "Brochure de convocation 2024 – Assemblée générale mixte des actionnaires", 30 April 2024.

63 - Alex Polfliet, "LTO of Tihange 3 & Doel 4", Conference Presentation, 21 March 2024

64 - Federal Public Service Justice, "26 AVRIL 2024. - Loi modifiant la loi du 31 janvier 2003 sur la sortie progressive de l'énergie nucléaire à des fins de production industrielle d'électricité", *Moniteur Belge*, op. cit.

65 - Ibidem.

66 - Ibidem

European Commission Opens Formal Procedure for Potential Violation of State Aid Regulations

On 21 June 2024, the Belgian Government officially notified the European Commission of the agreement with Engie concerning the support package of the lifetime extension plan for Doel-4 and Tihange-3. By letter dated 22 July 2024,[67] the Commission informed the Belgian Government that it was launching a procedure according to Article 108, paragraph 2 of the Treaty on the Functioning of the European Union (TFEU).[68] In a press statement, the Commission expressed its "doubts as to its compatibility with EU State aid rules" and has therefore decided to open an in-depth investigation. In particular, the Commission says it intends to further investigate:

- The necessity of the additional financial support mechanisms on top of the CfD [Contract for Difference], in particular the creation of the joint-venture and its financing, as well as of the operating cashflow guarantee and the €580 million [US$627 million] loan;
- The appropriateness of the CfD design and the combination of financial and structural arrangements as they may unduly relieve the beneficiaries from too big a share of the market and operational risks;
- The proportionality of the combination of financial and structural arrangements and of the €15 billion [US$16 billion] lumpsum;
- Compliance with relevant EU sectoral legislation, in particular concerning the design of the CfD mechanism; and
- The impact of the measure on the market in light of the CfD design and the selection and independence of the agent selling the nuclear electricity.[69]

The Commission considers that the CfD design, that provides a guaranteed remuneration for the two nuclear reactors, "might have an adverse effect on the functioning of the E.U. [electricity] market, contrary to the principles set out" in the E.U. regulations.[70] An initial strike price shall be set in 2025 that takes into account the cost of upgrading required by the nuclear safety authority. In 2028, the strike price shall be updated and fixed for the rest of the operational period.

The term "risk" comes up on 55 of the 78-page letter, often several times on a given page. The Commission has listed technical and management risks, risks related to waste management and decommissioning, market and investment risks as well as regulatory and political risks. Engie's strategy since 2020 was to withdraw from nuclear activities in Belgium and "de-risk

67 - Editor's Note: While this event took place after the editorial deadline of 1 July 2024, its significance justifies a last-minute summary.

68 - European Commission, " State aid SA.106107 (2024/N) — Lifetime extension of two nuclear reactors (Doel 4 and Tihange 3)— Invitation to submit comments pursuant to Article 108(2) of the Treaty on the Functioning of the European Union", C/2024/4921, *Official Journal of the European Union*, 8 August 2024, see https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C_202404921, accessed 28 August 2024.

69 - European Commission, "Commission opens in-depth State aid investigation into Belgian support for lifetime extension of two nuclear reactors", Press Release, 22 July 2024, see https://ec.europa.eu/commission/presscorner/detail/en/IP_24_3901, accessed 20 August 2024.

70 - European Commission, " State aid SA.106107 (2024/N) — Lifetime extension of two nuclear reactors (Doel 4 and Tihange 3)— Invitation to submit comments pursuant to Article 108(2) of the Treaty on the Functioning of the European Union", C/2024/4921, *Official Journal of the European Union*, 8 August 2024, op. cit.

its exposure as nuclear operator to market price volatility."[71] All studies into potential lifetime extension at Doel and Tihange were halted. Therefore, when the Belgian Government pushed the company to reopen the option:

> Engie made it clear from the start that without a risk sharing mechanism and a solution for the costs of nuclear waste stemming from the operation of the seven nuclear power plants, it would not consider the lifetime extension of the two nuclear reactors, which forces Engie to substantially modify its company strategy and risk exposure.

The European Commission highlights in particular the "considerable" uncertainties regarding the final investment costs, as "the scope of the necessary investments will only become clear in a later stage," once inspections and studies have been carried out and the upgrading work program has been approved by the safety authorities. The scope of work will determine how long the units will have to remain off-grid without generating income.

The letter states that:

> the Commission does not have sufficient elements to conclude whether the conditions for the compatibility of any possible aid with the internal market (...) are met, in particular, whether the aid is necessary, appropriate and proportionate, does not violate Union law and does not affect competition in a way contrary to the common interest.

The Commission "wishes to remind Belgium that Article 108(3) TFEU has suspensory effect" and "that all unlawful aid may be recovered from the recipient." The Commission "warns Belgium" that it will inform interested parties by publishing this letter in the Official Journal of the European Union. The Commission "requests Belgium to submit its comments and to provide all [...] information [...] to assess the measure" by 8 September 2024.

Nuclear Safety Authority Needs Yet to Approve Upgrading Program

On 20 July 2023, the Federal Agency for Nuclear Control (FANC) communicated its expectations to Engie Electrabel to allow for lifetime extensions beyond 2025. The regulator proposes to stagger upgrading work to 2028 to allow for the two reactors to be available during the winters 2025–2026 and 2026–2027. Engie Electrabel now has to come up with concrete proposals on how and by when to implement the requested upgrading work.[72]

As of mid-2024, FANC stated on its website, updated on 23 February 2024, that "AFCN expects Engie Electrabel's complete file by the beginning of 2025, and will analyze and comment on it in depth within the following six months."[73]

Many technical and legal challenges remain to be solved prior to the operation of Doel-4 and Tihange-3 beyond 2025. In February 2023, Engie has ruled out the lifetime extension of the three other remaining operating reactors Doel-1 and -2, and Tihange-1 calling the option

71 - All quotes in this section from previous source if not otherwise specified.

72 - AFCN/FANC, "L'AFCN envoie ses exigences de sûreté à ENGIE Electrabel pour la prolongation de Doel 4 et Tihange 3", 20 July 2023 (in French), see https://afcn.fgov.be/fr/actualites/lafcn-envoie-ses-exigences-de-surete-engie-electrabel-pour-la-prolongation-de-doel-4-et, accessed 21 July 2023.

73 - AFCN/FANC, "Exploitation à long terme (LTO) de Doel 4 et Tihange 3 jusqu'en 2035", Updated 23 February 2024 (in French), see https://afcn.fgov.be/fr/dossiers/centrales-nucleaires-en-belgique/exploitation-long-terme-lto-de-doel-4-et-tihange-3-jusquen, accessed 24 February 2024.

"unthinkable".[74] In March 2023, FANC ruled out the prolongation option for the three units on safety grounds.[75]

Previous Lifetime Extensions

In summer 2012, the operator identified an unprecedented number of hydrogen-induced crack indications in the pressure vessels of Doel-3 and Tihange-2, with respectively over 8,000 and 2,000 previously undetected defects, which later increased to over 13,000 and over 3,000. In spite of widespread concerns, and although no failsafe explanation about the negative initial test results was given, on 17 November 2015, FANC authorized the restart of Doel-3 and Tihange-2 (see previous WNISR editions for details).

The Belgian Government did not wait for the outcome of the Doel-3/Tihange-2 issue and decided in March 2015 to draft legislation to extend the lifetime of Doel-1 and Doel-2 by ten years to 2025. The law went into effect on 6 July 2015. On 22 December 2015, FANC authorized the lifetime extension and restart of Doel-1 and -2.[76]

On 6 January 2016, two Belgian NGOs filed a complaint against the 28 June 2015 law with the Belgian Constitutional Court, arguing in particular that the lifetime extension had been authorized without a legally required public enquiry. Following a 22 June 2017 pre-ruling decision, the Court addressed a series of questions to the European Court of Justice (ECJ), in particular concerning the interpretation of the Espoo and Aarhus Conventions, as well as the European legislation.[77]

On 29 July 2019, the ECJ stated that the lifetime extension of a reactor

> must be regarded as being of a comparable scale, in terms of risks of environmental impact, to the initial commissioning of those power stations. Consequently, it is mandatory for such a project to be the subject of an environmental impact assessment provided for by the EIA directive.[78]

In addition, as the Doel-1 and -2 reactors are particularly close to the Belgian-Dutch border, "such a project must also be subject to the transboundary assessment procedure." The judgement permitted to delay the implementation of the order, if a national court considers it is

74 - *L'Echo*, "Prolongation du nucléaire: la piste Doel 1, Doel 2 et Tihange 1 enterrée?", 28 February 2023 (in French), see https://www.lecho.be/dossiers/crise-energetique/prolongation-du-nucleaire-la-piste-doel-1-doel-2-et-tihange-1-enterree/10450477.html, accessed 31 October 2023.

75 - *NEI Magazine*, "Belgian regulator opposes life extension of oldest reactors", *Nuclear Engineering International*, 9 March 2023, see https://www.neimagazine.com/news/newsbelgian-regulator-opposes-life-extension-of-oldest-reactors-10660623, accessed 9 March 2023

76 - AFCN/FANC, "Exploitation à long terme (LTO) des centrales nucléaires belges - 2015", Agence fédérale de Contrôle nucléaire/Belgian Federal Agency for Nuclear Control, Updated 18 January 2022 (in French), see https://afcn.fgov.be/fr/dossiers/centrales-nucleaires-en-belgique/exploitation-long-terme-lto-des-centrales-nucleaires, accessed 30 August 2022.

77 - Cour Constitutionnelle, "Request for a preliminary ruling from the Cour constitutionnelle (Constitutional Court, Belgium) lodged on 7 July 2017 — Inter-Environnement Wallonie asbl, Bond Beter Leefmilieu Vlaanderen vzw v Conseil des ministers—Case C-411/17"", Constitutional Court of Belgium, *Official Journal of the European Union*, 11 September 2017, see https://eur-lex.europa.eu/legal-content/en/TXT/PDF/?uri=uriserv%3AOJ.C_.2017.300.01.0022.01.ENG, accessed 3 November 2023.

78 - ECJ, "The Belgian law extending the operating life of nuclear power stations Doel 1 and Doel 2 was adopted without the required environmental assessments being carried out first—Judgment in Case C-411/17", Press Release No 100/19, Court of Justice of the European Union, 29 July 2019, see https://curia.europa.eu/jcms/upload/docs/application/pdf/2019-07/cp190100en.pdf, accessed 30 August 2022.

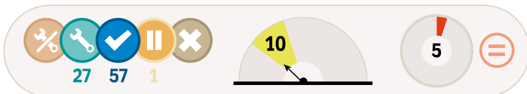
> justified by overriding considerations relating to the need to exclude a genuine and serious threat of interruption to the electricity supply in the Member State concerned, which cannot be addressed by other means or alternatives, inter alia in the context of the internal market. That maintenance may only last for the amount of time strictly necessary in order to remedy that illegality.[79]

On 5 March 2020, the Belgian Constitutional Court nullified the lifetime extension legislation in its entirety but gave the government until the end of 2022 "at the latest" to carry out an appropriate Environmental Impact Assessment (EIA) and a transboundary consultation.[80]

The Belgian Government argued that the lifetime extension "plays a vital role in securing its supply of electricity until 2025" and sent a notification for consultation to a number of European governments inviting them to comment on the "project" (that is the well engaged lifetime extension of Doel-1 and -2).[81]

The Belgian precedent has significant consequences on lifetime extension projects in European Union Member States that now all have to carry out full-scale EIAs and organize transboundary consultations prior to granting permission for lifetime extensions.

CHINA FOCUS



As of mid-2024, China had 57 reactors in operation with a total capacity of around 54 GW. The count of 57 is higher than the IAEA's count of 56 in its PRIS database because WNISR records the Shidao Bay project with twin High-Temperature Reactor Pebble-bed Modules (HTR-PM) as two 100-MW reactors. For unknown reasons, the China Experimental Fast Reactor (CEFR) is no longer mentioned in the PRIS database since May 2023, and has been placed in Long-Term Outage (LTO) as of this date in WNISR statistics.

Nuclear plants produced a record 406.5 TWh in 2023, an increase of 2.8 percent over the 395.4 TWh generated in 2022. The nuclear share was 4.9 percent of total electricity produced in 2023, marginally lower than the 5 percent recorded in 2022. In comparison, the 2024 edition of the Statistical Review of World Energy records nuclear power's share of total electricity produced (gross) as 4.6 percent, again marginally lower than the 2022 figure of 4.7 percent.[82] In late September 2023, the China Nuclear Energy Association has announced plans to expand nuclear power's contribution to 10 percent of total electricity production by 2035 and about

79 - Ibidem.

80 - Cour Constitutionnelle, "La Cour annule la loi qui prolonge l'activité des centrales nucléaires de Doel 1 et 2, en l'absence d'études préalables d'incidences environnementales, mais en maintient les effets jusqu'au plus tard le 31 décembre 2022" , Press Release (in French), Constitutional Court, 5 March 2020 see https://www.const-court.be/public/f/2020/2020-034f-info.pdf; for the text of the judgement (in French) see Cour Constitutionnelle, "Arrêt 34/2020", Constitutional Court, 5 March 2020, see https://www.const-court.be/public/f/2020/2020-034f.pdf, both accessed 30 August 2022.

81 - Marie-Christine Marghem, Letter dated 13 August 2020, Ministry of Energy, Environment and Sustainable Development, Belgium.

82 - Andrew Hayley, "China expects to OK 6-8 nuclear power units per year in green energy drive", *Reuters*, 27 September 2023, see https://www.reuters.com/business/energy/china-expects-ok-6-8-nuclear-power-units-per-year-green-energy-drive-2023-09-27/, accessed 4 August 2024.

18 percent by 2060.[83] These targets, while still very ambitious, are down from those announced in 2020 in a joint policy advisory report by the China Nuclear Development Institute (CNDC) and China Electric Power Research Institute (Cepri), respectively part of the National Energy Administration and China State Grid Corp. According to their 2020-projections, nuclear capacity would grow to 131 GW in 2030 contributing 10 percent to the national power generation and to 169 GW by 2035 with 13.5 percent of the total generation mix.[84]

In the year to mid-2024, only one nuclear reactor has started operating: Fangchenggang-4, a 1000-MW Hualong One, became critical on 3 April 2024.[85] The reactor was subsequently connected to the grid on 9 April 2024, and declared to be operating commercially on 25 May 2024. The reactor's first pour of concrete was on 23 December 2016, which represents a construction period of a bit over 87 months.

It is interesting to assess the construction durations of the 58 units connected to the Chinese grid between 1991 and July 2024. The 42 reactors of Chinese or Sinicized design had an average construction time of 5.7 years with a range from 4.1 to 10 years with the smallest, the SMR-type High Temperature reactors, showing the longest construction times. It took on average respectively only 4.5 years for two Canadian CANDUs, but 6.6 years for six French units (4.8–9.2 years), 6.9 years for four Russian reactors (5–11.2 years), 8.6 years for two U.S. AP-1000s, and 9 years for two AP-1000 built by a U.S.-Japanese consortium (see Figure 26). It is remarkable that, just as other nuclear countries, China does not seem to reduce construction times but rather experiences an increasing trend. The reasons are unclear.

China has a further 27 reactors under construction, with a combined capacity of around 29 GW (see also Annex 5 – Nuclear Reactors in the World "Under Construction"):

- The two CAP1400 reactors, Shidao Bay 2-1 and Shidao Bay 2-2, (since 2019) which are not listed in the IAEA's PRIS database.
- The five units that have started being constructed since WNISR2023 are: Lufeng-6, a Hualong One reactor (26 August 2023); Lianjiang-1 and -2, two 1224 MW CAP1000 reactors (27 September 2023 and 26 April 2024); Zhangzhou-3, a Hualong One reactor (22 February 2024); and Xudabu-1 (also called Xudapu or Xudabao), a CAP1000 reactor (3 November 2023).[86]
- Other (large) light water reactors being built, with details in earlier WNISR editions, are

83 - Li Hongyang, "Nuclear energy to provide 10% of China's electricity by 2035", *China Daily*, 26 September 2023, see https://www.chinadaily.com.cn/a/202309/26/WS651282b3a310d2dce4bb7ed7.html, accessed 4 August 2024.

84 - C.F. Yu, "Can China Meet Bullish Nuclear Growth Targets?", *Nuclear Intelligence Weekly*, 10 January 2020.

85 - David Dalton, "China / CGN Announces First Criticality At Fangchenggang-4 Nuclear Power Plant", *NucNet*, 10 April 2024, see https://www.nucnet.org/news/cgn-announces-first-criticality-at-fangchenggang-4-nuclear-power-plant-4-3-2024, accessed 10 April 2024; and CGN, "中广核防城港核电站4号机组首次达到临界状态", 3 April 2024, see http://www.cgnp.com.cn/cgnp/c100725/2024-04/26/content_0e377c8c39974e2ebdad0e1f6ea5af90.shtml, accessed 4 August 2024.

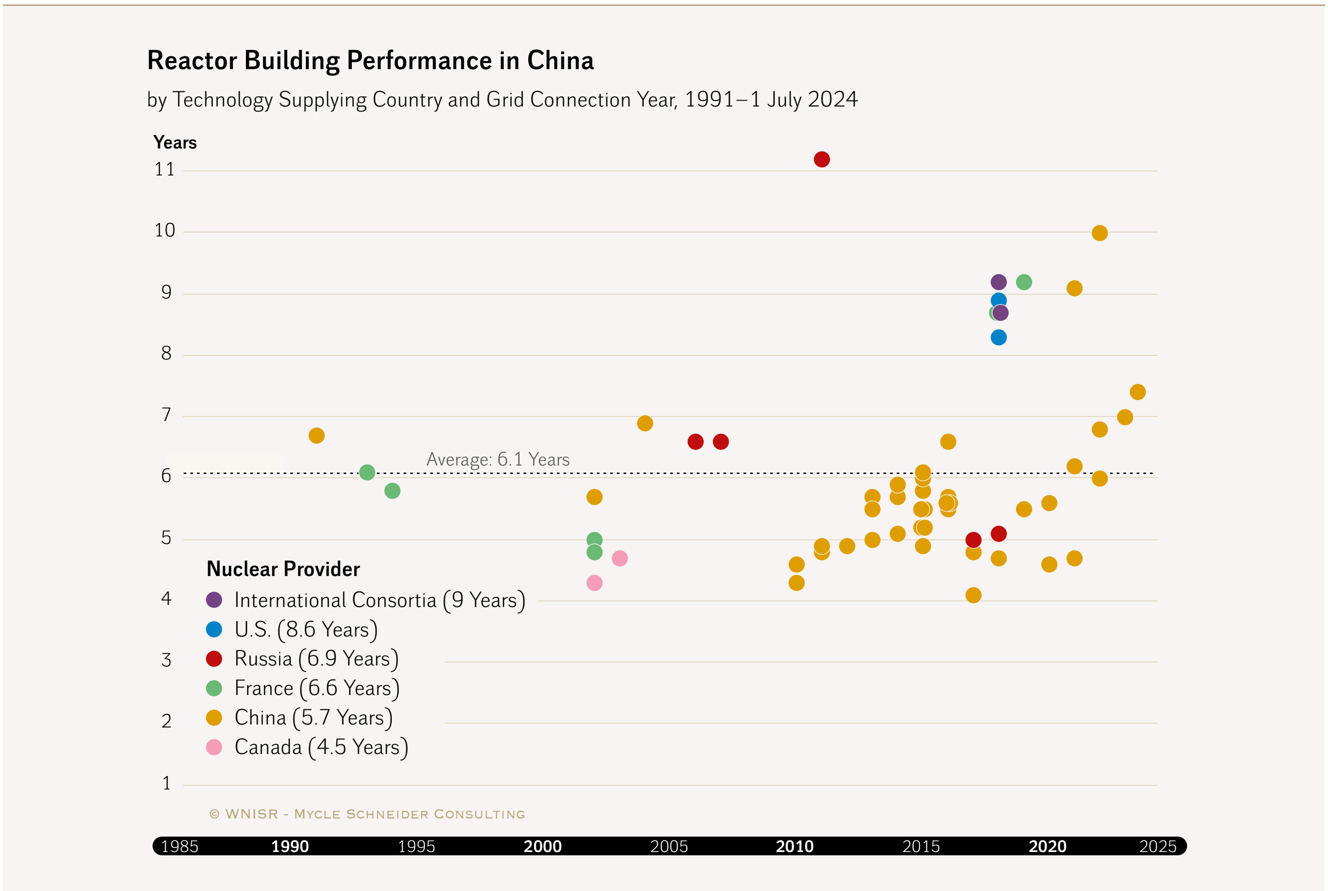
86 - CGN, "Unit No.34 of CGN's Fleet! Lufeng Unit6 starts construction", 27 August 2023, see http://en.cgnp.com.cn/encgnp/c100866/2024-01/10/content_9493062a9fc44d83b5d88312719a7070.shtml; and *WNN*, "Construction of first unit at Lianjiang under way", 9 October 2023, see https://www.world-nuclear-news.org/Articles/Construction-of-first-unit-at-Lianjiang-under-way; also *WNN*, "Construction starts of second Lianjiang unit", *World Nuclear News*, 29 April 2024, see https://www.world-nuclear-news.org/Articles/Construction-starts-of-second-Lianjiang-unit; and *Xinhua*, "China begins construction on 2nd phase of Zhangzhou nuclear power project", State Council Information Office, Government of China, 23 February 2024, see http://english.scio.gov.cn/chinavoices/2024-02/23/content_117015492.htm; also *NEI Magazine*, "China celebrates start of construction at Xudabao 1", 24 November 2023, see https://www.neimagazine.com/news/newschina-celebrates-start-of-construction-at-xudabao-1-11323924; all accessed 4 August 2024.

- since 2019: Taipingling-1 and Zhangzhou-1;
- since 2020: Taipingling-2, Sanaocun-1, and Zhangzhou-2;
- since 2021: Changjiang-3 and -4, Sanaocun-2, Tianwan-7, and Xudabu-3;
- since 2022: Tianwan-8, Xudabu-4, Sanmen-3, Haiyang-3, and Lufeng-5;
- since 2023: Haiyang-4, and Sanmen-4.

→ The Xiapu two fast reactor units started being built on 29 December 2017 and 27 December 2021 respectively.[87]

→ The SMR Changjiang (or Linglong-1) is under construction since 2021.[88]

Figure 26 · Construction Times of Reactors Built in China



Sources: WNISR with IAEA-PRIS, 2024

In December 2023, the State Council approved building two 1200 MW Hualong One units that would constitute the first phase of the Jinqimen nuclear power plant in Ningbo, Zhejiang Province; the China National Nuclear Corporation (CNNC) broke ground at the site in

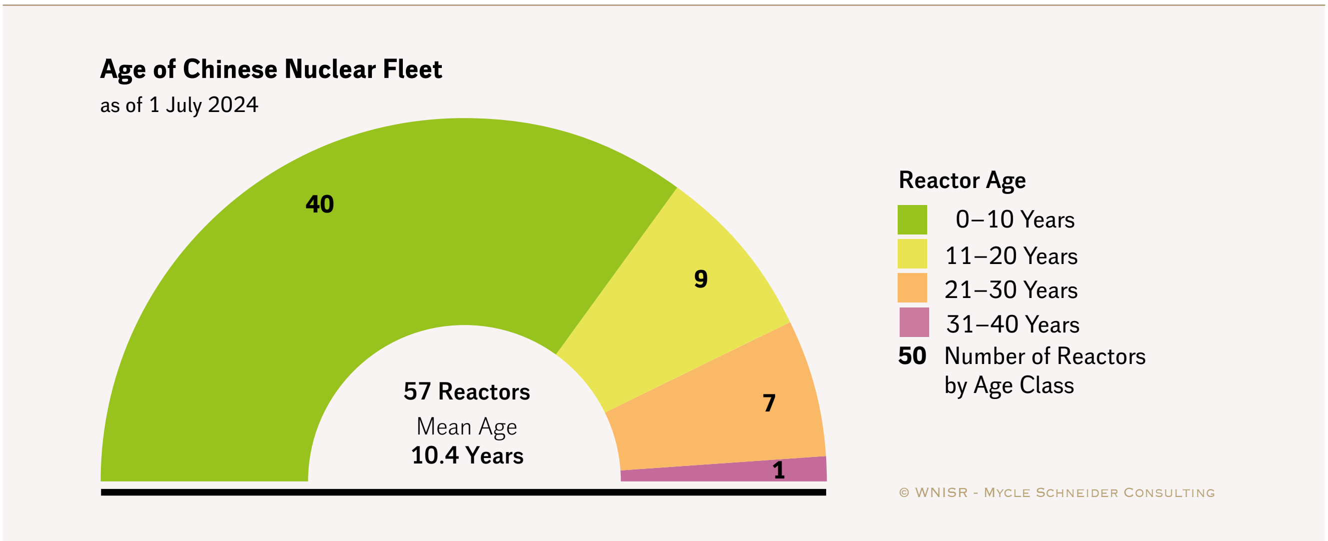
87 - *WNN*, "China begins building pilot fast reactor", 29 December 2017, see http://www.world-nuclear-news.org/NN-China-begins-building-pilot-fast-reactor-2912174.html, accessed 17 June 2019; and *NEI Magazine*, "China begins construction of second CFR-600 fast reactor", 4 January 2021, see https://www.neimagazine.com/news/newschina-begins-construction-of-second-cfr-600-fast-reactor-8435608, accessed 5 January 2021.

88 - CNNC, "World's first commercial Linglong One onshore small reactor starts construction", Press Release, China National Nuclear Corporation, 14 July 2021, see https://en.cnnc.com.cn/2021-07/14/c_642603.htm, accessed 31 August 2021.

February 2024.[89] Earlier, in July 2023, the State Council approved Unit 5 and 6 of the Ningde plant in Fujian Province, Unit 1 and 2 of the Shidaowan plant in Shandong Province, and Unit 1 (now under construction) and 2 of the Xudabao plant in Liaoning Province.[90]

The Chinese reactor fleet is very young. Almost three quarters of all units have not reached 10 years of age (see Figure 27). Only one unit, the 300-MW Qinshan-1, is over 31 years old, and it is the only Chinese unit, at 32.5 years, slightly exceeding the *average* age of the world nuclear fleet of 32.1 years.

Figure 27 • Age Distribution of the Chinese Nuclear Fleet



Sources: WNISR with IAEA-PRIS, 2024

Pakistan (see Pakistan in Annex 1) continues to be the only country to which China has been exporting nuclear reactors. Its plans to export a reactor to Argentina had earlier resulted in a February 2022 agreement signed by CNNC and Nucleoeléctrica Argentina SA (NA-SA) to build Atucha-3.[91] But the project had reportedly "hit a stumbling block over finances" last year.[92] (See Argentina in Annex 1.) Those problems have deepened with President Javier Milei coming to power in Argentina, and there is no clarity whether the project will eventually move forward.[93] The fact that CNNC remains on the U.S. Government's blacklist is not helping either.[94]

89 - *WNN*, "Preparations begin for new Chinese plant", 19 February 2024, see https://www.world-nuclear-news.org/Articles/Preparations-begin-for-new-Chinese-plant, accessed 19 February 2024.

90 - *WNN*, "Six reactors approved for construction in China", 1 August 2023, see https://www.world-nuclear-news.org/Articles/Six-reactors-approved-for-construction-in-China, accessed 2 August 2023.

91 - Nucleoeléctrica Argentina S.A. and China National Nuclear Corporation, "'Atucha III' Nuclear Power Plant Project Joint Statement", Press Release, 1 February 2022, see https://www.na-sa.com.ar/en/prensa/atucha-iii-nuclear-power-plant-project-joint-statement, accessed 4 August 2024.

92 - Bala Chambers, "Argentina seeks to realign bilateral ties as trade deficit with China grows", *TRT World*, 1 March 2023, see https://www.trtworld.com/magazine/argentina-seeks-to-realign-bilateral-ties-as-trade-deficit-with-china-grows-12799142, accessed 3 July 2023.

93 - Igor Patrick, "China, Argentina discussing Milei's possible visit to Beijing: sources", *South China Morning Post*, 15 June 2024, see https://www.scmp.com/news/china/article/3266717/china-and-argentina-early-talks-over-javier-mileis-possible-visit-beijing-sources, accessed 17 July 2024.

94 - Bureau of Industry and Security, "Supplement No. 4 to Part 744 – Entity List", U.S. Department of Commerce, 19 May 2023, see https://www.bis.doc.gov/index.php/documents/regulations-docs/2326-supplement-no-4-to-part-744-entity-list-4/file, accessed 5 August 2024.

China continues to expand renewable energy very rapidly. Installed capacities of wind and solar energy in 2023 were 441.9 GW and 609.9 GW, up from 96.8 GW and 28.4 GW in 2014.[95] The wind capacity includes 37.3 GW of offshore wind power, up from 0.4 GW in 2014. In the first five months of 2024, China has added around 79 GW of solar energy and 20 GW of wind power.[96]

According to the Energy Institute's Statistical Review of World Energy, renewable sources (not including large hydropower) produced 17.6 percent of the total electricity in 2023 (up from 15.5 percent in 2022), nearly four times the contribution from nuclear power plants. Electricity produced by non-hydro renewable sources increased by 21.5 percent in 2023, compared to a 19.5 percent increase in 2022 (see also Case Study on China in Nuclear Power vs. Renewable Energy Deployment). Thanks to the massive installations of solar and wind energy, the share of coal-fired generation in May 2024 fell to 53 percent, the lowest share on record; shares of solar energy and wind energy for May 2024 were 12 percent and 11 percent respectively.[97]

CZECH REPUBLIC FOCUS

The Czech Republic has six Russian-designed reactors in operation at two sites. Dukovany houses four VVER-440/v213 reactors, and Temelín operates two VVER-1000/v320 units. In 2023, nuclear power production represented a 40 percent share in electricity generation at 28.7 TWh, a slight decrease from 29.3 TWh in 2022.

In May 2022, ČEZ, the 70-percent-state-owned utility,[98] announced that it had received an indefinite operating license for Temelín-2, on the grid since 2002, with a caveat that it continually meets conditions for safe operation.[99] Temelín-1, commissioned in 2000, had received a ten-year license renewal in September 2020.[100] ČEZ is planning to extend operating cycles at both units from 12 to 18 months, for which it expects the "final phase of approval" to begin this year.[101] In 2023, the company announced that it would invest CZK3.6 billion (US$\$_{2023}$162 million) for the modernization of the reactors in view of extended lifetime

95 - IRENA, "Renewable Capacity Statistics 2024", International Renewable Energy Agency, March 2024, see https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2024/Mar/IRENA_RE_Capacity_Statistics_2024.pdf?rev=a587503ac9a2435c8d13e40081d2ec34, accessed 17 April 2024.

96 - Lauri Myllyvirta, "Analysis: China's clean energy pushes coal to record-low 53% share of power in May 2024", Asia Socity Policy Institute, Centre for Research on Energy and Clean Air, *Carbon Brief*, 11 July 2024, see https://www.carbonbrief.org/analysis-chinas-clean-energy-pushes-coal-to-record-low-53-share-of-power-in-may-2024/, accessed 18 July 2024.

97 - Ibidem.

98 - CEZ Group, "About us— ČEZ, a. s—Shareholders", 2023, see https://www.cez.cz/en/cez-group/cez/structure-of-shareholders, accessed 26 July 2023.

99 - *NEI Magazine*, "Temelin 2 receives permit for extended operation", *Nuclear Engineering International*, 1 June 2022, see https://www.neimagazine.com/news/newstemelin-2-receives-permit-for-extended-operation-9737994, accessed 26 July 2023.

100 - David Dalton, "Regulator Gives 10-Year Licence Renewal For Temelín-1", *NucNet*, 25 September 2020, see https://www.nucnet.org/news/regulator-gives-10-year-licence-renewal-for-temelin-1-9-5-2020, accessed 2 August 2023.

101 - CEZ Group, "2023 Annual Financial Report—Strong in the Flow of Change", March 2024, see https://www.cez.cz/webpublic/file/edee/ospol/fileexport/investori/vz-2023/cez-group-annual-financial-report-2023-pdf.pdf, accessed 28 May 2024.

operations to at least 60 years. Reportedly, as of February 2023, a total of over CZK28 billion (US$$_{2023}$1.26 billion) had been invested for upgrading the plant since startup.[102]

The Dukovany units were started up between 1985 and 1987 and have already undergone a lifetime-extension upgrading program under the expectation that they would operate until 2025. In March 2016, SÚJB extended the operating license of Dukovany-1 indefinitely,[103] soon followed by indefinite lifetime extensions for the other three units.[104] ČEZ expects that the plant will operate until 2037[105] with the possibility of an extension until 2047.[106] To allow for the operation of the plant "for at least 60 years", ČEZ announced in early 2023 that it would be spending around CZK2.3 billion (US$$_{2023}$104 million) during the year—28 percent more than in the previous year.[107] The output of the four Dukovany units is planned to be gradually increased by 2.3 percent during 2024.[108]

Efforts to Decrease Dependence on Russia

In June 2022, in response to ongoing sanctions against Russian assets, CEZ Group purchased Škoda JS—an originally Czech nuclear service company—from OMZ, a Russian engineering group controlled by Gazprombank.[109] Škoda JS had been acquired by OMZ together with two other former Škoda Holding subsidiaries in 2004.[110] With its acquisition by ČEZ having been finalized in November 2022,[111] Škoda JS has now been removed from U.S. sanction lists where it had been included due to its former ownership.[112] Further, by acquiring Škoda JS, ČEZ increased its share in the ÚJV Řež research facility from 17.39 percent to 69.85 percent.[113] With

102 - *WNN*, "Modernisation projects under way at Czech plants", *World Nuclear News*, 15 February 2023, see https://world-nuclear-news.org/Articles/Modernisation-projects-under-way-at-Czech-plants, accessed 2 August 2023.

103 - David Dalton, "Dukovany-2 And -3 To Undergo Extended Checks On Pipe Welds", *NucNet*, 13 May 2016, see https://www.nucnet.org/all-the-news/2016/05/13/dukovany-2-and-3-to-undergo-extended-checks-on-pipe-welds, accessed 9 April 2021.

104 - *NEI Magazine*, "A view over Europe", 28 March 2018, see https://www.neimagazine.com/advanced-reactorsfusion/a-view-over-europe-6098537/?cf-view, accessed 2 June 2024.

105 - ČEZ, "NPP Dukovany", CEZ GROUP, Undated, see http://www.cez.cz/en/energy-generation/nuclear-power-plants/dukovany, accessed 26 July 2023.

106 - Ibidem; and European Commission, "Progress of implementation of Council Directive 2011/70/EURATOM Accompanying the document Report from the Commission to the Council the European Parliament on progress of implementation of Council Directive 2011/70/EURATOM and an inventory of radioactive waste and spent fuel present in the Community's territory and the future prospects", 18 December 2019, see https://www.parlament.gv.at/dokument/XXVII/EU/7208/imfname_10949006.pdf, accessed 26 July 2023.

107 - *WNN*, "ČEZ increases investment in Dukovany, 16-month fuel cycles", 2 February 2023, see https://www.world-nuclear-news.org/Articles/CEZ-increases-investment-in-Dukovany,-16-month-fue, accessed 4 February 2023; and CEZ Group, "2023 Annual Financial Report", March 2024, op. cit., p. 81.

108 - CEZ Group, "2023 Annual Financial Report", March 2024, op. cit.

109 - *WNN*, "ČEZ buys Škoda JS from Russian owners", 20 June 2022, see https://www.world-nuclear-news.org/Articles/CEZ-buys-supplier-Skoda-JS-from-Russian-owners, accessed 20 June 2022.

110 - *Clarion Energy*, "OMZ – Power Machines Group purchase Skoda subsidiaries", *Power Engineering*, 5 July 2004, see https://www.power-eng.com/nuclear/omz-power-machines-group-purchase-skoda-subsidiaries/, accessed 2 August 2023.

111 - Škoda JS, "Yesterday, ČEZ finally took over ŠKODA JS, a major Czech company focusing on nuclear service and engineering", Press Release, 25 November 2022, see https://www.skoda-js.cz/press/yesterday-cez-finally-took-over-skoda-js/, accessed 7 November 2023.

112 - Škoda JS, "ŠKODA JS Removal from the U.S. OFAC's Sanctions List", Press Release, 16 May 2023, see https://www.skoda-js.cz/press/skoda-js-removal-from-the-u-s-ofacs-sanctions-list/, accessed 7 November 2023.

113 - Michal Hudec, "Slovak nuclear plants serviced by Gazprom-linked company", *Euractiv*, 5 April 2022, see https://www.euractiv.com/section/politics/short_news/slovak-nuclear-plants-serviced-by-gazprom-linked-company/, accessed 8 July 2022; and CEZ Group, "2022 Annual Financial Report—I. Activity Report", 2023, see https://www.cez.cz/webpublic/file/edee/ospol/fileexport/investori/vz-2022/cez-group-annual-financial-report-2022-pdf.pdf, accessed 7 November 2023.

this acquisition, Czech companies are now actively involved in several local nuclear power plant component suppliers such as Sigma Group, a supplier of pumps used in nuclear power plants. However, fittings manufacturer Arako is still owned by Rosatom, and Chinese-owned machinery company Žďas generated 20 percent of its turnover from sales to Russia as of March 2023.[114]

Refueling-cycle extensions go hand in hand with Czech efforts to diversify fuel supply and "gradually replace" the current Russian provider, TVEL. Ultimately, all four VVER-440 reactors at Dukovany are to operate with fuel manufactured by Westinghouse.[115] Preparations to receive Westinghouse fuel by the end of the year are ongoing, as are efforts to expand fuel storage capacity at both Dukovany and Temelín to secure increased onsite fuel reserves.[116] Meanwhile, ČEZ continues to use and increase its stockpile of TVEL fuel. The latest refueling, that began in October 2023 at Dukovany-4, was carried out with new-generation TVEL fuel[117] and ČEZ clarified that "the increase of nuclear fuel stocks will continue, at least until the operation of the plants with fuel from new suppliers is verified."[118]

Russian fuel is also to be replaced at Temelín. Framatome and Westinghouse were contracted in 2022 to deliver fuel for "more than 10 years" from 2024 onwards.[119] Westinghouse had already supplied fuel to Temelín in the first decade of operations,[120] but in 2010, the operators switched back to TVEL, supposedly for economic reasons.[121] However, there had also been technical difficulties with Westinghouse's VVER-1000 fuel that might have led to the decision to switch suppliers.[122] In 2019, six test assemblies manufactured by Westinghouse were loaded into Temelín-1,[123] likely easing the return to Western suppliers. See also Russia Nuclear Dependencies. Furthermore, in March 2024, ČEZ signed an agreement with French Orano for uranium enrichment services that would be used to supply fuel for both Czech plants.[124]

114 - Krzysztof Dębiec, "Czech nuclear showdown enters final straight", Ośrodek Studiów Wschodnich/Centre for Eastern Studies, March 2023, see https://www.osw.waw.pl/sites/default/files/OSW%20Commentary%20500.pdf, accessed 26 July 2023.

115 - CEZ Group, "2023 Annual Financial Report", March 2024, op. cit.

116 - Ibidem, and *WNN*, "ČEZ steps up preparations for arrival of Westinghouse fuel", 14 February 2024, see https://www.world-nuclear-news.org/Articles/CEZ-steps-up-preparations-for-arrival-of-Westingho, accessed 28 May 2024.

117 - *NEI Magazine*, "Dukovany 4 to switch to new generation Russian fuel", 24 October 2023, see https://www.neimagazine.com/news/dukovany-4-to-switch-to-new-generation-russian-fuel-11242878/, accessed 2 June 2024.

118 - CEZ Group, "2023 Annual Financial Report", March 2024, op. cit. p.79.

119 - ČEZ, "We are strengthening the energy security of the Czech Republic: we have signed contracts for the supply of fuel assemblies with Westinghouse and Framatome", Press Release, 28 June 2022, see https://www.cez.cz/en/media/press-releases/we-are-strengthening-the-energy-security-of-the-czech-republic-we-have-signed-contracts-for-the-supply-of-fuel-assemblies-with-westinghouse-and-framatome-160156, accessed 26 July 2023.

120 - Jan Höglund and Ulf Benjaminsson, "New fuel for Temelín 1", Technical Lead for Fuel Engineering, and Fuel Marketing Manager, Westinghouse, as published in *NEI Magazine*, 3 October 2019, see https://www.neimagazine.com/features/featurenew-fuel-temelin-1-7436970/, accessed 2 August 2023.

121 - *NEI Magazine*, "TVEL to supply fuel for Temelin", 22 July 2010, see https://www.neimagazine.com/news/newstvel-to-supply-fuel-for-temelin, accessed 2 August 2023.

122 - Daniel Ernst and Lukáš Milisdörfer, "10 years of experience with Westinghouse fuel at NPP Temelín", ČEZ, as presented at the VVER 2010 Conference, 1–3 November 2010, see https://inis.iaea.org/collection/NCLCollectionStore/_Public/42/016/42016135.pdf, accessed 2 August 2023.

123 - Jan Höglund and Ulf Benjaminsson, "New fuel for Temelín 1", Westinghouse, *NEI Magazine*, 3 October 2019, op. cit.; and *WNN*, "ČEZ set to test Westinghouse fuel at Temelín", 5 April 2019, see https://world-nuclear-news.org/Articles/CEZ-set-to-test-Westinghouse-fuel-at-Temelin, accessed 2 August 2023.

124 - CEZ Group, "2023 Annual Financial Report", March 2024, op. cit.

These developments are part of the broader ongoing Czech efforts to shift energy reliance away from Russia. Before Russia invaded Ukraine, the Czech Republic received about 50 percent of its oil supply and most of its natural gas from Russian sources. Despite diversification efforts, Czech crude oil imports from Russia—currently exempt from E.U. crude oil import bans—rose to 56 percent of its total oil imports in 2022 and 65 percent in the first half of 2023.[125] However, the state-owned oil pipeline operator indicated that Russian imports would be fully replaced "as early as mid-2025" following capacity upgrades on the alternative pipeline route.[126] Natural gas supplies are also being diversified via other pipelines and Liquefied Natural Gas (LNG) import capacities are being secured via Dutch terminals.[127] Further, the country is investing in shares of the German LNG terminal at Stade, scheduled to become operational in 2027.[128]

Newbuild Projects

Over the past two decades, the government and industry have repeatedly announced and withdrawn initiatives to build additional reactors.[129] On 13 November 2019, the Czech parliamentary committee for the construction of new nuclear resources approved the construction of the Dukovany II nuclear plant.[130] Subsequently, then-Prime Minister Andrej Babiš said that construction would start in 2029, and power production in 2036. This would have required holding a tender in 2021 and selecting a vendor by the end of 2022, two years ahead of the previous tentative schedule.[131]

In March 2020, ČEZ applied to SÚJB, the regulator, for the construction license of two 1,200-MW units at the Dukovany site. In June 2020, the government announced that it had agreed on a financing model whereby the state would provide a loan covering 70 percent of the project's approximated US$6 billion price tag, while ČEZ would have to front the remaining 30 percent on its balance sheet. It was planned to launch a tender in late 2020.[132]

125 - Jan Lopatka, "Russian oil grabs bigger slice of Czech imports despite reduction aim", *Reuters*, 11 September 2023, see https://www.reuters.com/business/energy/russian-oil-grabs-bigger-slice-czech-imports-despite-reduction-aim-2023-09-11/, accessed 28 May 2024; and Ministry of Industry and Trade, "Statistics of crude oil imports to the Czech Republic 2012—2022", Government of the Czech Republic, 30 May 2023, see https://www.mpo.gov.cz/en/energy/statistics/oil-and-oil-products/statistics-of-crude-oil-imports-to-the-czech-republic-2012_2022--274596/, accessed 4 June 2024.

126 - MERO ČR, "The Czech Republic is preparing to become independent of Russian crude oil. MERO ČR is continuing the TAL-PLUS project, which will ensure 100% supply of the Czech Republic via the western route of the IKL and TAL crude oil pipelines.", Press Release, 11 April 2024, see https://mero.cz/en/the-czech-republic-is-preparing-to-become-independent-of-russian-crude-oil-mero-cr-is-continuing-the-tal-plus-project-which-will-ensure-100-supply-of-the-czech-republic-via-the-western-route-of-the/, accessed 4 June 2024.

127 - Krzysztof Dębiec, "The TAL is expanding: the Czech Republic is gaining independence from Russian oil supplies", Ośrodek Studiów Wschodnich/Centre for Eastern Studies, 7 December 2022, see https://www.osw.waw.pl/en/publikacje/analyses/2022-12-07/tal-expanding-czech-republic-gaining-independence-russian-oil, accessed 26 July 2023.

128 - Government of the Czech Republic, "The government is fulfilling its policy statement and the Czech Republic is strengthening its long-term LNG energy security", Press Release, 23 November 2023, see https://vlada.gov.cz/en/media-centrum/aktualne/the-government-is-fulfilling-its-policy-statement-and-the-czech-republic-is-strengthening-its-long-term-lng-energy-security-210518/, accessed 28 May 2024; and Krzysztof Dębiec, "The TAL is expanding: the Czech Republic is gaining independence from Russian oil supplies", Ośrodek Studiów Wschodnich/Centre for Eastern Studies, 7 December 2022, see https://www.osw.waw.pl/en/publikacje/analyses/2022-12-07/tal-expanding-czech-republic-gaining-independence-russian-oil, accessed 26 July 2023.

129 - WNA, "Country Profiles—Nuclear Power in Czech Republic", World Nuclear Association, 3 May 2024, see https://world-nuclear.org/information-library/country-profiles/countries-a-f/czech-republic, accessed 29 May 2024.

130 - *NEI Magazine*, "Czech Republic approves new unit for Dukovany", 18 November 2019, see https://www.neimagazine.com/news/czech-government-approves-agreements-with-cez-on-new-dukovany-unit-7898604/, accessed 2 September 2024.

131 - Ibidem; and *NIW*, "Briefs - Czech Republic", *Nuclear Intelligence Weekly*, 15 November 2019.

132 - Gary Peach, "Prague Announces 70% Financing for Dukovany", *Nuclear Intelligence Weekly*, 5 June 2020.

The government was expected to prepare, by the end of June 2020, draft contracts with ČEZ and its project company subsidiary that would establish a long-term (30–40 years) offtake agreement from the prospective newbuild to give the project greater financial security. It was also suggested that the government was prepared to insulate the project from legislative and regulatory risks, so that if a subsequent government were to phase out nuclear power, it would have to buy the project and reimburse the investors.[133] It is not clear how the contracts between the state and ČEZ will be drawn up to provide such guarantees to ČEZ and minority shareholders. Current plans might lead to ČEZ restructuring, leading to full state responsibility for nuclear projects.[134]

By 2021, the government's intention was to conduct safety assessments of potential applicants over the course of 2021 to launch a tender in December 2021 that would conclude in 2023. At the time, ČEZ hoped to finalize a supply contract by 2024 and to start building in 2029.[135]

The choice of vendor for the project is controversial. Initially, five designs were said to be in the running, including Korea Electric Power Corporation's (KEPCO) APR-1000+, a revised, downsized version of EDF's EPR called EPR1200—a design that has not been completed on paper and is not certified anywhere—both of which are yet to be built anywhere, and an AP-1000 from Westinghouse. Other designs in the running were reactors from China General Nuclear Power Corporation (CGN) and Rosatom of Russia. However, in early 2021, CGN was ejected from the process—officially due to security concerns as CGN is blacklisted by the U.S. Government—and the Czech Parliament delayed a final decision as the opposition demanded the Rosatom design to also be removed.[136] Subsequently, the Cabinet unanimously approved the resolution and then-Deputy Prime Minister Karel Havlícek confirmed that security clearances would only be given to suppliers from France, South Korea, and the U.S.[137]

In March 2022, ČEZ subsidiary Elektrarna Dukovany II launched a newbuild tender for up to 1.2 GW. The three pre-qualified vendors—EDF, KEPCO subsidiary Korea Hydro & Nuclear Power (KHNP), and Westinghouse—submitted initial bids in November 2022 with the expectation that testing of the new units would begin in 2036. Estimations made in 2020 placed project costs at around CZK160 billion (US$$_{2020}$6.9 billion).[138] Given that only Westinghouse's AP-1000 would have fit the capacity constraints, some speculations around bid design to strengthen U.S.-Czech relations (recently reinforced by the purchase of F-35 fighter jets) arose. However, KEPCO was offering the lowest price and was willing to cooperate with Plzeň-based Škoda JS for turbine manufacturing.[139] In October 2023, all three vendors submitted their final

133 - Phil Chaffee, "Newbuild: Prague Advances Dukovany Plans", *Nuclear Intelligence Weekly*, 1 May 2020.

134 - Jan Lopatka and Jason Hovet, "Three companies vie to build new Czech nuclear plant", *Reuters*, 30 November 2022, see https://www.reuters.com/business/energy/cez-gets-3-initial-bids-build-new-unit-dukovany-nuclear-plant-2022-11-30/, accessed 5 June 2023.

135 - *NEI Magazine*, "Czech Trade Ministry's Dukovany tender proposals spark controversy", 29 March 2021, see https://www.neimagazine.com/news/newsczech-trade-ministrys-dukovany-tender-proposals-spark-controversy-8633315, accessed 2 August 2023.

136 - *NIW*, "Czech Parliament Delays Dukovany", *Nuclear Intelligence Weekly*, 12 February 2021.

137 - Phil Chaffee and Gary Peach, "Prague Excludes Rosatom From Dukovany II", *Nuclear Intelligence Weekly*, 23 April 2021.

138 - Jan Lopatka and Jason Hovet, "Three companies vie to build new Czech nuclear plant", *Reuters*, 30 November 2022, op. cit.; and NRR, "Opinion of the Czech Fiscal Council concerning the development of public sector finances and the set-up of fiscal and budgetary policy", Národní rozpočtová rada/Czech Fiscal Council, 3 June 2020, see https://www.rozpoctovarada.cz/wp-content/uploads/2020/06/Opinion-of-the-Czech-Fiscal-Council-of-3rd-June-2020-No_4_2020.pdf, accessed 2 August 2023.

139 - Krzysztof Dębiec, "Czech nuclear showdown enters final straight", Ośrodek Studiów Wschodnich/Centre for Eastern Studies, March 2023, see https://www.osw.waw.pl/sites/default/files/OSW%20Commentary%20500.pdf, accessed 26 July 2023.

bids for Dukovany-5 and non-binding offers for three additional reactors.[140] In parallel, ČEZ received the zoning permission for new nuclear facilities for the project.[141]

In January 2024, rather surprisingly, Westinghouse was removed from the competition; the government announced that the bid "did not meet the necessary conditions, and, above all, its offer is not binding and therefore cannot be evaluated in a comparable way."[142] EDF and KHNP were then asked to submit updated bids by the end of April 2024. These new binding bids were to include the construction of up to four reactors—instead of one—to reduce per-unit costs. According to Prime Minister Petr Fiala, "the course of the tender so far shows that the supply of several reactors at the same time could provide us with a lower price of up to one quarter for one reactor. Therefore, we have decided to ask bidders to submit binding offers for the supply of up to four new nuclear reactors. Based on them, we will then select a supplier and decide whether we will have more reactors built or not."[143] Both companies submitted their renewed bids on time.[144] In mid-July 2024, KHNP was selected to build a minimum of two reactors.[145, 146] Contract finalization is expected by March 2025, and the first reactor is scheduled for grid connection by 2036, the second following two years later. Each reactor is said to cost CZK200 billion (US$8.7 billion), and the Czech Government announced the beginning of

140 - CEZ Group, "CEZ Group's Dukovany Power Plant II has received final bids for the construction of a new nuclear power plant in Dukovany from three bidders", Press Release, 31 October 2023, see http://www.cez.cz/en/media/press-releases/cez-groups-dukovany-power-plant-ii-has-received-final-bids-for-the-construction-of-a-new-nuclear-power-plant-in-dukovany-from-three-bidders-183909, accessed 5 June 2024.; and Karel Janicek, "3 energy companies compete to build a new nuclear reactor in the Czech Republic", *The Associated Press*, 31 October 2023, see https://apnews.com/article/czech-energy-security-nuclear-dukovany-tender-bid-6b3b1c147ac3bdfbd639c05e8707fe33, accessed 28 May 2024.

141 - CEZ Group, "ČEZ is getting closer to the construction of new nuclear units at Dukovany after the zoning decision was issued", Press Release, 30 October 2023, see https://www.cez.cz/en/media/press-releases/cez-is-getting-closer-to-the-construction-of-new-nuclear-units-at-dukovany-after-the-zoning-decision-was-issued-183836, accessed 5 June 2024; and CEZ Group, "2023 Annual Financial Report", March 2024, op. cit.

142 - Ministry of Industry and Trade, "Nuclear tender enters the next stage. Government is going to call on interested parties to submit binding offers for the construction of several block", Press Release, Government of the Czech Republic, 31 January 2024, see https://www.mpo.gov.cz/en/guidepost/for-the-media/press-releases/nuclear-tender-enters-the-next-stage--government-is-going-to-call-on-interested-parties-to-submit-binding-offers-for-the-construction-of-several-block--279624/, accessed 5 June 2024.

143 - Ibidem; and *AP News*, "Czech government now seeks to build up to 4 nuclear reactors instead 1 to reduce price", *The Associated Press*, 31 January 2024, see https://apnews.com/article/czech-nuclear-reactors-fossil-fuels-energy-fafe34fb2e16446a75eeca7fddfe5e02, accessed 28 May 2024.

144 - CEZ Group, "Elektrárna Dukovany II of the CEZ Group received supplemented bids from bidders for the construction of a new nuclear source in Dukovany and binding options for three additional nuclear units", Press Release, 30 April 2024, see http://www.cez.cz/en/media/press-releases/elektrarna-dukovany-ii-of-the-cez-group-received-supplemented-bids-from-bidders-for-the-construction-of-a-new-nuclear-source-in-dukovany-and-binding-options-for-190873, accessed 28 May 2024.

145 - Government of the Czech Republic, "The Government Has Decided on a Preferred Supplier for the New Nuclear Power Source at Dukovany", Press Release, 17 July 2024, see https://vlada.gov.cz/en/media-centrum/aktualne/the-government-has-decided-on-a-preferred-supplier-for-the-new-nuclear-power-source--negotiations-on-the-construction-of-two-units-at-dukovany-will-be-214609/, accessed 22 July 2024; and KHNP, "KHNP is ready to support to secure the energy needs of the Czech Republic", Press Release, 17 July 2024, see https://www.khnp.co.kr/eng/selectBbsNttView.do?key=565&bbsNo=84&nttNo=56342, accessed 21 August 2024.

146 - In late August 2024, the Czech Office for the Protection of Competition (ÚOHS) released a brief statement informing that it was reviewing appeals in which both Westinghouse and EDF are contesting the selection process. ÚOHS was still to determine the admissibility of the claims. See ÚOHS, "Úřad obdržel návrhy na přezkoumání jaderného tendru od společností Westinghouse i EDF", Press Release (in Czech), Úřad pro ochranu hospodářské soutěže/Office for the Protection of Competition, 27 August 2024, see https://uohs.gov.cz/cs/informacni-centrum/tiskove-zpravy/verejne-zakazky/3960-urad-obdrzel-navrhy-na-prezkoumani-jaderneho-tendru-od-spolecnosti-westinghouse-i-edf.html; and Jan Lopatka and Jason Hovetaccessed, "EDF, Westinghouse appeal Czech nuclear tender decision", *Reuters*, see https://www.reuters.com/business/energy/edf-westinghouse-appeal-against-czech-nuclear-tender-2024-08-27/; both accessed 29 August 2024.

negotiations for two additional reactors to be built at Temelín, hoping to reduce per-unit costs by 20 percent[147] instead of the previously envisioned 25 percent.[148]

Westinghouse being ousted from the race is all the more remarkable given the ongoing technology licensing dispute between Westinghouse and KHNP. In October 2022, Westinghouse filed a lawsuit accusing KHNP of unauthorized transfer of technology and technical information (including through participation in the Czech bidding process) for its APR-1400 from an earlier design owned by Westinghouse (see Poland Focus and KEPCO/KHNP v. Westinghouse in South Korea Focus), which could impact KHNP's ability to provide reactor technology for the Dukovany project, amongst others.[149] In September 2023, the District Court for the District of Columbia ruled that export control enforcement lied solely with the U.S. Government, thereby dismissing Westinghouse's claim that this could be privately acted upon.[150] Westinghouse appealed the decision in October 2023.[151] However, with or without the appeal, Westinghouse's main claim regarding technology licensing is still under review by an arbitration panel, and a final ruling is not expected before the end of 2025.[152]

In parallel to finding a potential reactor vendor, the financing scheme for the Dukovany II project is also being designed. In July 2022, the European Commission launched a state aid review of the project, which was to look at the three government support mechanisms, namely:

> (i) a low-interest repayable State loan expected to cover 100% of the construction costs (approximately €7.5 billion [US$$_{2023}$8.1 billion];
>
> (ii) a power purchase agreement between EDU II and a State-owned company for the lifetime of the project (60 years)—according to the Czech authorities, this would lower the power purchase price and allow for price adaptations every 5 years; and
>
> (iii) a mechanism to protect the ČEZ Group and the State in case certain unforeseen events occur (e.g. if the Czech law changes and makes the realization of the project impossible).[153]

147 - Ibidem.

148 - Ministry of Industry and Trade, "Nuclear tender enters the next stage. Government is going to call on interested parties to submit binding offers for the construction of several block", Press Release, Government of the Czech Republic, 31 January 2024, see https://www.mpo.gov.cz/en/guidepost/for-the-media/press-releases/nuclear-tender-enters-the-next-stage--government-is-going-to-call-on-interested-parties-to-submit-binding-offers-for-the-construction-of-several-block--279624/, accessed 5 June 2024; and *The Associated Press*, "Czech government now seeks to build up to 4 nuclear reactors instead 1 to reduce price", 31 January 2024, op. cit.

149 - *NEI Magazine*, "US stalls South Korea's NPP export plans", 11 April 2023, see https://www.neimagazine.com/news/newsus-stalls-south-koreas-npp-export-plans-10747925; and Westinghouse, "Complaint", Case 1:22-cv-03228-APM, filed with the U.S. District Court for the District of Columbia, 21 October 2022, as published by *POWER*, see https://www.powermag.com/wp-content/uploads/2022/11/westinghousecomplaintkhnp-oct21.pdf; both accessed 2 August 2023.

150 - United States District Court for the District of Columbia, "Memorandum Opinion", Case No. 22-cv-3228 (APM), filed 18 September 2023, as published on Jus Mundi, see https://jusmundi.com/en/document/decision/en-korea-electric-power-corporation-and-korea-hydro-nuclear-power-co-ltd-v-westinghouse-electric-company-llc-memorandum-opinion-of-the-united-states-district-court-for-the-district-of-columbia-monday-18th-september-2023#decision_54807, accessed 21 August 2024; and *WNN*, "US court dismisses Westinghouse case against Korea", 19 March 2023, see https://www.world-nuclear-news.org/Articles/US-court-dismisses-Westinghouse-case-against-Korea, accessed 29 May 2024; also Shin Ha-Nee, "U.S. court dismisses nuclear power lawsuit against KHNP, Kepco", *Korea JoongAng Daily*, 19 September 2023, see https://koreajoongangdaily.joins.com/news/2023-09-19/business/industry/US-court-dismisses-Westinghouses-lawsuit-against-KHNP/1872665, accessed 7 November 2023.

151 - Counsel for Plaintiff Westinghouse Electric Company, LLC, "Case No. 1:22-cv-03228—Notice of Appeal", filed 16 October 2023 in the U.S. District Court for the District of Columbia, as published on Jus Mundi, 17 October 2023, see https://jusmundi.com/en/document/other/en-korea-electric-power-corporation-and-korea-hydro-nuclear-power-co-ltd-v-westinghouse-electric-company-llc-notice-of-appeal-monday-16th-october-2023, accessed 5 June 2024.

152 - *WNN*, "US court dismisses Westinghouse case against Korea", 19 March 2023, op. cit.

153 - European Commission, "State Aid: Commission opens in-depth investigation into Czech support for new nuclear power plant in Dukovany", Press Release, 30 June 2022, see https://ec.europa.eu/commission/presscorner/detail/en/IP_22_4244, accessed 26 July 2023.

The Commission reviewed "the appropriateness and proportionality" of the subsidies and their impact on the electricity market to ensure these were "fully in line with EU State aid rules".[154] Based on an earlier preliminary assessment, the Commission had "found the project necessary and considers that the aid facilitates the development of an economic activity",[155] and in April 2024, the Commission approved of the aid scheme with the Czech Government's amendments. This included, amongst others, the reduction of the price support scheme from 60 to 40 years, and the implementation of a "contract-for-difference" design. The plant will also receive the actual market price for every megawatt-hour of electricity produced; the Commission hopes that the exposure of the plant to market signals "[will limit] market distortions and [prevent] the displacement of renewables, to the benefits of the electricity system and facilitating its decarboni[z]ation."[156] The subsidized state loan is to go through as planned and include "a protection against unforeseen events or policy changes that may make the realization of the project impossible."[157]

SMRs for the Czech Republic?

In addition to a new reactor at Dukovany, ČEZ has long been interested in building additional units at Temelín, where two more units were under construction between 1985 and 1990, and in March 2022 announced that it had set aside land for the construction of SMRs.[158] Seven bidders are currently competing for the construction of an SMR at the Temelín site, with first operation scheduled for 2032 to 2035, which appears unrealistic (see chapter on SMRs). According to media reports, GE Hitachi, NuScale, and Rolls-Royce are considered to have the most prospects of winning the contract.[159]

In February 2023, ČEZ announced further potential sites for SMR construction post-2035 at the current sites of coal power plants Dětmarovice and Tušimice.[160] In total, ČEZ plans to build SMR-capacities adding up to 3 GW after 2050 with a pilot project envisioned to be online by 2032.[161] In the Czech SMR Roadmap, published by the Ministry of Industry and Trade, SMRs are discussed as potential electricity generation sources alongside high-capacity reactors and renewables. Cost estimations and scenarios are based on very optimistic assumptions (see

154 - Ibidem.

155 - Ibidem.

156 - EU Commission, "Commission approves State aid to support construction of nuclear power plant in Czechia", Press Release, European Commission, April 2024, see https://ec.europa.eu/commission/presscorner/detail/en/ip_24_2366, accessed 29 May 2024.

157 - Ibidem.

158 - *WNN*, "Space allocated at Temelín for future SMRs", 1 April 2022, see https://world-nuclear-news.org/Articles/Space-allocated-at-Temelin-for-future-SMR, accessed 7 July 2022.

159 - David Tramba, "Modulární reaktor do Temelína dodá jeden ze sedmi uchazečů. Který z nich má šanci uspět?", *Ekonomoický deník* (in Czech), 21 January 2023, see https://ekonomickydenik.cz/modularni-reaktor-do-temelina-doda-jeden-ze-sedmi-uchazecu-ktery-z-nich-ma-sanci-uspet/, accessed 26 July 2023.

160 - CEZ Group, "After preliminary assessment ČEZ has identified two preferred construction sites for small modular reactors, in addition to the Temelín pilot location, in Dětmarovice and Tušimice", Press Release, 27 February 2023, see https://www.cez.cz/en/media/press-releases/after-preliminary-assessment-cez-has-identified-two-preferred-construction-sites-for-small-modular-reactors-in-addition-to-the-temelin-pilot-location-in-detmaro-173427, accessed 5 June 2024.

161 - CEZ Group, "2023 Annual Financial Report", 2024, op. cit.

chapters on SMRs and Nuclear Economics and Finance in WNISR2023).[162] In November 2023, the government approved the roadmap, and drawing from it decided that SMRs would be "included in the State Energy Policy and recognized in the Spatial Development Policy of the Czech Republic."[163]

Energy Policy Context

According to Ember, in 2023, the Czech Republic generated a total 76.18 TWh of electricity, of which over 40 percent were attributed to coal, followed by nuclear power attaining just under 40 percent. Bioenergy contributed 7 percent of electricity generation while solar and hydro accounted for only 4 percent and 3 percent, respectively. Natural gas stood at around 3 percent, and just shy of 2 percent were generated by "other fossil fuels". Wind power contributed less than 1 percent.[164]

In October 2023, an update of the National Energy and Climate Plan (NECP) was completed.[165] The document builds on 2040-targets stipulated by the 2015 the Czech State Energy Concept[166] (in Czech: Státní energetické koncepce, SEK) which envisioned a reduction of the share of coal generation to 11–21 percent, the increase of nuclear to 46–58 percent, and a share of renewable electricity generation of a maximum of 25 percent. Given these rather low shares, and the newly elected government having hinted at an amendment of these targets in 2022,[167] an update of this SEK was expected to be published by end-2023.[168]

With a brief delay, a draft was published in February 2024 that aimed at a coal phaseout by 2033. The new 2040 electricity generation share targets envision a 47–65 percent share for nuclear. For renewables, the new target ranges from 33 to 47 percent.[169] While scenarios in the NECP projected a future mix with 13 GW of solar PV, 2.5 GW of wind, 2.2 GW of hydro and pumped storage, and less than 600 MW of "other renewables", with around 3.8 GW of

162 - Working Group on the Applicability of Small and Medium-Sized Reactors in the Czech Republic, "Czech SMR Roadmap", Ministry of Industry and Trade, Government of the Czech Republic, May 2023, see https://www.mpo.gov.cz/assets/en/guidepost/for-the-media/press-releases/2023/11/Czech-SMR-Roadmap_EN.pdf, accessed 29 May 2024; Björn Steigerwald, Jens Weibezahn et al., "Uncertainties in estimating production costs of future nuclear technologies: A model-based analysis of small modular reactors", German Institute for Economic Research, Copenhagen Business School and University of Mannheim, *Energy*, Vol. 281, October 2023.

163 - Ministry of Industry and Trade, "Czech Government approves SMR development Roadmap", Press Release, Government of the Czech Republic, 1 November 2023, see https://www.mpo.gov.cz/en/guidepost/for-the-media/press-releases/czech-government-approves-smr-development-roadmap--277847/, accessed 5 June 2024.

164 - Ember, "Electricity Data Explorer", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 28 May 2024.

165 - Government of the Czech Republic, "Update of the Czech National Plan of the Republics in the field of energy and climate", submitted to the European Commission, October 2023, see https://commission.europa.eu/publications/czech-draft-updated-necp-2021-2030_en, accessed 7 November 2023.

166 - Ibidem; and Ministry of Industry and Trade, "State Energy Policy of the Czech Republic", Government of the Czech Republic, December 2014, see https://www.czechia.eu/wp-content/uploads/2021/12/State-Energy-Policy-_2015__EN-1.pdf, accessed 29 May 2024.

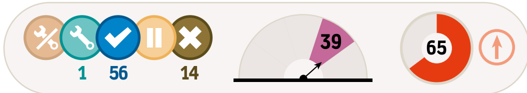
167 - Jason Hovet and Robert Muller, "New Czech government sees coal exit by 2033, backs nuclear power", *Reuters*, 7 January 2022, see https://www.reuters.com/markets/commodities/new-czech-government-sees-coal-exit-by-2033-backs-nuclear-power-2022-01-07/, accessed 2 August 2023.

168 - Ministry of Industry and Trade, "Starting points for the update the State Energy Policy of the Czech Republic and related strategic documents", Government of the Czech Republic, 13 April 2023, see https://www.mpo.gov.cz/en/energy/strategic-and-conceptual-documents/starting-points-for-the-update-the-state-energy-policy-of-the-czech-republic-and-related-strategic-documents--273675/, accessed 30 June 2024.

169 - MPO, "Aktualizace Státní energetické koncepce (SEK)", Press Release (in Czech), Ministerstvo Průmyslu a Obchodu/Ministry of Industry and Trade, Government of the Czech Republic, 7 February 2024, see https://www.mpo.gov.cz/cz/rozcestnik/pro-media/tiskove-zpravy/aktualizace-statni-energeticke-koncepce-sek--279668/, accessed 30 June 2024.

natural gas capacity and approximately 5.2 GW of nuclear power as well as 2.6 GW of battery capacity.[170] ČEZ envisions bringing a total of 6 GW of "new renewables" to the grid by 2030, albeit not clarifying the breakdown by technology.[171] As of the time of writing, a consultation process on the new draft had just ended and was under review for finalization.[172]

FRANCE FOCUS



Overview

EDF's Executive Director of Generation and Engineering of the Existing Nuclear and Thermal Fleet called the year 2022 "annus horribilis".[173] Nuclear output dropped below the level of 1990 when the installed nuclear capacity was some 5 GW lower. Nuclear generation actually peaked in 2005 at over 430 TWh and in nine of the following ten years, output exceeded 400 TWh, which was considered the norm until 2015. In 2022, French reactors produced 279 TWh, a drop of over 120 TWh from the 2005–2015 period. In 2023, nuclear power generation picked up by just under 15 percent to reach 320 TWh, still far from the 400 TWh level of earlier years.

The discovery in December 2021 of cracks in the emergency core cooling systems first led to the shutdown of the four largest (1500 MW) and latest French reactors. After the identification of the same phenomenon in other reactors, EDF decided to implement an unprecedented, comprehensive inspection and repair program that eventually should cover the entire fleet and last into 2025.

In June 2023, the National Assembly passed legislation for the "acceleration of procedures for the construction of new nuclear facilities near existing nuclear sites and for the operation of existing facilities"[174] (see France Focus in WNISR2023). While these measures can cut some red tape, they are unlikely to significantly ease the phenomenal industrial challenges.

In February 2022, the French President announced a plan to build six units of a new design, called EPR2, with a target date of the first startup by 2035. In addition, the option of building eight additional units until 2050 should be studied.[175]

170 - Government of the Czech Republic, "Update of the Czech National Plan of the Republics in the field of energy and climate", European Commission, October 2023, op. cit.

171 - CEZ Group, "2023 Annual Financial Report", 2024, op. cit.

172 - MPO, "Vyhodnocení veřejné konzultace k aktualizaci Vnitrostátního plánu ČR v oblasti energetiky a klimatu" Ministerstvo průmyslu a obchodu/Ministry of Industry and Trade, Government of the Czech Republic, 19 June 2024 (in Czech), see https://www.mpo.gov.cz/cz/energetika/strategicke-a-koncepcni-dokumenty/vyhodnoceni-verejne-konzultace-k-aktualizaci-vnitrostatniho-planu-cr-v-oblasti-energetiky-a-klimatu--281636/, accessed 30 June 2024.

173 - Cédric Lewandowski, EDF, Enquiry Committee Hearing at the National Assembly, 19 January 2023.

174 - French Government, "LOI no 2023-491 du 22 juin 2023 relative à l'accélération des procédures liées à la construction de nouvelles installations nucléaires à proximité de sites nucléaires existants et au fonctionnement des installations existantes", *Journal Officiel de la République Française*, enacted 22 June 2023, promulgated 23 June 2023 (in French), see https://www.legifrance.gouv.fr/download/pdf?id=32HzSNCPyz8WLoK-WsqAqoiX_erjixoTD_Jy3AVXRFk=, accessed 3 November 2023.

175 - Presidency of the French Republic, "Reprendre en main notre destin énergétique !", Speech by President Emmanuel Macron (in French), Elysée, French Government, 10 February 2022, see https://www.elysee.fr/emmanuel-macron/2022/02/10/reprendre-en-main-notre-destin-energetique, accessed 30 August 2022.

Currently, the EPR2 does not exist on the drawing board; no detailed design is available yet. The administration estimated in an October 2021 internal note that 19 million engineering hours still had to be deployed to get from "basic design" to the "detailed design" stage and that, if everything goes well, the first EPR2 could start up by 2039–2040. In case unexpected industrial difficulties occur—as they did in the past and do currently—it could take until 2043 to commission the first EPR2, the project review states.[176]

In August 2023, EDF applied for a building permit for the first pair of the "sixpack" to be built at the Penly site. The other pre-selected sites for a pair of EPR2 units are Bugey and Gravelines, and EDF is in the course of filing all administrative applications to implement these projects.

As of mid-2024, EDF announced that the total EPR2 development budget would reach €3 billion (US$3.2 billion) by the end of 2024. Also, EDF launched the manufacturing of EPR2 primary components (like heavy forgings). All of this is happening while no Final Investment Decision (FID) has been taken.[177]

Meanwhile, the Nuclear Safety Authority (ASN) stated in its Annual Report 2023:

> The EPR 2 program is starting at the rate of one pair of reactors every three years. This situation is creating considerable pressure on the industrial stakeholders, with the risk being that, faced with unrealistic objectives, deadlines compliances takes precedence over quality.[178]

French Economy and Finance Minister Bruno Le Maire was quoted as saying in early June 2024:

> The first EPR2 reactor should be completed by 2035, that is in nine years. In the next five years, we should be able to see how the program is advancing. If things are going well, rapidly and on cost, that will be the moment when we can consider building the extra EPR2 reactors.[179]

Performance Still Far From Normal

Until the closure of the two oldest French units at Fessenheim in the spring of 2020, the French nuclear fleet had remained stable for 20 years, except for the closure of the 250-MW fast breeder Phénix in 2009, two units in Long-Term Outage (LTO) within the period 2015–2017, and another one within the period 2021–2023 (see Figure 28). Penly-1, subject to the stress-corrosion cracking issue, was offline between 2 October 2021 and 13 July 2023.[180] Four units at Civaux and Chooz-B did not generate power throughout 2022 but did not meet the LTO criteria as they were restarted prior to mid-2023. Golfech-1 was shut down for almost two

176 - French Government, "Travaux relatifs au nouveau nucléaire—PPE 2019-2028", as published by *Contexte* (in French), October 2021, see https://www.contexte.com/article/energie/info-contexte-nucleaire-pas-encore-lances-les-futurs-epr-deja-en-retard-et-plus-chers_140631.html, accessed 30 August 2022.

177 - EDF, "2024 Half-year Results", 26 July 2024, see https://www.edf.fr/sites/groupe/files/2024-07/2024-07-26-half-year-results-financial-report-30-june-2024.pdf, accessed 18 August 2024.

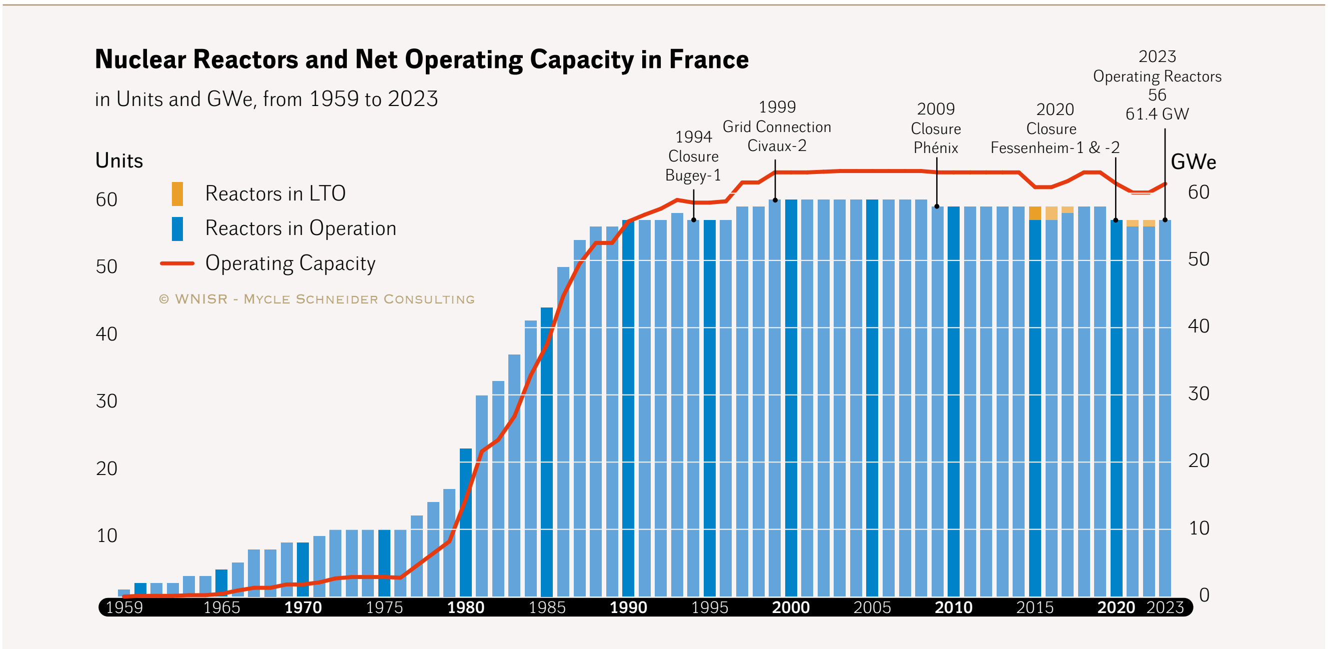
178 - ASN, "ASN report on the state of nuclear safety and radiation protection in France in2023", Autorité de sûreté nucléaire/Nuclear Safety Authority, 2024.

179 - *Nucleonics Week*, "French finance minister calls for delayed decision on eight additional reactors", 12 June 2024.

180 - EDF, "Les deux unités de production de la centrale nucléaire de Penly connectées au réseau électrique national", 13 July 2023 (in French), see https://www.edf.fr/la-centrale-nucleaire-de-penly/les-actualites-de-la-centrale-nucleaire-de-penly/les-deux-unites-de-production-de-la-centrale-nucleaire-de-penly-connectees-au-reseau-electrique-national, accessed 1 November 2023.

years, between 26 February 2022 and 14 January 2024, but did not meet the LTO criteria (down for a full calendar year plus six months of the following year).

Figure 28 · Operating Fleet and Capacity in France



Sources: WNISR with IAEA-PRIS, 2024

No new reactor has started up since Civaux-2 was connected to the French grid 25 years ago, in December 1999. The first and only Pressurized Water Reactor (PWR) closed prior to Fessenheim was the 300-MW Chooz-A reactor, which was retired in 1991. The other closures were that of eight first-generation natural-uranium gas-graphite reactors, two fast breeder reactors, and a small prototype heavy water reactor (see Figure 29).

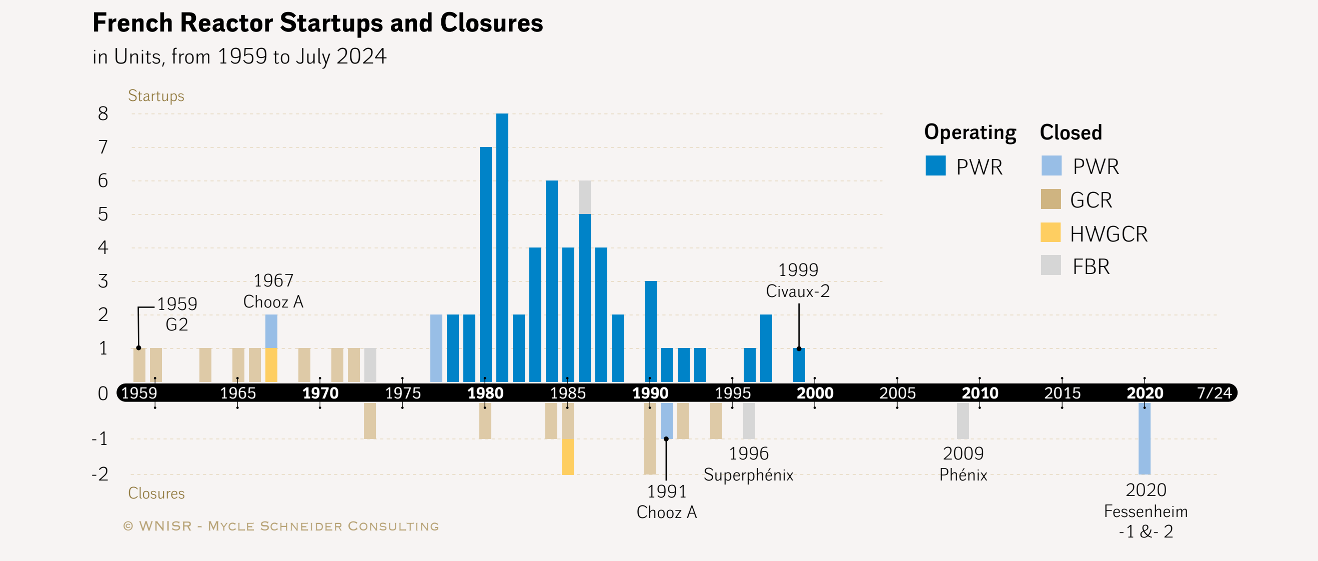
In 2023, the 56-reactor fleet[181]—one of which did not generate any power—produced 320 TWh, an increase of 41.5 TWh (+14.8 percent) over the previous year which saw the lowest output since 1988; the production remained at the level of 1992, when the six most recent units had not started operating. It also stayed below its level of 2020 and the eighth year in a row below 400 TWh. The national grid operator RTE summed up: "Nuclear power generation started to recover but is still far from its historic levels."[182] The difficulties are not over.

In 2005, nuclear generation peaked at 431.2 TWh. After the construction program was completed in 1999, it took the fleet five years to build up to that maximum generation, and with a quasi-stable installed nuclear capacity between late 1999 and early 2020, performance plunged after 2015 (see Figure 30).

181 - All Pressurized Water Reactors (PWRs), 32 x 900 MW, 20 x 1300 MW, and 4 x 1400 MW.

182 - RTE, "Annual electricity review 2023", 29 February 2024, see https://analysesetdonnees.rte-france.com/en/annual-review-2023/keyfindings, accessed 29 August 2024.

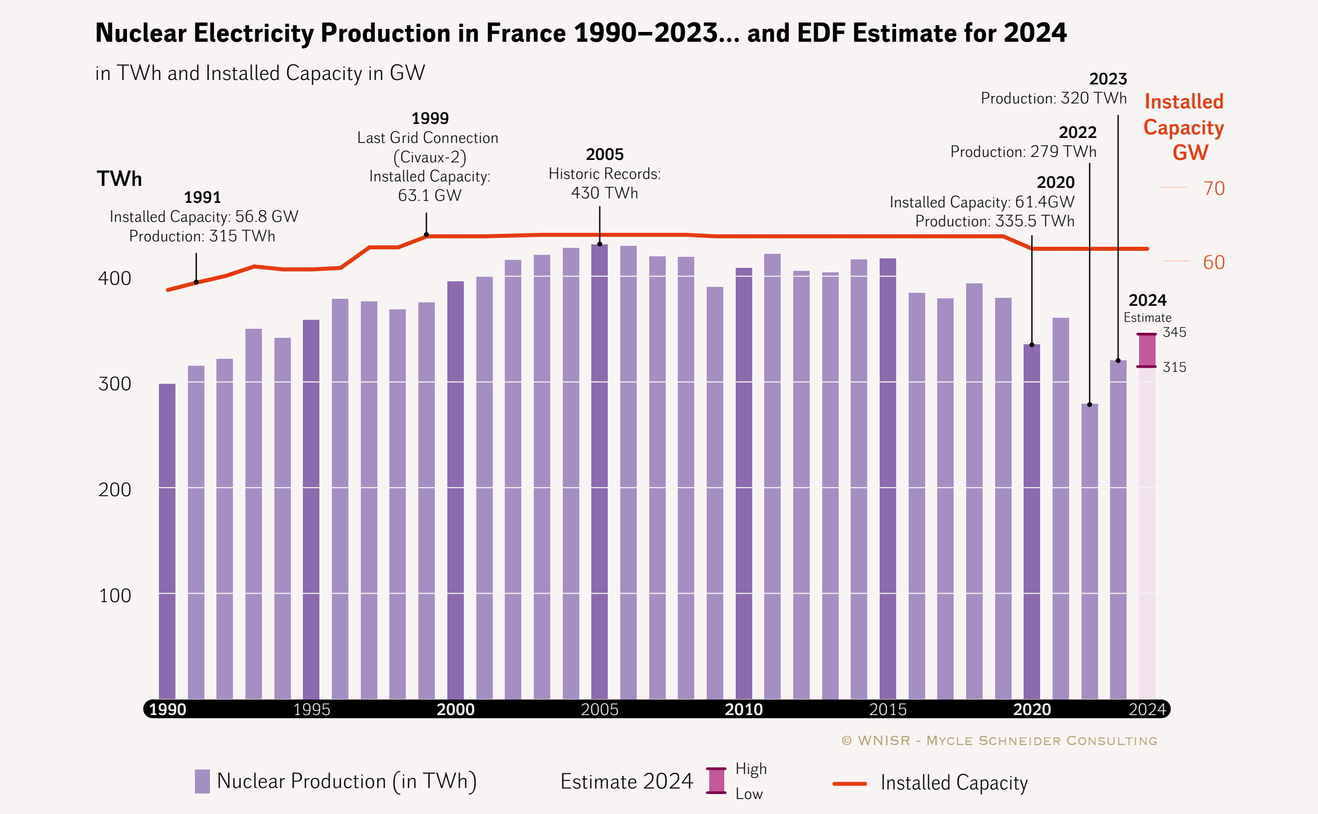
Figure 29 · Startups and Closures in France



Sources: WNISR, with IAEA-PRIS, 2024

Notes: **PWR**: Pressurized Water Reactor; **GCR**: Gas-Cooled Reactor; **HGWGCR**: Heavy Water Gas Cooled Reactor; **FBR**: Fast Breeder Reactor.

Figure 30 · Nuclear Electricity Production vs. Installed Capacity in France



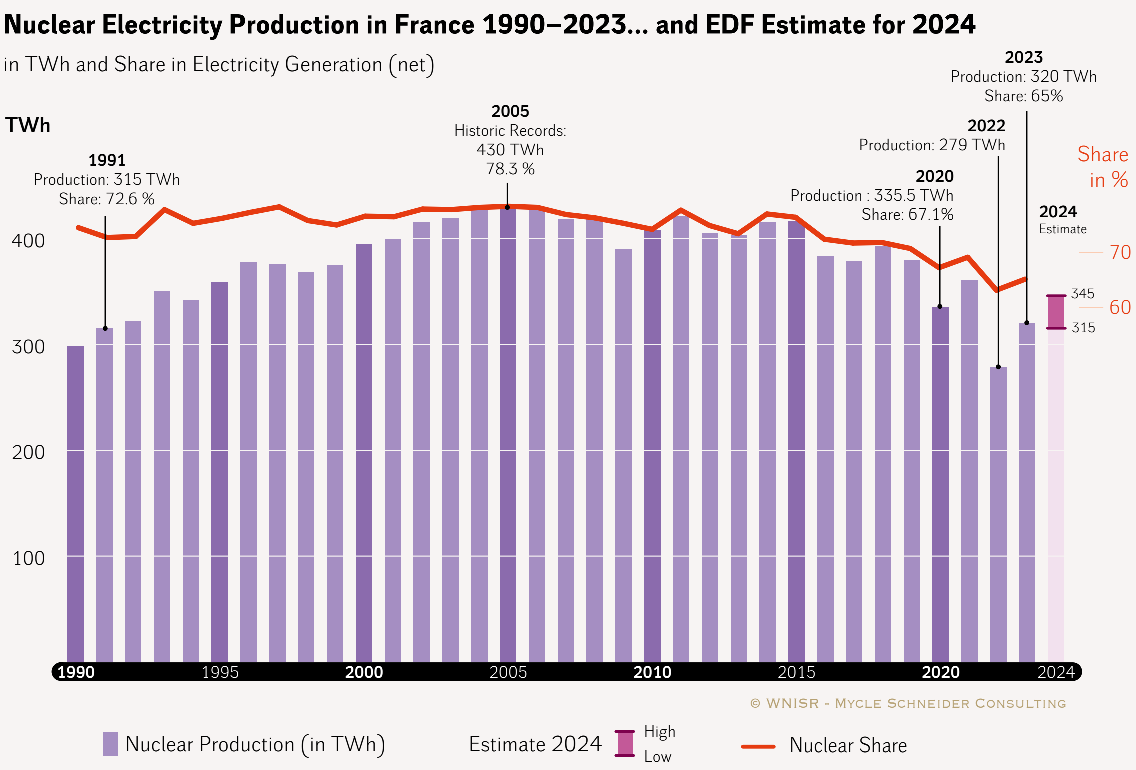
Sources: RTE, 2000–2024, EDF 2024

Note: In Figure 30, reactors in LTO are counted in the "installed capacity".

In 2023, nuclear plants provided 65 percent (+2.3 percentage points) of the country's electricity, but still less than in COVID-year 2020. The nuclear share peaked in 2005 at 78.3 percent. As of mid-year, EDF estimated the production for 2024 to be in the upper end of the 315–345 TWh range and in the 335–365 TWh range for 2025 and 2026[183] (see Figure 30 and Figure 31).

The year 2023 saw record additions of solar (+ 3 GW) and offshore wind power (+360 MW) capacities as well as record solar and total onshore and offshore wind generation—solar increasing by 16 percent and wind by one third compared to 2022—reaching close to 22 TWh and 51 TWh, respectively, together accounting for almost 15 percent of the electricity supply in the country. Offshore wind remains relatively marginal yet with a cumulated installed capacity of only 840 MW compared to 21.8 GW of onshore wind capacity as of the end of 2023.[184]

Figure 31 • Nuclear Electricity Production vs. Nuclear Share in France



Sources: RTE, 2000–2024, EDF, 2024

Monthly production has continued to deteriorate in early 2023 with a lower output in every month of the first quarter of the year than in any year over the past decade, and while output improved starting in the second quarter, it remained below the 2021 level until December (see Figure 32). In the first half of 2024, the production level stayed again slightly below the 2021-performance.

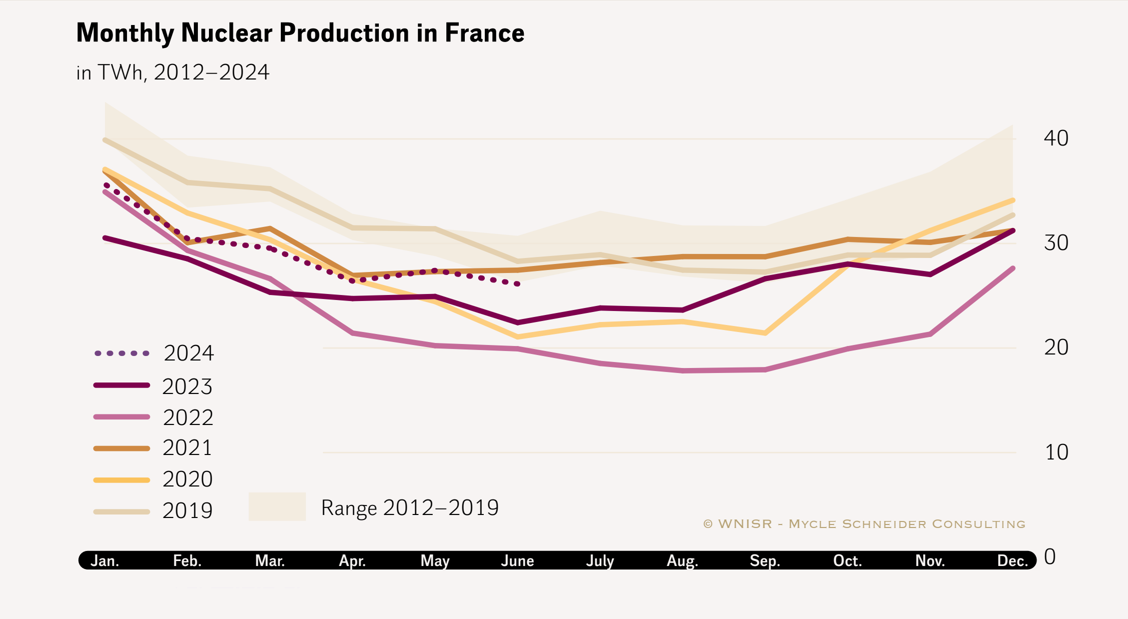
Electricity represented 25 percent of final energy in France in 2023. As nuclear plants provided 65 percent of electricity, they covered 16.3 percent of final energy. The largest share being

183 - EDF, "2024 Half-year Results", 26 July 2024, op. cit.

184 - RTE, "Annual electricity review 2023", 29 February 2024, op. cit.

covered by fossil fuels at 60 percent, with oil at 42.5 percent, and natural gas at 17.2 percent (coal <1 percent).[185]

Figure 32 • Monthly Nuclear Electricity Generation, 2012–mid-2024



Sources: RTE and EDF, 2021–2024[186]

Nuclear Unavailability Review 2023

In 2023, there were 7,103 reactor-days— around 1,400 fewer reactor-days than in 2022 but still the second highest number in the past five years—an average of 127 days, or over four months, with zero-production per reactor. This does not include load following or other operational situations with reduced, but above-zero output. The number is 32 percent higher than the average 96 days per reactor in pre-COVID year 2019 and 10 percent higher than in 2020. Fifty-five reactors were subject to outages lasting from five to 365 days (see Figure 34). One reactor was offline during the whole year (Golfech-1) and one produced all year round (Saint Alban-2).

The declared "forced" outages have increased by 43 percent from 278 to 399 days exceeding any of the four previous years.

Table 5 illustrates that, while the declared "planned" outage-days dropped significantly in 2023, the declared "forced" outages have increased by 43 percent from 278 to 399 days exceeding any of the four previous years.

185 - Ministry of Energy Transition, "Bilan énergétique de la France en 2023 – Données provisoires", Ministère de la Transition Énergétique, French Government, Mai 2024 (in French), see https://www.statistiques.developpement-durable.gouv.fr/bilan-energetique-de-la-france-en-2023-donnees-provisoires-0.

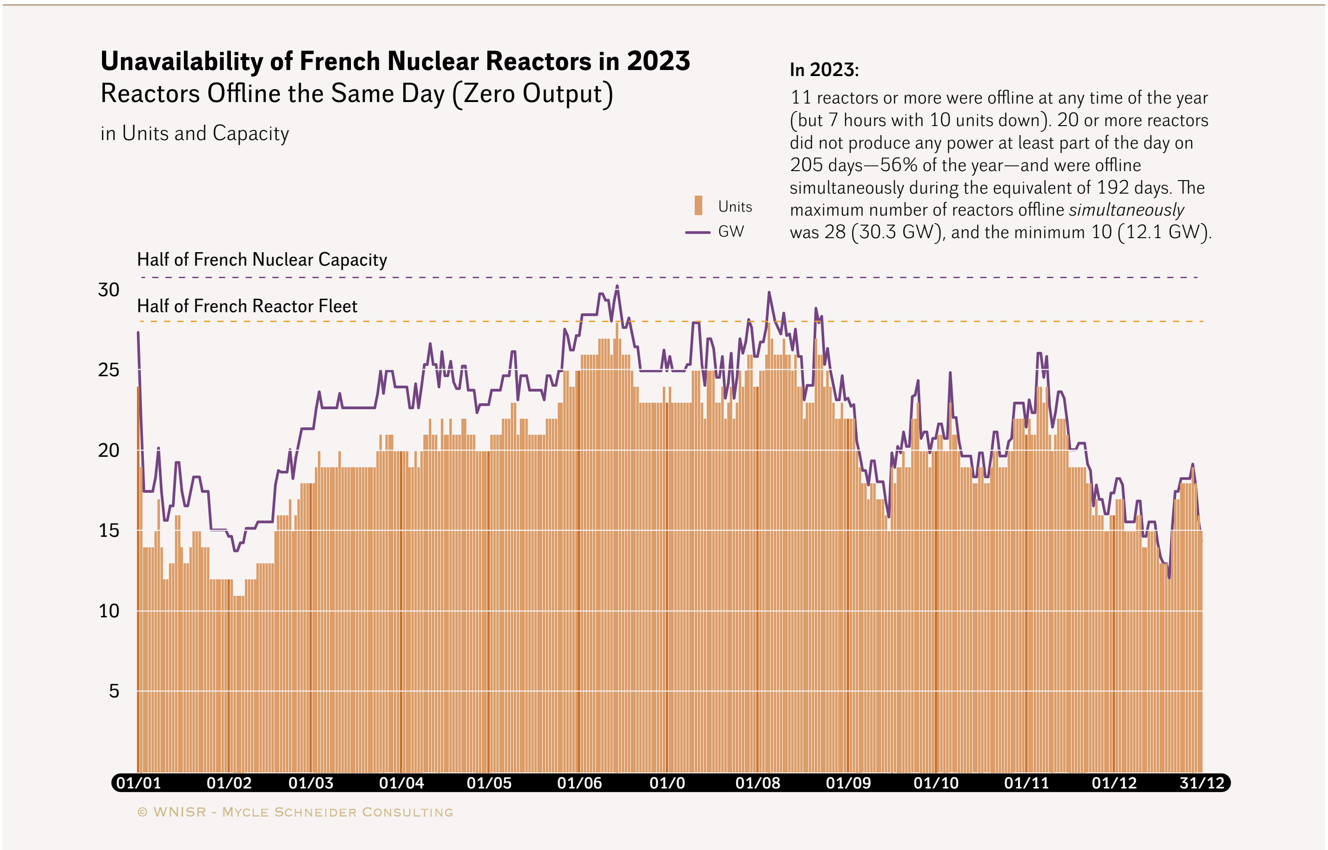
186 - RTE, "Production d'électricité en France ", 2024, see https://analysesetdonnees.rte-france.com/production/synthese; and EDF, "Nuclear Generation", 2021–2024, see https://www.edf.fr/en/the-edf-group/dedicated-sections/investors/financial-and-extra-financial-performance/operational-performance/nuclear-generation, accessed 28 August 2024.

Table 5 · Total Unavailability of French Nuclear Reactors, 2019–2023 (in Reactor-Days)

	Declared Type of Unavailability			
	"Planned"	Forced	Total	Average per Reactor
2019	5,273	316	5,588	96
2020	6,179	286	6,465	115
2021	5,639	172	5,811	14
2022	8,287	278	8,515	152
2023	6,704	399	7,103	127

Sources: RTE and EDF REMIT Data, 2019–2024

Figure 33 · Reactor Outages in France in 2023



Sources: compiled by WNISR, with RTE and EDF REMIT Data, 2024

Note: For each day in the year, this graph shows the total number of reactors offline, not necessarily simultaneously as all unavailabilities do not overlap, but on the same day.

The unavailability analysis for the year 2023 on Figure 33 further shows:

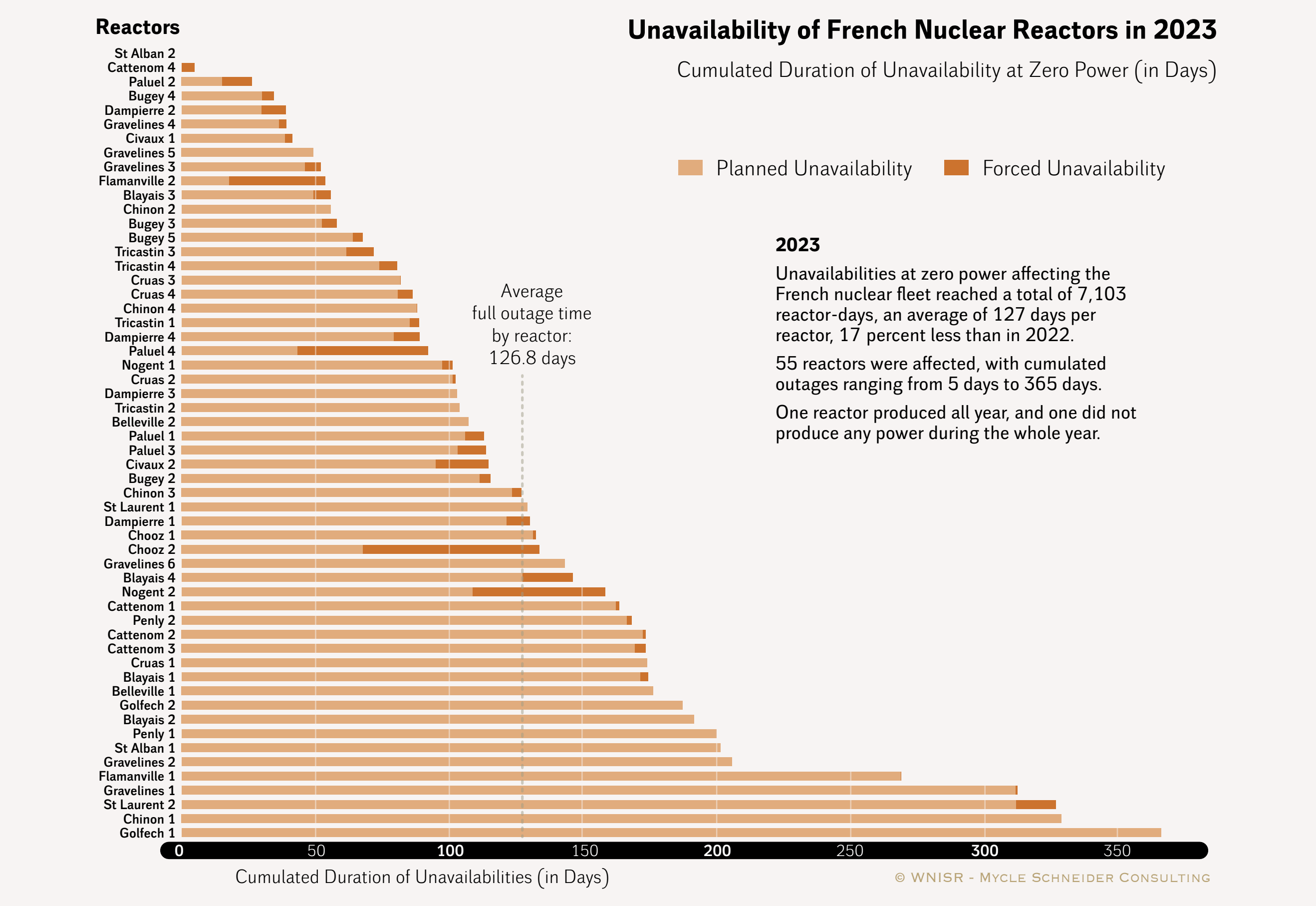
- During the whole year at least 11 units and up to 28 were down during the same day.
- On 252 days (69 percent of the year), 19 or more units were shut down for at least part of the day.

- At least eleven reactors were down (zero capacity) *simultaneously* at any day of the year but for 7 hours with only ten reactors offline.
- At least 20 reactors were offline *simultaneously* during the equivalent of 192 days.

According to EDF's classification of "planned" and "forced" unavailabilities, in 2023:

- 16 reactors did not experience any "forced" outage (of which 13 were in "planned" outage for more than 100 days during the year)
- at six units "forced" outages lasted less than one day,
- at 24 cumulated "forced" outage duration represented between one and 10 days,
- and at 10 reactors "forced" outage cumulated between 10 and 65 days over the year (see Figure 34).

Figure 34 · Forced and "Planned" Unavailability of Nuclear Reactors in France in 2023



Sources: compiled by WNISR, with RTE and EDF REMIT Data, 2024

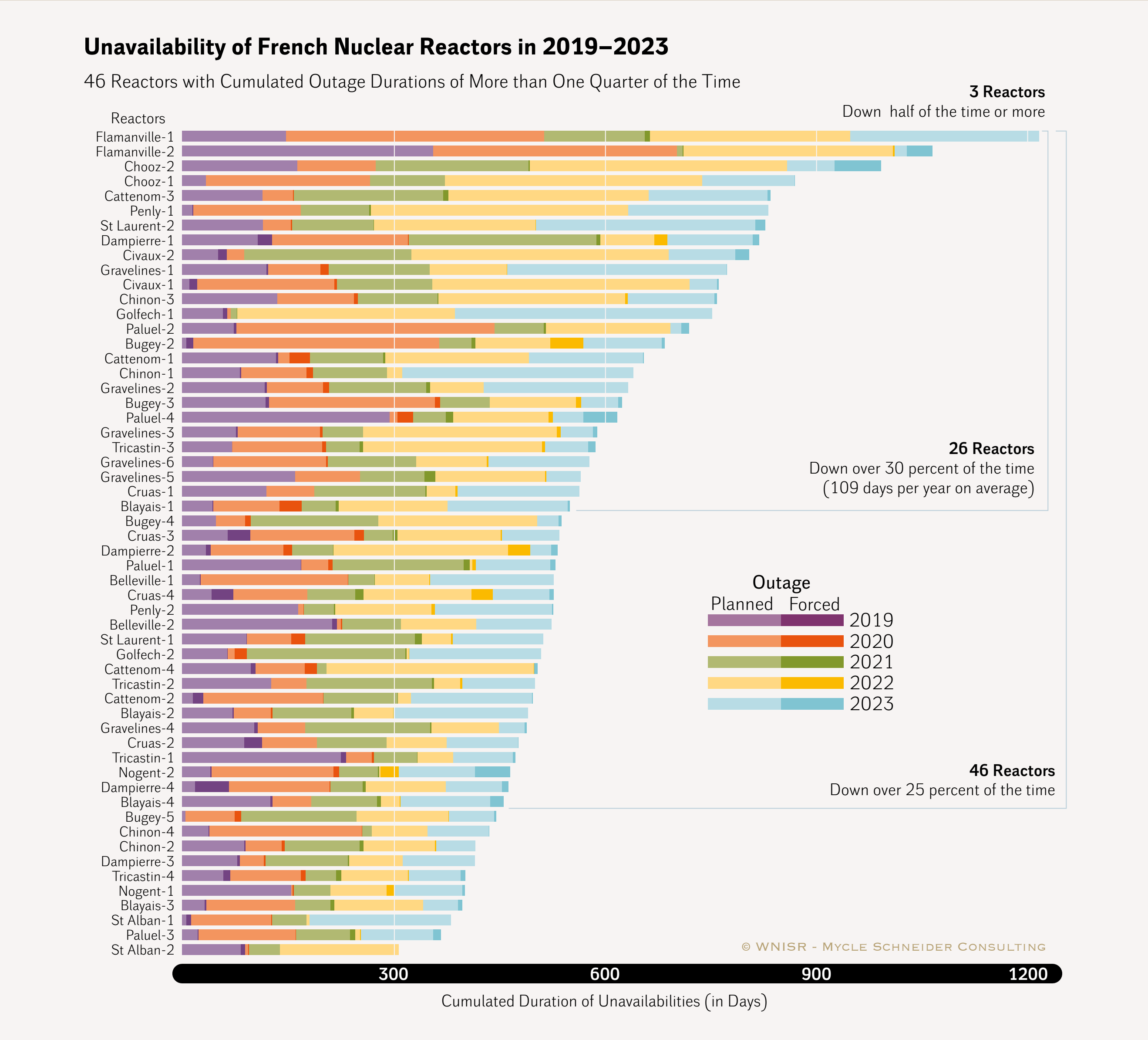
Notes: This graph only compiles outages at zero power, thus excluding all other operational periods with reduced capacity >0 MW. Impact of unavailabilities on power production is therefore significantly larger.

"Planned" and "Forced" unavailabilities as declared by EDF.

However, EDF's declaration of "planned" vs. "forced" outages is highly misleading. EDF considers an outage as "planned" whatever the number and length of extensions (or, in rare cases, reductions) of its total duration if the outage was first declared as "planned".

Detailed WNISR analysis for earlier years shows a different picture.

Figure 35 • Unavailability of a Selection of French Nuclear Reactors, 2019–2023



Sources: compiled by WNISR, with RTE and EDF REMIT Data, 2019–2024

Note: The categorization follows EDF's classification. However, it is not reflecting reality as a "planned" outage remains in that category even if it lasts much longer than "planned".

The cumulated outage analysis over the five years 2019–2023 reveals the following (see Figure 35):

→ Three reactors were down half of the time or more (Flamanville-1 and -2, Chooz-1);

- 26 reactors were generating zero power for 30 percent of the time, that is 109 days and more per year on average;
- 46 reactors were off-grid for at least one quarter of the time, in other words, they did not generate any power for the equivalent of one in four years.

Stress Corrosion Cracking and Thermal Fatigue

Severe stress corrosion cracking had been first identified in late 2021 at the safety injection systems of the four largest and most recent French reactors at Chooz and Civaux.[187] Later additional reactors were identified and a program of pre-emptive replacement of particularly sensitive piping sections was decided for the "P'4" reactor series. While apparently so far rare, the phenomenon has also been identified on other 1300-MW and some 900-MW reactors. EDF decided to inspect its entire reactor fleet by the end of 2025 and claims that, as of mid-2024, already 50 of its 56 units had been "controlled and treated".[188]

In February 2023, an additional issue was identified during destructive examination at Penly-1. Close to a weld of a line of the safety injection system that had been repaired during construction of the plant, a 15.5 cm long—about one quarter of the circumference—and up to 2.3 cm deep crack—for a 2.7 cm thick tube—was identified. The origin has been determined as thermal fatigue rather than stress corrosion cracking. This discovery meant that an extensive inspection program of all repaired welds had to be added to the stress corrosion cracking investigations. According to planning, 90 percent of the repaired welds in the safety injection and shutdown cooling systems of the entire reactor fleet are to be inspected by the end of 2024 with the remaining ones in 2025.[189]

Lifetime Extensions – Regulator Flexibility

By mid-2024, the average age of the 56 nuclear power reactors exceeded 39 years (see Figure 36). Lifetime extension beyond 40 years—52 operating units are now over 31 years old, of which 23 are over 41 years—requires significant additional upgrading. Also, relicensing is subject to public inquiries reactor by reactor.

EDF will likely seek lifetime extensions beyond the 4th Decennial Safety Review (VD4) for most, if not all, of its remaining reactors. President Macron in his February 2022 programmatic speech made it clear that the government had no intention of closing reactors anymore. He stated, "While the first extensions beyond 40 years have been implemented successfully since 2017, I'm asking EDF to examine the conditions of the [lifetime] extensions beyond 50 years, in conjunction with the nuclear safety authority."[190]

187 - ASN, "Phénomène de corrosion sous contrainte détecté sur les réacteurs 1 et 2 de Civaux, B2 de Chooz et 1 de Penly", Information Notice (in French), 31 January 2022, see https://www.asn.fr/l-asn-informe/actualites/phenomene-de-corrosion-sous-contrainte-detecte-sur-certains-reacteurs, accessed 13 November 2023.

188 - EDF, "2024 Half-year Results", 26 July 2024, op.cit.

189 - EDF, "Le phénomène de corrosion sous contrainte sur les circuits auxiliaires du CPP – État des lieux actualisé", presented 4 July 2023 (in French), see https://www.anccli.org/wp-content/uploads/2023/07/Webinaire-CSC_2023-07-04_01-Etat-des-lieux_EDF.pdf, accessed 2 November 2023.

190 - Presidency of the French Republic, "Reprendre en main notre destin énergétique !", Speech by President Emmanuel Macron (in French), Elysée, French Government, 10 February 2022, op.cit.

The first reactor to undergo the VD4 was Tricastin-1 in 2019. Bugey-2 and -4 were scheduled for the same in 2020, and Tricastin-2, Dampierre-1, Bugey-5, and Gravelines-1 started in 2021… until the COVID-19 pandemic further disrupted the safety review schedule.[191] Until 1 July 2024, 16 units had undergone their VD4 and a further 4 were underway (see Table 6).

The Chief Technical Officer of EDF Group and EDF Director of R&D, Bernard Salha, told French Parliament in February 2023 that the work volume of a VD4 was five times larger than that of a VD3.

While ASN judged the VD4-premiere on Tricastin-1 "satisfactory", it questioned whether EDF's engineering resources were sufficient to carry out similar extensive reviews simultaneously at several sites.[192] Beyond the human resource issue, the experience raises the question of affordability. EDF had scheduled an outage for Tricastin-1 of 180 days in 2019, which was first extended by 25 days to 205 days. Including further, unrelated unavailabilities, the reactor was finally in full outage for two thirds of that year (232 days).

The following VD4 exercises also saw significant delays between expected and real durations (see Table 6).

EDF expects these VD4 outages to last six months, much longer than the average of three to four months experienced through VD2 and VD3 outages. The Chief Technical Officer of EDF Group and EDF Director of Research & Development (R&D), Bernard Salha, told the French Parliament in February 2023 that the work volume of a VD4 was five times larger than that of a VD3. He also said investments into the operating fleet have doubled over the past decade.[193]

As illustrated, many factors could lead to significantly longer outages. EDF has already started negotiating with ASN for the workload to be split in two packages, with the supposedly smaller second one to be postponed four years after the VD4.[194]

191 - EDF, "4èmes Visites Décennales des Réacteurs du Palier 900 MW—Rapport annuel sur la mise en oeuvre des presriptions du 4ème réexamen périodique des réacteurs 900 MWe—2022", 2023.

192 - Bernard Doroszsuk, "Présentation du rapport annuel 2019 de l'Autorité de sûreté nucléaire (ASN) sur l'état de la sûreté nucléaire et de la radioprotection en France", President, Autorité de sûreté nucléaire/French Nuclear Safety Authority, Hearing before The Parliamentary Office for Scientific and Technological Assessment (OPECST), French Parliament, 28 May 2020 (in French), see http://videos.senat.fr/video.1628244_5ecf547f8a96f.audition-pleniere---autorite-de-surete-nucleaire?timecode=2963962, accessed 13 August 2020.

193 - Bernard Salha, Oral Evidence before the Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST), 16 February 2023; see OPECST, "Comptes Rendus de l'Office Parlementaire d'Evaluation des Choix Scientifiques et Technologiques—Nouvelle organisation du contrôle et de la recherche en sûreté nucléaire et en radioprotection", Office Parlementaire d'Evaluation des Choix Scientifiques et Technologiques/Parliamentary Office for the Evaluation of Scientific and Technological Choices, French Parliament, 16 February 2023, see https://www.senat.fr/travaux-parlementaires/office-et-delegations/office-parlementaire-devaluation-des-choix-scientifiques-et-technologiques.html, accessed 14 November 2023.

194 - ASN, "Réexamen périodique associé aux quatrièmes visites décennales des réacteurs du palier 900 MWe", Autorité de Sûreté Nucléaire/French Nuclear Safety Authority, Presentation at a meeting of Commission locale d'information des grands équipements énergétiques du Tricastin/Local information committee on the major energy facilities at Tricastin (CLIGEET), 4 July 2018.

Table 6 · Fourth Decennial Visits of French 900-MW Reactors, 2019–2024

Reactor	Capacity	Grid Connection	VD4 Outage	Expected Duration	Total Duration
Tricastin-1	915	31 May 1980	01/06/19–23/12/19	180	205
Bugey-2	910	10 May 1978	18/01/20–15/02/21	181	395
Bugey-4	880	8 March 1979	22/11/20–24/06/21	226	214
Dampierre-1	890	23 March 1980	19/06/21–05/02/22	170	231
Tricastin-2	915	7 August 1980	06/02/21–26/07/21	180	170
Bugey-5	880	31 July 1979	31/07/21–21/04/22	189	265
Gravelines-1	910	13 March 1980	14/08/21–11/04/22	188	240
Tricastin-3	915	10 February 1981	12/03/22–21/11/22	171	254
Gravelines-3	910	12 December 1980	23/03/22–22/12/22	191	275
Dampierre-2	890	10 December 1980	27/04/22–31/12/22	171	248
Blayais-1	910	12 June 1981	31/07/22–19/06/23	185	323
Saint-Laurent-2	915	1 June 1981	20/01/23–20/11/23	223	304
Chinon B-1	905	30 November 1982	07/02/23–19/05/24	265	467
Gravelines-2	910	26 August 1980	10/06/23–07/03/24	197	272
Blayais-2	910	17 July 1982	24/06/23–31/03/24	182***	281
Dampierre-3	890	30 January 1981	23/09/23–2/03/24	170	161
Bugey-3	910	21 September 1978	11/11/23–28/08/24**	177	291
Tricastin-4	915	12 June 1981	19/01/24–16/07/24	194	179
Gravelines-4	910	14 June 1981	20/01/24–23/08/24**	195	215**
Blayais-3	910	17 August 1983	08/06/24–16/12/24*	191	
Cruas-3	915	14 May 1984	04/08/24–24/03/25*	232	
Dampierre-4	890	30 January 1981	12/07/24–16/01/25*	188	

Sources: compiled by WNISR, based on EDF REMIT-Data[195]

Notes: The expected duration is based on outage dates in use as of outage start, or within the few days after the reactor was disconnected from the grid. For ongoing decennial visits, end of outage date is the date in use as of 1 November 2023, and can vary from the original date:

* Expected duration as of Outage start;
** Revised date/duration, as provided as of 17 August 2024;
*** Original duration.[196]

On 23 February 2021, ASN issued detailed generic requirements for plant life extension.[197] The key aspects of ASN's decision were not the five short administrative articles but the two annexes setting the technical conditions and the timetable for work to be carried out. The challenge for operator EDF will be high, as ASN outlines:

> Over the coming five years, the nuclear sector will have to cope with a significant increase in the volume of work that is absolutely essential to ensuring the safety of the facilities in operation.
>
> Starting in 2021, four to five of EDF's 900 Megawatts electric (MWe) reactors will undergo major work as a result of their fourth ten-yearly outages. (…)

195 - EDF, "List of Outages", August 2024, see https://www.edf.fr/en/the-edf-group/who-we-are/activities/optimisation-and-trading/list-of-outages-and-messages/list-of-outages, accessed 17 August 2024.

196 - The original outage was cancelled in February 2024 and replaced by an outage with a longer initial duration; see EDF, "List of Outages and Messages", Updated February 2024, see https://www.edf.fr/en/the-edf-group/who-we-are/activities/optimisation-and-trading/list-of-outages-and-messages/list-of-outages?mrid=05470-edf-t-00047355, accessed 17 August 2024.

197 - ASN, "L'ASN prend position sur les conditions de la poursuite de fonctionnement des réacteurs de 900 MWe au-delà de 40 ans", Information Notice (in French), Autorité de Sûreté Nucléaire/French Nuclear Safety Authority, 25 February 2021, see https://www.asn.fr/Informer/Actualites/La-poursuite-de-fonctionnement-des-reacteurs-de-900-MWe-au-dela-de-40-ans, accessed 25 February 2021.

> All of this work will significantly increase the industrial workload of the sector, with particular attention required in certain segments that are under strain, such as mechanical and engineering, at both the licensees and the contractors.[198]

This was prior to the corrosion issues that struck EDF's fleet at the end of 2021. ASN has shown remarkable tolerance for extended timescales of refurbishments and upgrades in the past; many of the post-Fukushima measures have not yet been implemented eleven years after the events, for example. As of the end of 2020, none of the 56 French reactors were backfitted entirely according to ASN requests issued in 2012. According to some estimates, the completion of the work program could take until 2039.[199]

Additionally, the implementation of work to be carried out as part of the lifetime extension beyond 40 years stretches over 15 years until 2036, when the last 900-MW reactor is supposed to be upgraded: Chinon B-4, connected to the grid in 1987, gets the 15-year delay to implement 15 of a total of 37 measures. By then, the unit will have operated for 49 years. This is just one example, and it is the newest of the operating 900-MW reactors. ASN has accepted similar timescales for all 32 of the 900-MW units. The French Nuclear Safety Authorities have proven flexible, and—considering the dire state of the reactor fleet—pressure for even more flexibility might increase in the future.

On 13 October 2023, EDF applied for permission to delay many of the required upgrades of the 32-unit fleet of 900-MW units by years, "given the difficulties of meeting them." EDF justified the application by

- the occurrence of technical contingencies during the implementation of certain requirements;
- changes in the scheduling of refueling outages, linked in particular to the discovery of stress corrosion on auxiliary lines, to fortuitous long-term shutdowns, and to stresses affecting the power grid;
- the concomitance of other periodic reviews, putting a strain on engineering capacity.[200]

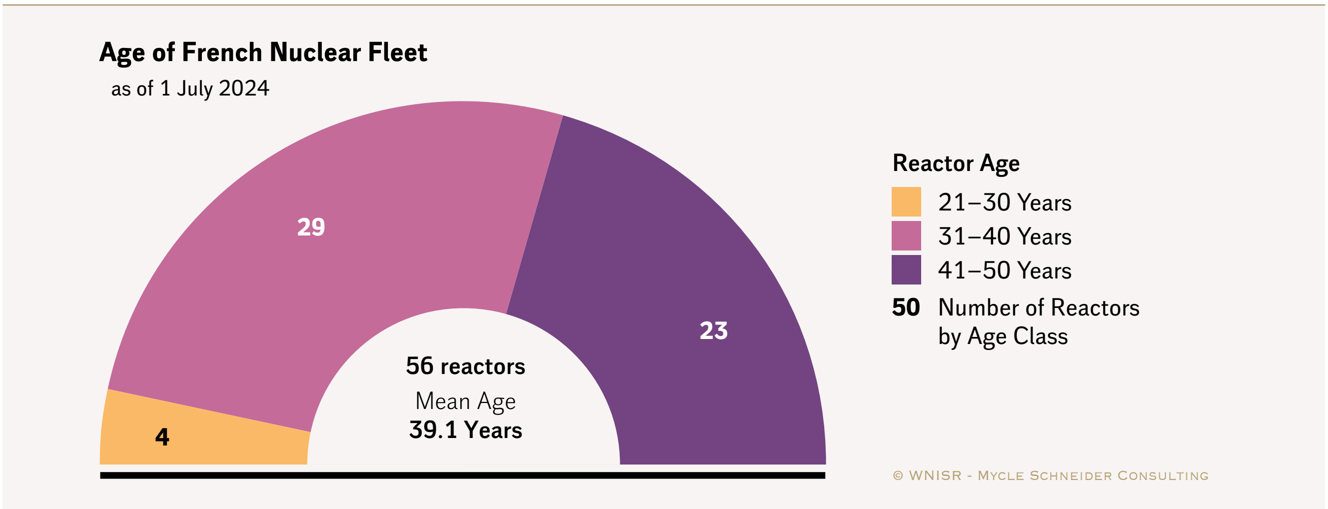
Following a public consultation for three weeks between 13 November and 1 December 2023, ASN, on 19 December 2023, modified its February 2021 publication of generic requirements, and delayed target dates for 31 of the 32 units for at least one but up to 14 upgrading work-packages (of a total of 36 per reactor) for periods of one to five years. This regulatory decision is another demonstration of the remarkable flexibility of the French nuclear safety authority.

198 - ASN, "Abstracts ASN Report on the state of nuclear safety and radiation protection in France in 2020", 2021, see http://www.french-nuclear-safety.fr/Information/Publications/ASN-s-annual-reports/ASN-Report-on-the-state-of-nuclear-safety-and-radiation-protection-in-France-in-2020, accessed 27 July 2021.

199 - Manon Besnard and Yves Marignac, "Les mesures de renforcement du parc nucléaire français, dix ans après Fukushima", Institut négaWatt, 5 March 2021 (in French), see https://cdn.greenpeace.fr/site/uploads/2021/03/Institut-n%C3%A9gaWatt-Les-mesures-de-renforcement-du-parc-nucl%C3%A9aire-fran%C3%A7ais-10-ans-apr%C3%A8s-Fukushima-rapport-mars-2021-1.pdf, accessed 30 August 2022.

200 - ASN, "Évolutions de certaines prescriptions du 4e réexamen périodique des réacteurs de 900 MWe", 9 August 2024, see https://www.asn.fr/l-asn-reglemente/consultations-du-public/evolutions-de-certaines-prescriptions-du-4e-reexamen-periodique-des-reacteurs-de-900-mwe, accessed 30 August 2024.

Figure 36 · Age Distribution of French Nuclear Fleet (by Decade)



Sources: WNISR, with IAEA-PRIS, 2024

Financial Issues

Operating and maintenance costs of the ageing fleet of reactors have significantly increased over the past decade (see also previous WNISR editions), but whatever the uncertainties over various cost estimates might be, there is little doubt that the additional costs for refurbishment and upgrades in view of lifetime extensions remain below any cost estimate for newbuild.

Outages that systematically exceed planned timeframes are particularly costly. EDF's net financial debt increased by about €10 billion (US$$_{2021}$11.8 billion) over the period 2019–2021 to a total of €43 billion (US$$_{2021}$51 billion) as of the end of 2021.[201] In 2022 alone, net debt jumped by €21.5 billion (US$$_{2022}$22.6 billion) to €64.5 billion (US$$_{2022}$67.9 billion) at the end of the year.[202] Luc Rémont, EDF's incoming CEO, stated during a hearing at the Finance Commission of the National Assembly:

> We are on the eve of an industrial challenge which, in reality, is out of all proportion with the Group's history for several reasons. The first is that we are beginning this steep path towards greater investment in electrification with the somewhat heavy rucksack of a 65 billion euro [US$$_{2023}$70 billion] debt which is—I'm sure, even for the Finance Commission, 65 billion euros is a significant amount—I can assure you for a company, it is the heaviest amount a company can experience in Europe and so, naturally, it is part of the elements that define our capacities and the ways in which we can envisage this new investment cycle.[203]

Rémont added that the Group never before had to invest on the order of €25 billion per year (US$_{2023}$$27 billion/year) of which 80 percent in France while "debt can hardly increase more".[204]

201 - EDF, "Consolidated Financial Statements at 31 December 2021", 13 April 2021, see https://www.edf.fr/sites/groupe/files/2022-02/annual-results-2021-consolidated-financial-statements-20220218.pdf, accessed 4 July 2021.

202 - EDF, "Consolidated Financial Statements at 31 December 2022", February 2023, see https://www.edf.fr/sites/groupe/files/2023-02/annual-results-2021-consolidated-financial-statements-2023-02-17.pdf; and

203 - Luc Rémont, oral evidence to the Finance Commission of the National Assembly, 19 July 2023.

204 - Ibidem.

In 2023, profiting from increased nuclear and hydro power output as well as a good year for renewables, EDF managed to go from a record loss to a €10 billion (US$$_{2023}$10.8 billion) profit and was able to reduce its debt load by an equivalent amount to €54.4 billion (US$$_{2023}$58.8 billion).[205] EDF's 2024 Half-Year Results show a stabilization of the debt load at €54.2 billion (US$58.6 billion).[206]

However, the struggle with rapidly changing market situations leading to lower average prices and, increasingly often, to negative prices on the spot market, have significant impact on the management of France's nuclear fleet. EDF states in its 2024 half-year financial report that "the decline in sale prices had an estimated impact of -€8.1 billion [US$8.8 billion]" in the first six months of the year. And further: "For example, on 12 May 2024, the French nuclear power fleet adjusted its capacity from 36.4 GW to 22.6 GW and the lowest hourly spot price in the whole half-year, -€87.3/MWh [US$94.4/MWh], was recorded at 2 pm the same day."[207]

The Flamanville-3 EPR Saga Continued

The 2005 construction decision of Flamanville-3 (FL3) was mainly motivated by the industry's attempt to confront the serious problem of maintaining nuclear competence. Fifteen years later, ASN still drew attention to the "need to reinforce skills, professional rigorousness and quality within the nuclear sector."[208]

In December 2007, EDF started construction on Flamanville-3 (FL3) with a scheduled startup date of 2012. The project has been plagued with design issues and quality-control problems, including basic concrete and welding difficulties similar to those at the Olkiluoto (OL3) project in Finland, which started construction two-and-a-half years earlier and was connected to the grid only in March 2022 (see earlier WNISR editions.) These problems never stopped.

In March 2020, EDF had stated that fuel loading would be delayed to "late 2022" and re-evaluated construction costs at €12.4$_{2015}$ billion (US$$_{2015}$13.8 billion), an increase of €1.5$_{2015}$ billion (US$$_{2015}$1.7 billion) over the previous estimate.[209] In addition to the overnight construction costs, as of December 2019, EDF indicated more than €4.2 billion (US$$_{2019}$4.7 billion) was needed for various cost items, including €3 billion (US$$_{2019}$3.4 billion) of financial costs.

In January 2022, EDF estimated the overnight costs at €$_{2015}$12.7 billion (US$$_{2015}$14.1 billion).[210] In December 2022, the figure was updated to €$_{2015}$13.2 billion (US$$_{2015}$14.6 billion).[211] In 2020, the

205 - EDF, "Universal Registration Document 2022 Including the Annual Financial Report", 4 April 2024, see https://www.edf.fr/sites/groupe/files/2024-04/edf-urd-annual-financial-report-2023-en-updated-2024-04-11.pdf, accessed 29 August 2024.

206 - EDF, "Half-Year Financial Report at 30 June 2024", 25 July 2024, op. cit.

207 - Ibidem.

208 - ASN, "ASN Report on the state of nuclear safety and radiation protection in France in 2020—Abstracts", Autorité de Sûreté Nucléaire/French Nuclear Safety Authority, 2021, see https://www.french-nuclear-safety.fr/content/download/178655/file/Abstracts-of-the-full-ASN-Report-on-the-State-of-nuclear-safety-and-radiation-protection-in-France-in-2020.pdf, accessed 30 August 2022.

209 - EDF, "Annual Financial Report 2019—Universal Registration Document—New version of the Reference Document", original version filed 13 March 2020, see https://www.edf.fr/sites/default/files/contrib/groupe-edf/espaces-dedies/espace-finance-en/financial-information/regulated-information/reference-document/edf-urd-annual-financial-report-2019-en.pdf, accessed 14 November 2023.

210 - EDF, "Update on the Flamanville EPR", Press Release, 12 January 2022, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/update-on-the-flamanville-epr, accessed 31 August 2022.

211 - EDF, "Universal Registration Document 2022 Including the Annual Financial Report", original document in French filed 21 March 2023, see https://www.edf.fr/en/the-edf-group/dedicated-sections/investors/regulated-information, accessed 3 November 2023.

French Court of Accounts estimated the total cost, including financing and other associated costs, at €$_{2015}$19.1 billion (US$$_{2015}$21 billion).[212] The Court estimated that the cost of electricity from FL-3 would be €$_{2015}$110–120/MWh (US$$_{2015}$122–133/MWh). This estimate has not been publicly updated.

The fuel issue that struck the Taishan EPRs and kept Unit 1 off-grid for over one year had consequences for FL3. EDF decided to refabricate 64 of the 241 fuel assemblies that had already been produced. These were approved by ASN and delivered to the site. Fuel loading was finally completed in May 2024. Since then, EDF representatives repeatedly stated that the reactor startup was "imminent" with grid connection happening "a few weeks later". As of mid-year 2024, this did not happen.[213]

Conclusion

The French nuclear industry remains under a high level of stress. The full re-nationalization of EDF, analysts agree, will not solve its structural problems: an ageing nuclear fleet with lowest performance in decades, manpower and competence challenges, unprecedented investment needs at times of unprecedented net debt, and never-ending problems at the only active construction site at Flamanville.

Not covered here, but to this list should be added serious fuel chain issues, climate impact, social movements, and some unexpected opposition. Especially the plutonium-economy part of the industry is experiencing its own crisis with historically low throughput at the spent fuel reprocessing plant at La Hague and at the uranium-plutonium mixed-oxide (MOX) fuel fabrication facility MELOX at Marcoule. Consequently, spent fuel pools are filling up and the stocks of unirradiated plutonium have increased to unprecedented levels.

Confronted with this avalanche of problems, the French Government has chosen to insist on the launch of a nuclear newbuild program—supported by a majority in the National Assembly. And EDF follows suit:

> On 29 June 2023, EDF announced that it was making the applications for approval to launch construction of the first pair of EPR 2 reactors at Penly, and starting other administrative procedures required for their completion and connection to the electricity transmission network. EDF's objective is to begin preparatory work in mid-2024.[214]

212 - Court of Accounts, "La filière EPR", Cour des Comptes, 9 July 2020. See WNISR2020 for excerpts from the report.

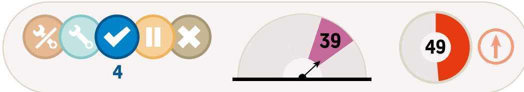
213 - It did not happen until the end of August 2024 either, as new technical issues were identified in early July 2024. See Sharon Wajsbrot, "Pourquoi EDF a repoussé le lancement de l'EPR de Flamanville", *Les Echos*, 28 August 2024 (in French), see https://www.lesechos.fr/industrie-services/energie-environnement/nucleaire-une-nouvelle-tentative-de-divergence-se-prepare-pour-lepr-de-flamanville-2115700, accessed 29 August 2024.

214 - EDF, "Half-Year Financial Report at 30 June 2023", 27 July 2023, see https://www.edf.fr/sites/groupe/files/2023-07/2023-07-27-half-year-results-financial-report.pdf, accessed 5 November 2023.

The EPR2 does not even exist on paper. It increasingly looks as if the current administration and nuclear establishment have not learned the lessons of the Flamanville EPR1 disaster, as spelled out in the chapter headlines of a 2019-assessment commissioned by EDF's President: "An unrealistic initial [cost] estimate; (…) An inappropriate project governance; Struggling project teams; (…) Insufficiently advanced studies at launch; (…) Generalized loss of competence."[215]

Largely unreported, the science community in France is far from offering unanimous support of the newbuild initiative. As of the end of October 2023, close to 1,200 scientists had signed the "Call by scientists against a new nuclear program".[216]

HUNGARY FOCUS



Hungary has one operating nuclear power plant at Paks where four VVER-440/v213 reactors provided 15.1 TWh or 48.8 percent of the country's electricity in 2023. The nuclear share in the national power mix peaked at 53.6 percent in 2014. The reactors began operating between 1982 and 1987 and have undergone engineering work to enable their operation for up to 50 years (compared to their initial 30-year license). The first unit received permission to operate for another 20 years in 2012, the second in 2014, the third in 2016, and the fourth in December 2017, enabling the plant's operation until the mid-2030s.

In Hungary, renewable capacities have been increasing over the past decade, driven by the expansion of solar from just 89 MW in 2014 to over 5.8 GW in 2023, representing about 86 percent of the country's renewable sources.[217] In an updated version of Hungary's National Energy and Climate Plan, submitted in September 2023, 12 GW of PV capacity is expected to be reached in 2030, while wind power capacity shall more than triple over the same period from currently around 330 MW to still modest 1 GW. This would bring the total renewable electricity generation share to 31 percent. The plan assumes continued operation of all four operational reactors at Paks, plus the Paks II reactors currently under construction, amounting to 4.4 GW of nuclear capacity by 2030. It also envisions the potential deployment of Small Modular Reactors (SMRs). This would account for around 50 percent of annual electricity production from nuclear.[218] At the International Atomic Energy Agency's (IAEA's) Nuclear Energy Summit held in March 2024 in Brussels, Prime Minister Viktor Orbán announced, without providing

215 - Jean-Martin Folz, "La construction de l'EPR de Flamanville – Rapport au Président Directeur Général d'EDF", commissioned by EDF in July 2019, Ministry of Economy and Finances, delivered 25 October 2019 (in French), see https://www.vie-publique.fr/rapport/271429-la-construction-de-lepr-de-flamanville, accessed 5 November 2023.

216 - Group of Scientists for Information on Nuclear Energy, Global Chance et al., "Call by scientists against a new nuclear program", June 2023, see https://appel-de-scientifiques-contre-un-nouveau-programme-nucleaire.org/en/.

217 - IRENA, "Renewable Capacity Statistics 2024", International Renewable Energy Agency, March 2024, see https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2024/Mar/IRENA_RE_Capacity_Statistics_2024.pdf?rev=a587503ac9a2435c8d13e40081d2ec34, accessed 17 April 2024.

218 - Government of Hungary, "National Energy and Climate Plan—Revised Version 2023", 2023, see https://commission.europa.eu/publications/hungary-draft-updated-necp-2021-2030_en, accessed 29 May 2024.

any details, that his government was planning to expand this share to 70 percent by adding a further 2.4 GW by the "beginning of the next decade".[219]

According to Ember, natural gas contributed 21.1 percent and solar 18.4 percent to the Hungarian electricity production in 2023.[220] The remainder consisted of a mix of bioenergy (4.9 percent), wind (1.8 percent), hydro (0.6 percent), and "other" fossil fuels (1 percent).[221]

In July 2022, the government announced it would put forward economic and technical plans to further extend the operating lives of the existing nuclear reactors at Paks by up to 20 years.[222] This decision was approved with an overwhelming majority in parliament (170 votes in favor, eight against, one abstention) in December 2022,[223] and in December 2023, these plans, that would extend the operational lifetimes of the four reactors to 70 years, were officially announced to the E.U. Commission. A detailed implementation plan shall be provided by 2028. Costs for "revamping [of] the electric and control systems" are estimated at around €1.5 billion (US$$_{2023}$1.7 billion).[224]

Cooperation With Russia and Belarus

Hungary's energy supply heavily depends on Russia.[225] With its continued blocking of E.U. sanctions against Russia, especially in the nuclear sector, Hungary is being rewarded by a continued supply of Russian gas mostly via the Turkstream pipeline.[226] After a meeting between Hungarian Prime Minister Viktor Orbán and Russian President Vladimir Putin in October 2023 in Beijing, *increased* gas supplies from Russian state-owned company Gazprom were announced.[227] Paks operator MVM Paksi Atomerőmű Zrt reportedly said that from 2024 it would be storing three years' instead of previously two years' worth of nuclear fuel onsite. The increase would be intended «to reduce the uncertainties resulting from the conflict in Ukraine."[228]

219 - *The Budapest Times*, "Orbán: Nuclear energy only way to produce sustainable, safe electricity", 21 March 2024, see https://www.budapesttimes.hu/world/orban-nuclear-energy-only-way-to-produce-sustainable-safe-electricity/, accessed 30 June 2024; and *About Hungary*, "Speech by Viktor Orbán at the Nuclear Energy Summit", Cabinet Office of the Prime Minister, Government of Hungary, 21 March 2024, see https://abouthungary.hu//speeches-and-remarks/speech-by-viktor-orban-at-the-nuclear-energy-summit, accessed 10 June 2024.

220 - Ember puts the nuclear share at 44.5 percent, and IAEA-PRIS indicates 48.8 percent.

221 - Ember, "Electricity Data Explorer", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 29 May 2024.

222 - *NEI Magazine*, "Key licences issued for Paks-II", 6 July 2022, see https://www.neimagazine.com/news/key-licences-issued-for-paks-ii-9829343/, accessed 7 June 2024.

223 - Anita Komuves, "Hungary parliament approves lifespan extension of Paks nuclear power plant", *Reuters*, 7 December 2022, see https://www.reuters.com/world/europe/hungary-parliament-approves-lifespan-extension-paks-nuclear-power-plant-2022-12-07/, accessed 27 July 2023.

224 - *WNN*, "Hungary aims to extend life of Paks nuclear plant by 20 years", *World Nuclear News*, 7 December 2023, see https://www.world-nuclear-news.org/Articles/Hungary-aims-to-extend-life-of-Paks-nuclear-plant, accessed 29 May 2024.

225 - IEA, "Hungary 2022 Energy Policy Review", International Energy Agency, September 2022, op. cit.

226 - Krisztina Than, "Hungary's foreign minister holds energy talks with Russia's premier", *Reuters*, 29 March 2023, see https://www.reuters.com/world/europe/hungarys-foreign-minister-holds-energy-talks-with-russias-premier-2023-03-29/; and Krisztina Than and Boldizsar Gyori, "Hungary agrees on option for more Russian gas shipments, oil transit fees", 11 April 2023, *Reuters*, see https://www.reuters.com/business/energy/hungary-agrees-option-more-russian-gas-shipments-oil-transit-fees-2023-04-11/; both accessed 28 July 2023.

227 - *euronews*, "Russia's Gazprom to increase gas supplies to Hungary", with *Reuters*, 23 October 2023, see https://www.euronews.com/business/2023/10/23/russias-gazprom-to-increase-gas-supplies-to-hungary, accessed 30 May 2024.

228 - *WNN*, "Hungary aims to extend life of Paks nuclear plant by 20 years", 7 December 2023, op. cit.

Furthermore, after being the first E.U. minister to visit Belarus since the imposition of substantial sanctions in May 2024, Hungarian Foreign Minister Péter Szijjártó announced that Belarusian and Hungarian officials had signed an agreement to cooperate on nuclear energy, reportedly envisaging personnel training and nuclear waste handling. He stated that he "[hoped] that Belarusian companies will soon join American, German and French companies that are already working as partners of Rosatom on the construction of the Paks [II] nuclear power plant."[229] The former project manager of Rosatom's Belarusian new build project (see Belarus in Annex 1), Vitaly Polyanin, became project leader of the Paks II newbuild project in November 2023, discussed below.[230]

"I would like to stress there will be no European sanctions against the nuclear industry in the future, all the more so as it would be against our national interests. So, of course, we will keep at bay any such attempts," Szijjártó was quoted as saying in September 2023.[231] Hungary's stance on blocking sanctions against Russia or granting financial aid to Ukraine continued in 2024.[232] In March 2024, Hungary's Prime Minister Orbán stated during the above-mentioned Nuclear Summit in Brussels:

> We are happy to note that regardless of the geopolitical difficulties, a wide range of international professional and scientific cooperation still exists on the field of nuclear energy. While Russia became the number one uranium supplier of the United States last year, a number of American, German, French, Swedish, Swiss, and even Austrian subcontractors are working together with the Russian constructors on our nuclear expansion project. It is the interest of all of us to prevent nuclear energy to become a hostage of geopolitical conflicts, hypocrisy, and ideological debates. Therefore let me finally thank all of you for intervening in the European Court case regarding our nuclear investment and to ensure the safe delivery of nuclear fuel to our existing plant.[233]

Hungary's dependence on Russian nuclear fuel became remarkably evident in April 2022, when fresh nuclear fuel was flown from Russia following the award of a special permit to bypass the E.U. airspace closure to Russian aircraft.[234] Hungarian nuclear fuel for the operating plant is provided solely by Russian TVEL, and the Paks II plant will also be provided with fuel

229 - Government of Hungary, "Magyarországot elborzasztják a háború eszkalációjával fenyegető nyilatkozatok", Press Release (in Hungarian), 29 May 2024, see https://kormany.hu/hirek/magyarorszagot-elborzasztjak-a-haboru-eszkalaciojaval-fenyegeto-nyilatkozatok, and Yuras Karmanau, "Hungary's foreign minister visits Belarus despite EU sanctions, talks about expanding ties", *The Associated Press*, 29 May 2024, see https://apnews.com/article/belarus-hungary-foreign-minister-peter-szijjarto-eu-fb299cb255074bf4f711059fb66c5d3a, accessed 30 May 2024.

230 - *24.hu*, "Fehéroroszországból érkezik Paks II. új építésvezetője", 21 November 2023 (in Hungarian), see https://24.hu/fn/gazdasag/2023/11/21/paks-ii-atomeromu-nuklearis-energia-feheroroszorszag-roszatom-orosz-magyar-aramtermeles/, accessed 30 May 2024.

231 - Rosatom, "Newsletter #269—Paks II Enters Key Stage", September 2023, see https://rosatomnewsletter.com/2023/09/26/paks-ii-enters-key-stage/, accessed 9 June 2024.

232 - Henry Foy, "Why Hungary is again blocking the latest round of Russia sanctions", *The Financial Times*, 15 February 2024, see https://www.ft.com/content/53f2e696-5ff2-4be9-bcf0-f6a144fbdbff; and Jorge Liboreiro, "EU countries voice exasperation over Hungary's vetoes on Ukraine aid", *euronews*, 27 May 2024, see https://www.euronews.com/my-europe/2024/05/27/it-has-gone-very-far-eu-countries-voice-exasperation-over-hungarys-vetoes-on-ukraine-aid; both accessed 29 May 2024; and *About Hungary*, "FM: 14th sanctions package is against Hungary's interest", Office of the Prime Minister, Government of Hungary, 28 May 2024, see https://abouthungary.hu/news-in-brief/fm-14th-sanctions-package-is-against-hungary-s-interest, accessed 9 June 2024.

233 - *About Hungary*, "Speech by Viktor Orbán at the Nuclear Energy Summit", Government of Hungary, 21 March 2024, op. cit.

234 - Ashutosh Pandey, "Why EU sanctions don't include Russian nuclear industry", *Deutsche Welle*, 19 July 2023, see https://www.dw.com/en/russia-nuclear-industry-eu/a-66275352, accessed 27 July 2023.

by TVEL.[235] Since 2022, Russian fuel has been coming to Hungary via the Black Sea, where ships escorted by Russian Navy warships unload the fuel in Varna, Bulgaria, from where it is transported to Hungary via rail. Before 2022, fuel had been delivered via train through Ukraine.[236] After a stockpile of three years' worth of fuel had been secured,[237] the Hungarian Parliament in November 2023 passed an amendment to the official nuclear policy that would allow alternative sources for nuclear fuel to be used.[238] This followed contradicting reports that Hungary would not change supplier,[239] the signing of an MoU for "long-term cooperation" with French fuel supplier Framatome,[240] and its participation in the consortium, led by U.S. supplier Westinghouse, which was selected for the E.U. Accelerated Program for Implementation of Secure VVER Fuel Supply (or APIS project) intended to "secure [VVER] fuel supply in Europe and Ukraine."[241]

The PAKS II Saga

For a decade and a half, plans have been discussed and developed to build additional nuclear power plants. In March 2009, Parliament approved a government decision-in-principle to build additional reactors[242] and a tender was prepared according to E.U. rules. In 2014, the Paks II project, consisting of two 1200-MW reactors, was suddenly awarded to Rosatom without reference to any public tender, with Russia financing 80 percent of the project through loans.[243] The original Russian-Hungarian bilateral financing agreement from 2014 consisted of a €10 billion (US$$_{2014}$13 billion) loan to the Hungarian state, to be repaid from 2026 onwards irrespective of whether the plant had come online by that time. Hungary would have to invest 20 percent or up to €2.5 billion (US$$_{2014}$3.3 billion) into the project. Then in April 2021, the loan terms were revised to allow Hungary to start repaying the loan in 2031, five years later than originally agreed.[244] Rosatom had been awarded the project at a fixed price contract that "might no longer be favorable", while in Hungary cheaper solar deployment is rapidly highlighting

235 - Patricia Lorenz, "Russian Grip on EU Nuclear Power", Wiener Umweltanwaltschaft, May 2022, Updated January 2024, see https://wua-wien.at/images/stories/publikationen/russian-grip-on-eu-nuclear-power.pdf, accessed 30 June 2024.

236 - *WNN*, "Hungary to Consider Alternative Sources for Nuclear Fuel", *World Nuclear News*, 24 November 2023, see https://world-nuclear-news.org/Articles/Hungary-to-consider-alternative-sources-for-nuclea, accessed 29 May 2024.

237 - *WNN*, "Hungary Aims to Extend Life of Paks Nuclear Plant by 20 Years", December2023, op. cit.

238 - *WNN*, "Hungary to Consider Alternative Sources for Nuclear Fuel", November 2023, op. cit.

239 - *TASS*, "No plans by Hungary to swap Russian nuclear fuel for Paks plant for French supply — envoy", *Russian News Agency*, 11 September 2023, see https://tass.com/world/1672791, accessed 30 June 2024.

240 - Framatome, "Framatome signs Memorandum of Understanding with Hungary to extend long-term cooperation in nuclear power", Press Release, 12 September 2023, see https://www.framatome.com/medias/framatome-signs-memorandum-of-understanding-with-hungary-to-extend-long-term-cooperation-in-nuclear-power/, accessed 19 December 2023.

241 - Westinghouse, "Westinghouse-led Project will Secure VVER Fuel Supply in Europe and Ukraine", Press Release, 6 July 2023, see https://info.westinghousenuclear.com/news/westinghouse-led-project-will-secure-vver-fuel-supply-in-europe-and-ukraine, accessed 30 June 2024.

242 - PAKS II, "Background of the Project", Undated, see https://www.paks2.hu/web/paks-2-en/background-of-the-project; and *WNN*, "Hungarian parliament approves Paks expansion", 31 March 2009, see https://www.world-nuclear-news.org/Articles/Hungarian-parliament-approves-Paks-expansion; both accessed 28 July 2023.

243 - Csaba Tóth, "Hungary, Russia sign Paks II implementation agreements", *The Budapest Beacon*, 9 December 2014, see https://budapestbeacon.com/hungary-russia-sign-3-implementation-agreements-paks-ii/, accessed 27 July 2023.

244 - Marton Dunai, "CORRECTED-Hungary gets 5-year payment delay on Russian-led nuclear plant project", *Reuters*, 29 April 2021, see https://www.reuters.com/article/hungary-nuclearpower-russia-financing-idINL8N2MM8SW, accessed 27 July 2023.

the high costs of potential electricity to be produced by Paks II, which would be borne by the taxpayers.[245]

Legal Challenges to State Aid for Paks II

In November 2016, after a one-year procedure, the European Commission cleared the award of the contract to Rosatom of any infringement of its procurement rules,[246] and in March 2017, it also approved the financial package for Paks II.[247] However, in February 2018 the Austrian Government challenged the validity of the decision.[248] In November 2022, the European General Court ruled that because Hungary's state aid for the Paks II project "concerns solely the costs of investment in two new reactors intended to replace the four old reactors […] and with no operating aid being foreseen, the effect on the energy market will only be limited." The legal challenge had been supported by the Government of Luxembourg, while the Czech Republic, France, Hungary, Poland, Slovakia, and the United Kingdom stood with the European Commission.[249] In April 2023, the Hungarian Government and Rosatom updated the delivery contract reportedly saying that "even without the war and sanctions 'life and the technological situation have changed so much'" since the initial signature. Details on the contract remain confidential.[250] According to the government, the amendments were approved by the European Commission in May 2023,[251] allowing to speed up the process.[252] An Engineering, Procurement and Construction (EPC) contract amendment was also signed by all parties in August 2023, thus concluding "the preparatory phase" of the project and allowing it to "move to the second phase, the actual physical construction phase", according to Minister Szijjártó, with "the so-called first concrete moment to be realized by the end of [2024]."[253]

245 - Gary Peach, "Hungary: Exorbitant Costs, Solar Energy Remove Luster From Paks II", *Nuclear Intelligence Weekly*, 22 May 2020.

246 - Philip Blenkinsop, "EU drops part of reservation to Hungary's Paks nuclear project", *Reuters*, 18 November 2016, see https://www.reuters.com/article/us-hungary-nuclearpower-eu-idUSKBN13D0QN, accessed 27 July 2023.

247 - European Commission, "Commission Decision (EU) 2017/2112 of 6 March 2017 on the measure/aid scheme/State aid SA.38454—2015/C (ex 2015/N) which Hungary is planning to implement for supporting the development of two new nuclear reactors at Paks II nuclear power station", L 317/45, *Official Journal of the European Union*, 6 March 2017, see https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017D2112, accessed 27 July 2023.

248 - *Official Journal of the European Union*, "Case T-101/18—Action brought on 21 February 2018 — Austria v Commission", published 30 April 2018, C152/40, see https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A62018TN0101&qid=1717880757515, accessed 8 June 2024.

249 - General Court, "Report of Cases—Judgment of the General Court (Third Chamber)—Judgment of 30.11.2022 Case T-101/18 [Extracts]—Austria v Commission", ECLI:EU:T:2022:728, Court of Justice of the European Union, 30 November 2022, see https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:62018TJ0101&qid=1717881256039; and Nikolaus J. Kurmayer, "Austria loses EU court case against Hungarian nuclear power plant", *Euractiv*, 1 December 2022, see https://www.euractiv.com/section/energy/news/austria-loses-eu-court-case-against-hungarian-nuclear-power-plant/, both accessed 8 June 2024.

250 - *About Hungary*, "FM: European Commission has approved modifications to Paks upgrade contract", Cabinet Office of the Prime Minister, Government of Hungary, 26 May 2023, see https://abouthungary.hu/news-in-brief/fm-european-commission-has-approved-modifications-to-paks-upgrade-contract, accessed 9 June 2024.

251 - David Dalton, "European Commission Has Approved Changes To Paks 2 Nuclear Contracts With Russia, Says Foreign Minister", *NucNet*, 26 May 2023, see https://www.nucnet.org/news/european-commission-has-approved-changes-to-paks-2-nuclear-contracts-with-russia-says-foreign-minister-5-5-2023, and *WNN*, "EC outlines approval grounds for Paks II contract amendments", 30 May 2024, see https://world-nuclear-news.org/Articles/EC-outlines-approval-grounds-for-Paks-II-contract; both accessed 9 June 2024.

252 - *About Hungary*, "FM: European Commission has approved modifications to Paks upgrade contract", Cabinet Office of the Prime Minister, Government of Hungary, 26 May 2023, see https://abouthungary.hu/news-in-brief/fm-european-commission-has-approved-modifications-to-paks-upgrade-contract, accessed 9 June 2023.

253 - Paks II, "The amendment of the EPC contract has been signed", Press Release, 18 August 2023, see https://paks2.hu/web/paks-2-en/w/the-amendment-of-the-epc-contract-has-been-signed, accessed 30 June 2024.

Opposition Against the Construction License for Paks II

In March 2017, the Hungarian Atomic Energy Authority (HAEA) issued the site license for the new construction.[254] However, since then, there have been increasing concerns regarding the availability of cooling water given the warmer summer months and higher water temperatures of the Danube River, especially if both Paks I and II are in operation. During the Environmental Impact Assessment (EIA) process, the "proposed solution" to this problem was reportedly the temporary shutdown of the plant in such instances, which could affect the economics of the project and the grid balance.[255]

In addition, a 2021-report published by the Austrian Federal Environmental Agency found that the Dunaszentgyörgy-Harta seismic fault passes through the Paks II site. According to the report, the fault is both active and capable. The assessment concludes that "[t]he Paks II site should therefore be deemed unsuitable."[256] The Hungarian authorities, responding to the publication of the Austrian report, stated that the licensing process had not found any issues that indicated that the site was unsuitable.[257] The licensing documents for the project remain confidential, prompting Hungarian independent news agency Átlátszó to sue for their release after having been denied access.[258] Furthermore, the site is apparently located on soil that has an increased risk of liquefaction, necessitating preparatory counter measures on site.[259]

Process Continues Despite Concerns

On 30 June 2020, Paks II Ltd. submitted the construction license application to the HAEA. The regulator started its assessment procedure the next day and had 12 months to make its views known.[260] That period was extended by an additional three months in May 2021.[261] If all went according to plan, site preparation would have taken an additional 18 months, and formal construction would have started in mid-2022, some six years after the Hungarian and Russian Governments signed the corresponding intergovernmental agreements. That did not happen,

254 - HAEA, "Announcement of regulatory decision", Press Release, 31 March 2017, see https://www.haea.gov.hu/web/v3/HAEAportal.nsf/web?OpenAgent&article=news&uid=ED20996520032F56C12580F40025638B, accessed 9 June 2024.

255 - Gary Peach, "Five Years on, Hungary's Paks Expansion Stumbles Along", *Nuclear Intelligence Weekly*, 8 February 2019.

256 - Kurt Decker and Esther Hintersberger, "NPP Paks II—Paleoseismological Assessment of the Siting Report and the Site License with Respect to Fault Capability—Executive Summary", REP-0759, Umweltbundesamt/Environment Agency Austria, 2021, see https://www.umweltbundesamt.at/fileadmin/site/publikationen/rep0759bfz.pdf, accessed 27 July 2023.

257 - Eszter Zalan, "Hungary's nuclear power plant expansion unnerves Austria", *EUobserver*, 7 June 2021, see https://euobserver.com/climate/152035, accessed 19 June 2021.

258 - Orsolya Fülöp, "We are suing for the Paks II licensing documents, still no consensus on the risks of the tectonic fault line", *Atlatszo*, 18 January 2024, see https://english.atlatszo.hu/2024/01/18/we-are-suing-for-the-paks-ii-licensing-documents-still-no-consensus-on-the-risks-of-the-tectonic-fault-line/, accessed 9 June 2024.

259 - Paks II, "Tudtad-e, hogy a Paks II. Atomerőmű területén készülő talajszilárdításnak kettős célja van?", Press Release (in Hungarian), 5 February 2024, see https://paks2.hu/web/guest/w/tudtad-e-hogy-a-paks-ii-atomeromu-teruleten-keszulo-talajszilarditasnak-kettos-celja-van-, accessed 30 May 2024.

260 - HAEA, "Paks II. Ltd. submitted the construction license application to the HAEA", Press Release, 30 June 2020, see https://www.haea.hu/web/v3/HAEAportal.nsf/web?OpenAgent&article=news&uid=5B9108F378B8DFBCC1258597003BF3DE, accessed 9 June 2024.

261 - HAEA, "Hirdetmény közzététele az ügyintézési határidő meghosszabbításáról a paksi telephelyen létesítendő 5. és 6. atomerőművi blokkok létesítési engedélyezési eljárásában", Press Release (in Hungarian), 19 May 2021, see https://www.haea.gov.hu/web/v3/oahportal.nsf/web?OpenAgent&article=news&uid=4346A8D52E23910EC12586DA0023F45A, accessed 27 July 2023.

and in October 2021, following IAEA feedback, HAEA announced that it needed more time "to fully verify all requirements," without communicating an updated timeline.[262]

Despite the economy-wide sanctions against Russian companies, Paks II is proceeding, as nuclear energy is not subject to E.U. sanctions as of mid-2024. In June 2024, Hungary obtained the exclusion of Paks II from future E.U. sanctions, by making it the main condition for its government to approve the union's 14th sanctions package against Russia, which targets the Russian LNG sector for the first time.[263] In May 2022, following Rosatom reassurances, Hungarian authorities seemed confident that "in terms of technology they are able to complete the project."[264] In July 2022, the government announced that further site preparation licenses had been awarded by HAEA,[265] and in August 2022, construction licenses for two new VVER-1200 reactors were granted.[266]

On 5 July 2023, Rosatom announced that work on building a groundwater cut-off had begun and onsite preparatory work was ongoing.[267] In December 2023, project management reportedly indicated that the construction start of the first unit had been scheduled for March 2025, but could in fact start "ahead of schedule" by December 2024, a timeline that has since been officially maintained.[268] However, there had already been even earlier announcements that construction was to begin in 2024.[269] In April 2024, it was announced that the reactor pressure vessel of Unit 5 was being forged in St. Petersburg, Russia.[270]

There is conflicting information regarding the current planned completion date. Per a statement issued in April 2024, the to-be-operating company Paks II Ltd. plans to "connect the new units to the grid by the beginning of 2030,"[271] while earlier reports suggested this for

262 - *WNN*, "Paks II construction licence delayed", 1 October 2021, see https://www.world-nuclear-news.org/Articles/Paks-II-construction-licence-delayed, accessed 3 October 2021; and HAEA, "Announcement of the Hungarian Atomic Energy Authority", 13 October 2021, see https://www.haea.gov.hu/web/v3/HAEAportal.nsf/web?OpenAgent&article=news&uid=F819FBDEC81262D4C125876D00231E4B, accessed 9 June 2024.

263 - Anita Zimmermann, Camille Gijs, Victor Jack and Koen Verhelst, "EU approves first-ever sanctions on Russian gas", *Politico*, 20 June 2024, see https://www.politico.eu/article/eu-approves-first-ever-sanctions-russian-gas-lng-vladimir-putin-ukraine-invasion/, accessed 30 June 2024.

264 - *About Hungary*, "FM: Upgrade of Paks nuclear plant is in Hungary's interest", Cabinet Office of the Prime Minister, Government of Hungary, 6 May 2022, see https://abouthungary.hu/news-in-brief/fm-upgrade-of-paks-nuclear-plant-is-in-hungarys-interest, accessed 9 June 2024.

265 - *NEI Magazine*, "Key licences issued for Paks-II", *Nuclear Engineering International*, 6 July 2022, see https://www.neimagazine.com/news/key-licences-issued-for-paks-ii-9829343/, accessed 9 June 2024.

266 - HAEA, "The HAEA issued the construction license to Paks II. Ltd.", Press Release, 26 August 2022, see https://www.haea.hu/web/v3/HAEAportal.nsf/web?OpenAgent&article=news&uid=273E525123362584C12588AA002F9FE1, accessed 9 June 2024.

267 - Rosatom, "ROSATOM started the first phase of construction of Paks II NPP units", Press Release, 5 July 2023, see https://rosatom.ru/en/press-centre/news/rosatom-started-the-first-phase-of-construction-of-paks-ii-npp-units/, accessed 27 July 2023.

268 - *TASS*, "Строители АЭС «Пакш-2» рассчитывают залить первый бетон до конца 2024 года", 21 December 2023, see https://tass.ru/ekonomika/19597301; and Paks II, "Péter Szijjártó: Paks II. will be the guarantee of our energy supply", Press Release, 7 February 2024, see https://www.paks2.hu/web/paks-2-en/w/peter-szijjarto-paks-ii-will-be-the-guarantee-of-our-energy-supply; both accessed 9 June 2024.

269 - Rosatom, "Newsletter #263—Nuclear Station: Eyeing the Future", March 2023, see https://rosatomnewsletter.com/2023/03/22/nuclear-station-eyeing-the-future/, accessed 10 June 2024.

270 - Paks II, "The Forging of the Reactor Vessel Started in Saint Petersburg", Press Release, 26 April 2024, see https://paks2.hu/web/paks-2-en/w/the-forging-of-the-reactor-vessel-started-in-saint-petersburg, accessed 30 May 2024.

271 - Ibidem.

2032[272] or more vaguely at "the start of the next decade."[273] The announcement of an agreement regarding a non-published accelerated construction schedule also envisioned completion for "the early 2030s."[274] In 2014, the first unit had been scheduled to start up in 2023,[275] a target that has been gradually pushed back over the years.

Despite the European Commission's green light and the successful Hungarian obstruction of sanctions in the nuclear sector, the Paks-II project is facing some difficulties. For example, German company Siemens was supposed to deliver parts of control-command systems for Paks II jointly with French Framatome, but export grants, necessary due to dual-use legislation, were reportedly being withheld by the German Government in early 2023.[276] As retaliation, the Hungarian Government threatened Siemens with the cancellation of other orders, e.g. for locomotives, and was seeking to focus on Framatome as major European supplier for nuclear plant components.[277]

Despite the ongoing war in Ukraine, the French Government actively supports the involvement of French suppliers in the Paks II project, arguing that "French nuclear industry players support our European partners, and in particular Hungary, in all their efforts and in all the projects on their soil as long as they strictly respect the European framework of international sanctions. To date, European sanctions [against Russia] do not target the nuclear industry."[278] French involvement is set to further increase as EDF, in late 2022, announced that an agreement had been reached to acquire GE Steam Power's nuclear activities,[279] whose subsidiary GE Hungary had won the tender to supply the turbines for Paks II in 2018.[280] The acquisition was completed in May 2024.[281]

272 - *NEI Magazine*, "Paks-II now scheduled for 2032", 13 January 2023, see https://www.neimagazine.com/news/newspaks-ii-now-scheduled-for-2032-10515669, accessed 14 January 2023; and *WNN*, "Hungary says Paks II work to start in July", 7 June 2023, see https://world-nuclear-news.org/Articles/Hungary-says-Paks-II-work-to-start-in-July, accessed 15 June 2023.

273 - *About Hungary*, " FM: Construction phase of the Paks nuclear power plant is underway", Cabinet Office of the Prime Minister, Government of Hungary, 15 November 2023, see https://abouthungary.hu/news-in-brief/fm-construction-phase-of-the-paks-nuclear-power-plant-is-underway, accessed 9 June 2024.

274 - *WNN*, "Construction schedule agreed for Paks II in Hungary", 14 November 2023, see https://world-nuclear-news.org/Articles/Construction-schedule-agreed-for-Paks-II-in-Hungar, accessed 30 June 2024.

275 - *WNN*, "Paks project company to be sold to state", 16 October 2014, see https://world-nuclear-news.org/Articles/Paks-project-company-to-be-sold-to-state, accessed 27 July 2023.

276 - *Portfolio*, "Harmadszorra is beleszállt a német kormányba Szijjártó Péter és belengette a még szorosabb orosz együttműködést", 22 February 2023 (in Hungarian), see https://www.portfolio.hu/gazdasag/20230222/harmadszorra-is-beleszallt-a-nemet-kormanyba-szijjarto-peter-es-belengette-a-meg-szorosabb-orosz-egyuttmukodest-598634, accessed 1 March 2023; and Krisztina Than, "UPDATE 1-Germany 'blocking' equipment for Paks reactors, Hungarian minister says ", *Reuters*, 14 February 2023, see https://www.reuters.com/article/hungary-nuclear-siemens-idINL1N34U1M2, accessed 28 July 2023.

277 - *Hungary Today*, "Government to Restrict Business Relations with Siemens", 15 May 2023, see https://hungarytoday.hu/government-to-restrict-business-relations-with-siemens/, accessed 5 June 2023; and Paks II, "Szijjártó: we will further increase the French involvement in the Paks NPP expansion project", Press Release, 13 March 2023, see https://www.paks2.hu/web/paks-2-en/w/szijjarto-we-will-further-increase-the-french-involvement-in-the-paks-npp-expansion-project, accessed 10 June 2024.

278 - Jean-Baptiste Chastand, Adrien Pécout and Philippe Ricard, "Paris approves the building of Russian-led nuclear reactors in Hungary", *Le Monde*, 28 April 2023, see https://www.lemonde.fr/en/international/article/2023/04/28/in-hungary-paris-is-willing-to-help-build-russian-led-nuclear-reactor_6024637_4.html, accessed 5 June 2023.

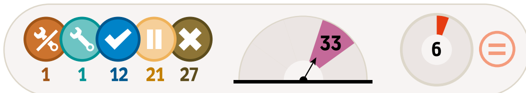
279 - *Power Technology*, "EDF signs agreement to acquire GE Steam Power's nuclear activities", 7 November 2022, see https://www.power-technology.com/news/edf-ge-steam-powers-nuclear/, accessed 2 August 2023.

280 - *WNN*, "General Electric wins turbine contract for Paks II", 17 January 2018, see https://world-nuclear-news.org/Articles/General-Electric-wins-turbine-contract-for-Paks-II, accessed 2 August 2023.

281 - EDF, "EDF acquires GE Steam Power's nuclear activities from GE Vernova", Press Release, 31 May 2024, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/edf-acquires-ge-steam-powers-nuclear-activities-from-ge-vernova, accessed 1 June 2024.

In March 2023, Szijjártó had suggested bringing Russian suppliers into the mix if Framatome failed to "take over leadership of the [Franco-German] consortium."[282] Reportedly, the Hungarian Government had been working on sidelining Siemens to cooperate solely with Framatome.[283] However, when attending the opening of a new gas-turbine component manufacturing facility of Siemens Energy in late May 2024 in Budapest, Minister Szijjártó said, in a surprise announcement, that the company would indeed be delivering command-and-control equipment to the Paks II plant.[284] Siemens neither confirmed nor denied this. After the announcement of the project's exemption from future E.U. sanctions, Paks II CEO Gergely Jákli was quoted as saying in June 2024 that he was "certain that Siemens Energy will [...] fulfill its contractual obligations," albeit noting that Germany's Federal Office for Economic Affairs and Export Control might still block the export.[285] In late 2023, Siemens Energy Supervisory Board Chairman Joe Kaeser had warned of damages having to be paid to Rosatom if delivery contracts were to be broken.[286] Other issues regarding the transportation of components, originally planned via Ukraine, the hiring of skilled labor, and the cooperation of German, French, and Russian workers put additional pressure on the Paks II project.[287]

JAPAN FOCUS



Overview

During Financial Year (FY) 2023, which runs from April 2023–March 2024, Japan operated 12 reactors with a capacity of 11.6 GW (gross).[288] The average load factor for the entire Japanese nuclear fleet (including reactors not currently operating) has improved from 18.7 percent in 2022 to 28 percent in 2023 (calendar years).[289] The total nuclear power generation increased by 49 percent, from 51.9 TWh in 2022 to 77.5 TWh in 2023, mainly due to the restart of two

282 - *NEI Magazine*, "France or Russia to provide equipment to Paks-II if Germany refuses", 3 March 2023, see https://www.neimagazine.com/news/newsfrance-or-russia-to-provide-equipment-to-paks-ii-if-germany-refuses-10648100, accessed 28 July 2023.

283 - Dániel Deme, "Government to Side-Step Siemens in Another Blow for German Industry", *Hungary Today*, 8 June 2023, see https://hungarytoday.hu/government-to-side-step-siemens-in-another-blow-for-german-industry/, accessed 28 July 2023.

284 - Rainer Ackermann, "Dual und in Paks dabei", *Budapester Zeitung / The Budapest Times*, 25 May 2024 (in German), see https://www.budapester.hu/?p=70917, accessed 30 May 2024.

285 - Sarkadi-Illyés Csaba, "Arccal nyugat felé: Paks II. túléli az orosz-ukrán háborút", *Economx.hu*, 26 June 2024 (in Hungarian), see https://www.economx.hu/belfold/paks-ii-jakli-gergely-oroszorszag-szankcio-atomenergia.792002.html, accessed 30 June 2024.

286 - Rainer Ackermann, "Wird Vertragsbruch teuer für Siemens?", *Budapester Zeitung / The Budapest Times*, 1 November 2023 (in German), see https://www.budapester.hu/ausland/wird-vertragsbruch-teuer-fuer-siemens/, accessed 30 May 2024.

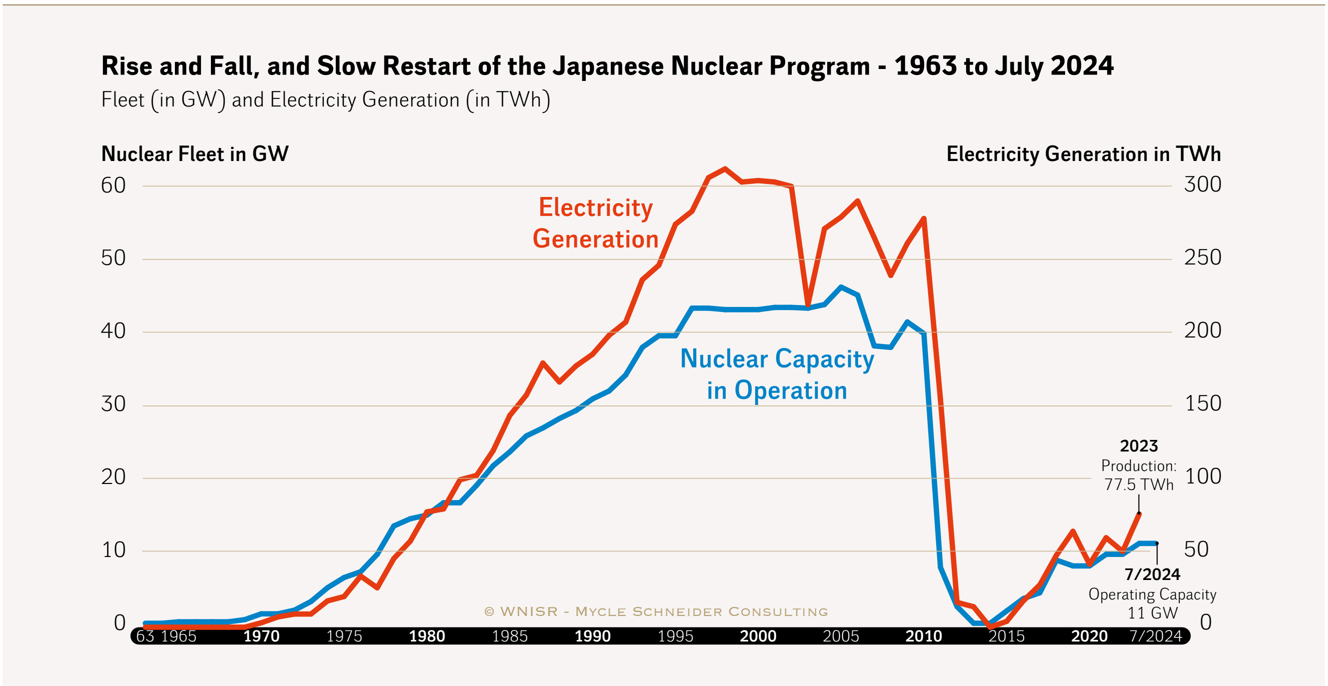
287 - Nick Thorpe, "Hungary's risky bet on Russia's nuclear power", *BBC News*, 15 December 2022, see https://www.bbc.com/news/world-europe-63964744, accessed 17 December 2022.

288 - JAIF, "日本の原子力発電炉（運転中、建設中、計画中など）", Japan Atomic Industrial Forum, as of 8 May 2024 (in Japanese), see https://www.jaif.or.jp/cms_admin/wp-content/uploads/2024/05/jp-npps-operation20240508.pdf; and JAIF, "Current Status of Nuclear Power Plants in Japan", as of 8 May 2024, see https://www.jaif.or.jp/cms_admin/wp-content/uploads/2024/05/jp-npps-operation20240508_en.pdf; accessed 12 July 2024.

289 - Ibidem.

reactors. However, the share of nuclear power in the total power generation fell slightly from 6.1 percent in 2022 to 5.6 percent in 2023 (see Figure 37).[290]

Figure 37 · Rise and Fall, and Slow Restart of the Japanese Nuclear Program



Sources: WNISR with IAEA-PRIS, 2024

The current reactor fleet consists of 33 units (33.1 GW gross) of which 25 units (24.8 GW gross) have applied for operating licenses under the new post-Fukushima regulations.[291] So far, new licenses have been granted for 17 units while eight applications remain under review. The Nuclear Regulation Authority (NRA) did not issue any new operating licenses during the past year.

As of 1 July 2024, twelve reactors were in operation (Ikata-3, Genkai-3 & -4, Mihama-3, Ohi-3 & -4, Sendai-1 & -2, Takahama 1–4), of which one was shut down from 27 March to 3 June 2024 for periodic inspections (Genkai-4),[292] and 21 reactors were in Long-Term Outage (LTO).[293] In 2022, the IAEA adopted a new category called "Suspended Operation" to which it reclassified 21 reactors that WNISR considers to be in LTO. In other words, Japan and the IAEA have adopted an approach similar to the LTO concept that WNISR introduced in 2014. (See Figure 38).

290 - PRIS Country statistics Japan, IAEA, see https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=JP, accessed 22 July 2024.

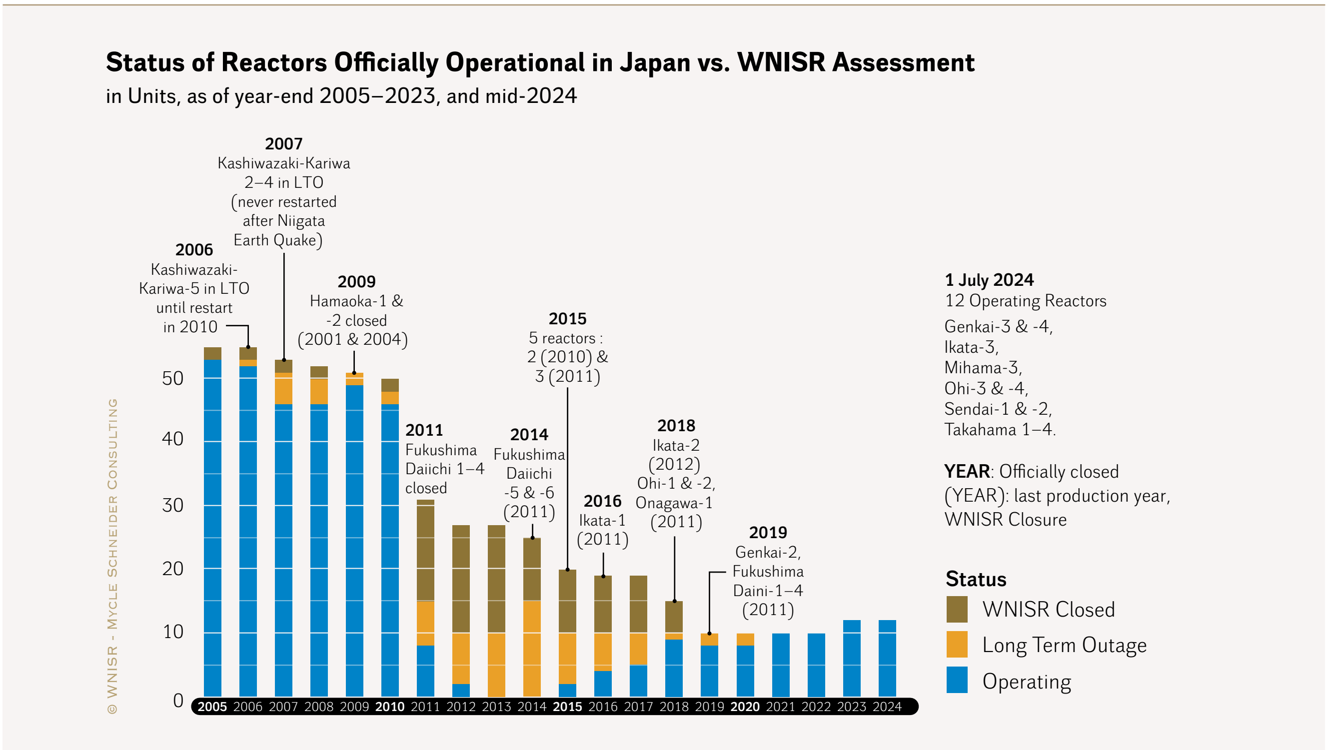
291 - JAIF, "日本の原子力発電炉（運転中、建設中、計画中など）" and "Current Status of Nuclear Power Plants in Japan", as of 8 May 2024, op. cit.

292 - Kyushu Electric Power Company "玄海原子力発電所4号機は通常運転に復帰しました" ["Genkai Nuclear Power Plant Unit 4 has returned to normal operation"], Press Release (in Japanese), 28 June 2024, see https://www.kyuden.co.jp/press_240628b-1.html, accessed 14 July 2024. Regular inspection of Genkai Unit 4 started on 27 March 2024, and power generation resumed on 3 June. Output was gradually increased until, on 28 June 2024, Kyushu Electric Power completed all verification work and resumed normal operation.

293 - WNISR considers a nuclear reactor in Long-Term Outage or LTO if it has not generated any electricity in the previous calendar year and in the first half of the current calendar year. It is withdrawn from operational status retroactively from the day it was disconnected from the grid.

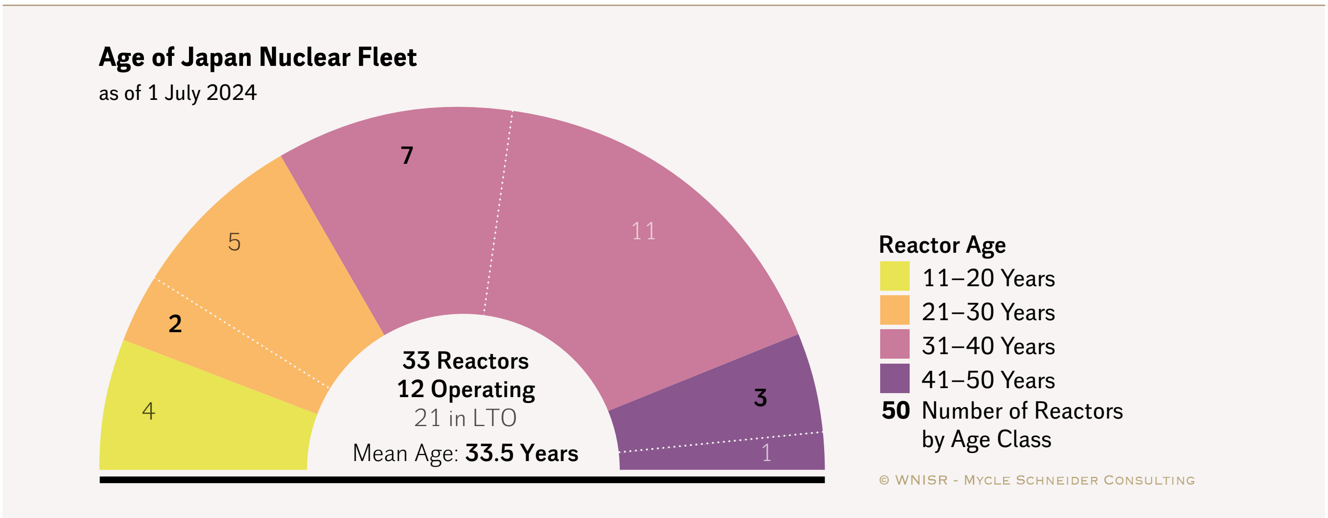
Thirteen years after the Fukushima accidents were triggered, the reactors in operation are all Pressurized Water Reactors (PWRs) although five Boiling Water Reactors (BWRs), i.e., Kashiwazaki-Kariwa-6 & -7, Tokai-2, Onagawa-2, and Shimane-2, have passed NRA's new regulatory requirements set in 2013.

Figure 38 • Status of the Japanese Reactor Fleet



Sources: Various, compiled by WNISR, 2024

Figure 39 • Age Distribution of the Japanese Nuclear Fleet



Sources: WNISR with IAEA-PRIS, 2024

As of mid-2024, the Japanese nuclear fleet consisting of 33 units including 21 in LTO had reached a mean age of 33.5 years, with 22 units over 31 years (see Figure 39).

Nuclear Power Plant Restarts and Earthquakes in Japan

The Noto Peninsula earthquake, which occurred on 1 January 2024, recorded magnitude 7.6 (maximum intensity seven based on the Japanese Meteorological Agency's scale),[294] and caused enormous damages in the area. The Hokuriku Electric Power Company-run Shika Nuclear power station, which has been shut down since 2011, was also affected. The plant's transformers were damaged, and it lost external power supply, although the supplemental power lines remained operational; however, no serious damage immediately identifiable occurred at the plant.[295] The actual cause of the damages to the transformers has not been identified yet.

The Shika Nuclear power station has two Boiling Water Reactors (BWRs). Shika-1 is relatively small with 505 MW (net) capacity, and Shika-2 has a reference unit capacity of 1108 MW.[296] In the vicinity of the site, seven out of the eleven roads designated as evacuation routes in the event of a serious accident involving significant radioactivity releases were closed following the earthquake due to collapses and cracks.[297] The effectiveness of the evacuation plan came into question (see Nuclear Energy in Japan in View of the Noto Peninsula Earthquake below).

On 27 December 2017, Tokyo Electric Power Co.'s (TEPCO) Kashiwazaki-Kariwa-6 and -7 became the first BWRs to pass the conformity test with the new regulatory requirements from NRA. The NRA decided at a meeting on 27 December 2023 to lift an administrative order that prohibited TEPCO from moving nuclear fuel or loading it into reactors after the company had committed nuclear security violations in 2021.[298] TEPCO started fuel loading at the idled Unit 7 on 15 April 2024. All 872 nuclear fuel assemblies were transferred to the reactor by 26 April. It now needs the local governor's approval to resume operation while residents are concerned about the effectiveness of the evacuation plan at the Kashiwazaki-Kariwa nuclear power plant in the aftermath of the Noto Peninsula earthquake.[299]

Tohoku Electric Power Co.'s Onagawa-2 will likely be the first BWR to resume operation since the Fukushima accidents started unfolding. It received the NRA's official approval of conformity to new regulatory requirements on 26 February 2020, and work on outstanding safety

294 - The scale is from "0", at which "people do not feel any shaking", to "7", at which "furniture that is not fixed in place will move or fall over or even be thrown by the earthquake"; see Geospatial Information Authority of Japan, "Earthquake information : Explanation of the seismic intensity", as published by Japan Meteorological Agency, Undated, see https://www.data.jma.go.jp/multi/quake/quake_advisory.html?lang=en, accessed 22 August 2024.

295 - Yuka Obayashi, "Japan's Hokuriku Elec reports second oil leak from Shika nuclear plant", *Reuters*, 10 January 2024, see https://www.reuters.com/world/asia-pacific/japans-hokuriku-elec-reports-second-oil-leak-shika-nuclear-plant-2024-01-10/, accessed 3 June 2024.

296 - IAEA-PRIS, "Country Statistics–Shika-1", Power Reactor Information System, International Atomic Energy Agency, Updated 21 August 2024, see https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=375; and IAEA-PRIS, "Country Statistics—Shika-2", 21 August 2024, see https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=842; both accessed 21 August 2024.

297 - *Kyodo News*, "志賀原発の避難道路、過半が寸断 能登地震で7路線、実効性揺らぐ" ["Evacuation road for Shika Nuclear Power Plant cut off, 7 routes shaken by Noto quake"], as published on *47News*, 30 January 2024 (in Japanese) see https://www.47news.jp/10463358.html, accessed 3 May 2024.

298 - *WNN*, "NRA lifts ban on Kashiwazaki-Kariwa fuel activities", *World Nuclear News*, 2 January 2024, see https://www.world-nuclear-news.org/Articles/NRA-lifts-ban-on-Kashiwazaki-Kariwa-fuel-activitie, accessed 3 May 2024.

299 - *NHK News*, "柏崎刈羽原発 長岡市長 '住民の不安解消を' 再稼働の判断で'", *Japan Broadcasting Corporation*, 17 April 2024 (in Japanese) see https://www3.nhk.or.jp/lnews/niigata/20240417/1030029030.html, accessed 3 May 2024.

measures was completed in May 2024.[300] Operation is planned to restart in September 2024.[301] Chugoku Electric Power Co.'s Shimane-2 received approval from NRA to restart operation on 15 September 2021 and from the local governor in June 2022.[302] But in April 2024, because of delay in safety related work, Chugoku Electric Power announced that it will postpone the restart of operation until December 2024.[303]

Japan Atomic Power Co.'s (JAPC) Tokai-2 was the first BWR to get an extension (from 40 to 60 years) approval from NRA in November 2018, but currently the construction of a Specialized Safety Facility (SSF) against terrorist attacks is underway. Mamoru Muramatsu, president of JAPC said at a press conference in March 2024 that it would be difficult to complete the safety measures by September 2024 as planned.[304]

Kansai Electric Power Co. (KEPCO) owns the largest number of reactors (seven PWRs), all of which are currently operating (as of mid-2024). This is the first time in 15 years since February 2009 that all of KEPCO's operational reactors are put into operation.[305] Takahama-1 and Takahama-2 were restarted on 4 August and 20 September 2023, respectively, after NRA approved both reactors' operating license extension from 40 to 60 years on 20 June 2016.[306] On 25 April 2023, KEPCO applied for license extension beyond 40 years for Takahama-3 and -4. On 29 May 2024, they were granted a license extension of 20 years (from 40 to 60 years).[307]

On 22 January 2024, Takahama-1's electric output was reduced to 40 percent due to a steam leak from a pump in the turbine building.[308] Takahama-1 was shut down for regular inspection on 31 May 2024.[309]

Takahama-2 applied for a 10-year safety management plan, required under its operating license extension beyond 40 years, on 19 July 2024.[310] Takahama-3 was shut down on 18 September 2023

300 - *NHK*, "女川原発2号機 安全対策工事完了を発表 東北電力", *Japan Broadcasting Corporation*, 27 May 2024 (in Japanese), see https://www3.nhk.or.jp/news/html/20240527/k10014462331000.html accessed 28 May 2024.

301 - Tohoku Electric Power Company, "女川原子力発電所２号機における安全対策工事完了時期の見直しについて" ["Revision of the timing of completion of safety measures at Onagawa Nuclear Power Plant Unit 2"], 19 February 2024 (in Japanese), see https://www.tohoku-epco.co.jp/news/atom/1239390_2549.html, accessed 3 May 2024.

302 - *The Asahi Shimbun*, "Governor of Shimane agrees to restart idled nuclear reactor", 2 June 2022, see https://www.asahi.com/ajw/articles/14635842, accessed 27 June 2023.

303 - *NHK*, "島根原発2号機 再稼働 ことし12月に延期 安全対策工事が長期化", *Japan Broadcasting Corporation*, 30 April 2024 (in Japanese), see https://www3.nhk.or.jp/news/html/20240430/k10014436561000.html, accessed 3 May 2024.

304 - *NHK*, "東海第二原発 安全対策工事 "９月までの完成厳しい"", *Japan Broadcasting Corporation*, 29 March 2024 (in Japanese), see https://www3.nhk.or.jp/lnews/mito/20240329/1070023780.html, accessed 4 May 2024.

305 - *The Asahi Shimbun*, "高浜原発4号機が起動へ 福井の全7基「フル稼働」、福島の事故後初", 22 April 2024 (in Japanese), see https://www.asahi.com/articles/ASS4Q334TS4QPGJB00HM.html, accessed 10 May 2024.

306 - JAIF, "日本の原子力発電炉（運転中、建設中、計画中など）" and "Current Status of Nuclear Power Plants in Japan", as of 8 May 2024, op. cit.

307 - KEPCO, "高浜発電所３、４号機の運転期間延長認可" ["Approved extension of operation period for Takahama Power Station Units 3 and 4"], Press Release (in Japanese), Kansai Electric Power Co,29 May 2024, see https://www.kepco.co.jp/corporate/pr/2024/pdf/20240529_2j.pdf, accessed 26 July 2024.

308 - KEPCO, "高浜発電所１号機の出力降下について" ["Concering power output decrease at Takahama No.1 unit"], Press Release (in Japanese), 22 January 2024, see https://www.kepco.co.jp/corporate/pr/2024/pdf/20240122_1j.pdf, accessed 26 July 2024.

309 - KEPCO, "高浜発電所１号機の定期検査開始" ["Periodic inspection of Takahama Power Station Unit 1 begins"], Press Release (in Japanese), 31 May 2024, see https://www.kepco.co.jp/corporate/pr/2024/pdf/20240531_1j.pdf, accessed 26 July 2024.

310 - KEPCO, "高浜発電所２号機の４０年以降運転における―長期施設管理計画の認可申請" ["Application for Approval of Long-Term Facility Management Plan for Takahama Power Station Unit No. 2 in Operation beyond 40 Years"], Press Release (in Japanese), 19 July 2024, see https://www.kepco.co.jp/corporate/pr/2024/pdf/20240719_1j.pdf, accessed 22 August 2024.
Note: after regulatory changes in 2023, operators must apply for a long-term facility management program for the safety assessment of facilities every 10 years after lifetime extension.

for a periodic inspection. It resumed commercial operation on 23 January 2024.[311] Takahama-4 was shut down on 16 December 2023 for a periodic inspection, during which steam generator tube damage was confirmed on 22 January 2024.[312] It resumed power generation on 26 April 2024 and commercial operation on 21 May 2024.[313]

On 26 July 2024, the NRA in effect rejected JAPC's request to restart Tsuruga-2, noting that it does not meet new safety rules established after the Fukushima nuclear accident. The main issue was whether the utility can prove there is no geological fault underneath the plant, and the NRA concluded that the utility's explanation lacked concrete evidence to prove the absence of a fault.[314]

This is the first time the NRA effectively declined to approve a license application because it did not satisfy the new regulatory standards. JAPC's Mamoru Muramatsu said that his company will conduct additional research and had not given up on restarting the unit.[315]

Kyushu Electric Power Co. applied for a 20-year license extension beyond 40 years for Sendai-1 and -2 on 12 October 2022. Their respective licenses would have expired on 3 July 2024 and 27 November 2025. The NRA approved the 20-year lifetime extension of both reactors on 1 November 2023.[316]

As no additional reactor has been declared for permanent closure during the past year, the total number of closed reactors remains unchanged at 27, including 21 units closed as a consequence of the Fukushima accidents (see Table 7 for details).

Legal Cases Against the Restart of Reactors

Various legal cases against the operation of existing reactors continue. The following are two key decisions made during the past year, both of which rejected local residents' appeals for injunction to halt aging reactors.

On 15 March 2024, Osaka High Court rejected a petition to close Unit 3 of Kansai Electric Power Co.'s Mihama nuclear plant in Fukui Prefecture, reportedly saying that there would be "no concrete danger" that these reactors could trigger a serious accident. The petition was filed by seven residents of Fukui as well as nearby Shiga and Kyoto who claimed that "safety measures for the reactor, which has passed 40 years since becoming operational, are inadequate." But the

311 - KEPCO, "高浜発電所３号機の本格運転再開について" ["Resumption of Full-Scale Operation of Takahama Power Station Unit 3"], Press Release (in Japanese), 23 January 2024, see https://www.kepco.co.jp/corporate/pr/2024/pdf/20240123_1j.pdf, accessed 22 August 2024.

312 - KEPCO, "高浜発電所４号機の蒸気発生器伝熱管損傷について" ["Damage to Steam Generator Heat Transfer Tube at Takahama Power Station Unit 4"], Press Release (in Japanese), 22 January 2024, see https://www.kepco.co.jp/corporate/pr/2024/pdf/20240122_2j.pdf, accessed 22 August 2024.

313 - KEPCO, "高浜発電所４号機の本格運転再開について" ["Resumption of Full-Scale Operation of Takahama Power Station Unit 4"], Press Release (in Japanese), 21 May 2024, see https://www.kepco.co.jp/corporate/pr/2024/pdf/20240521_1j.pdf, accessed 22 August 2024.

314 - Nanako Takehara, "JAPC Continues Efforts Toward Restarting Tsuruga-2", Japan Atomic Industrial Forum, 6 August 2024, see https://www.jaif.or.jp/en/news/7156, accessed 22 August 2024.

315 - *Kyodo News*, "Japan regulator blocks plan to restart Tsuruga nuclear unit", 26 July 2024, see https://english.kyodonews.net/news/2024/07/23409b0dee11-update1-japan-regulator-blocks-plan-to-restart-tsuruga-nuclear-unit.html, accessed 4 August 2024.

316 - *Jiji Press*, "Japan's NRA OKs Extension of Sendai N-Reactor Lifetimes", as published by *The Japan News/The Yomiuri Shimbun*, 1 November 2023, see https://japannews.yomiuri.co.jp/business/companies/20231101-147097/, accessed 4 May 2024.

judge rejected such appeal, saying "no proper documents have been identified indicating that the faults could cause quakes involving major changes in the land surface."[317]

On 29 March 2024, Fukui District Court rejected petitions to suspend operation of aging nuclear reactors at KEPCO's Mihama and Takahama plants in Fukui Prefecture. Local residents claimed in the petitions that safety measures for Mihama-3 and Takahama-1 to -4 were inadequate. The plaintiffs claimed that the earthquake ground motions taken into account in the design basis for the Mihama and Takahama plants would be too low, considering past earthquakes observed in Japan. According to *The Japan Times*, "Presiding Judge Yasushi Kato pointed out that it is necessary to fully consider regional differences when evaluating earthquake ground motions, and found no problems with KEPCO's survey or the Nuclear Regulation Authority's (NRA) screening."[318]

Reactor Closures, Spent Fuel Management, and HLW Disposal Plan

No additional reactors operating or in outage at the time of the Fukushima events were formally declared for decommissioning in the year to 1 July 2024. The eleven commercial Japanese reactors now confirmed to be decommissioned (not including the Monju Fast Breeder Reactor and the ten Fukushima reactors) had a total generating capacity of 6.4 GW, representing about 15 percent of Japan's official operating nuclear capacity as of March 2011. Together with the ten Fukushima units, the 21 units totaled 15.2 GW or just under 35 percent of nuclear capacity prior to 3/11 (see Figure 38 and Table 7). In total, including units closed prior to 3/11, as of mid-2024, Japan has 27 closed reactors (27.1 GW) (see Japan in Decommissioning Status Report).

Regarding spent fuel management, on 24 April 2024, Chugoku Electric Power Co. began a drilling survey to investigate the geology of the planned construction site of an interim spent-fuel storage facility in Kaminoseki town, Yamaguchi Prefecture. Chugoku Electric Power Co. and KEPCO plan to apply for a construction permit from the municipal government if the site is found to be suitable and jointly build and operate the facility.[319] The preselected site was originally chosen for the construction of a nuclear power plant, but Chugoku Electric suspended work on that in 2011 due to nuclear safety concerns following the Fukushima Daiichi disaster.[320] In August 2023, the Kaminoseki municipal government permitted Chugoku Electric to conduct a survey for the construction of a joint storage facility.[321]

KEPCO was looking for a place to store spent nuclear fuel, but it was difficult to find one. As a condition for the operation of Mihama-3 and Takahama-1 and -2, which have been in operation for more than 40 years, the company promised the governor of Fukui Prefecture that it would finalize a candidate site for storage outside Fukui Prefecture by the end of 2023. The joint

317 - *Jiji Press*, "High Court Rejects Petition to Halt Aging Kansai Electric Reactor", 15 March 2024, see https://sp.m.jiji.com/english/show/31847, accessed 10 May 2024.

318 - *Jiji Press*, "Court rejects petitions to halt aging Kansai electric reactors", as published by *The Japan Times*, 29 March 2024, see https://www.japantimes.co.jp/news/2024/03/29/japan/crime-legal/court-rejects-petitions-to-halt-reactors/, accessed 10 March 2024.

319 - *Jiji Press*, "Drilling survey starts in Yamaguchi town for nuclear facility", as published by *The Japan Times*, 24 April 2024, see https://www.japantimes.co.jp/news/2024/04/24/japan/yamaguchi-town-drilling-survey-nuclear-fuel/, 15 May 2024.

320 - *The San-in Chuo Shimpo*, " 論説 上関に中間貯蔵計画 一時しのぎでいいのか" ["Is the interim storage plan in Kaminoseki a temporary stopgap?"], 7 August 2024 (in Japanese), see https://www.sanin-chuo.co.jp/articles/-/429888, accessed 3 June 2024.

321 - *The Japan News*, "Yamaguchi Town OK's Survey for Spent Nuclear Fuel Interim Storage Facility", *The Yomiuri Shimbun*, 18 August 2023, see https://japannews.yomiuri.co.jp/society/general-news/20230818-130505/, accessed 13 July 2024.

development with KEPCO was proposed by Chugoku Electric in place of constructing a nuclear power plant.[322]

At KEPCO's three nuclear plants in Fukui Prefecture (Mihama, Takahama, and Ohi), storage pools for spent nuclear fuel are expected to be saturated over the next few years. According to a projection made by the Federation of Electric Power Companies in January 2024, the Takahama site will reach 100 percent of its operational capacity in only four years, while the Mihama and Ohi plants are expected to reach 90 percent and 98 percent of their respective spent-fuel storage capacities in five years.[323]

KEPCO had promised the prefecture to find a candidate site for a temporary dry storage facility by the end of 2023 and that should it fail to do so, it would halt operation of three aging reactors in Fukui Prefecture: Mihama-3, Takahama-1 and -2.[324]

On 12 June 2023, KEPCO told the Fukui Governor that the company plans to ship 200 tons of spent nuclear fuel from its Takahama plant to France in the late 2020s for demonstration purposes of reprocessing of spent MOX fuel by the early 2030s.[325] However, while representing a large amount for a test, the 200 tons account for only about 5 percent of all spent nuclear fuel at Kansai Electric's Takahama, Mihama, and Ohi nuclear power plants.[326]

In October 2023, KEPCO submitted the Roadmap for Spent-fuel Measures to Fukui Prefecture and its plan to build dry cask storage facilities at the three nuclear power plants. On 8 February 2024, KEPCO submitted to Fukui Prefecture and the municipalities of Mihama, Takahama, and Ohi the request to build storage facilities at all three sites. According to the plan, KEPCO is aiming at a total of about 2,000 tons of spent-fuel storage capacity by 2030.[327] For KEPCO, securing an interim storage facility for spent fuel is a pre-condition for the operation of its reactors. On 15 March 2024, Fukui Prefecture approved Kansai Electric Power's application to the central government for the installation of dry cask storage facilities.[328]

On 29 July 2024, Aomori Governor, Soichiro Miyshita, former Mayor of Mutsu City and son of late Mayor Junichiro Miyashita who decided to host an interim spent-fuel storage facility, agreed to sign the "Safety Agreement" with the Recyclable-Fuel-Storage Co. This opened the opportunity for Mutsu City to start accepting spent fuel from JAPC and TEPCO. In March 2025, TEPCO will start sending spent fuel from its Kashiwazaki-Kariwa plant to the Mutsu facility.

322 - Tokyo Shimbun, "「原発マネー」で生まれた奇策　使用済み核燃料の中間貯蔵施設を上関町に　中国電力と関西電力で苦肉の共同開発案" ["Chugoku Electric Power Co. and Kansai Electric Power Co. have proposed the bitterly contested joint development of an interim storage facility for spent nuclear fuel in Kaminoseki Town, a scheme born of 'nuclear power money'"], 3 August 2023 (in Japanese), see https://www.tokyo-np.co.jp/article/267439, accessed 23 July 2024.

323 - JAIF, "Kansai EP to Install Dry Spent Fuel Storage Facilities at All Its NPP Sites", Japan Atomic Industrial Forum, 19 February 2024, see https://www.jaif.or.jp/en/news/6908, accessed 4 June 2024.

324 - *Tokyo Shimbun*, "「原発マネー」で生まれた奇策　使用済み核燃料の中間貯蔵施設を上関町に　中国電力と関西電力で苦肉の共同開発案", 3 August 2023, op. cit.

325 - *Nihon Keizai Shimbun* "関西電力、使用済みMOX燃料を福井県外に 仏で再処理" ["KEPCO transported spent MOX fuel out of the prefecture. Outsourced reprocessing to France"], 12 June 2023 (in Japanese), see https://www.nikkei.com/article/DGXZQOUF128AL0S3A610C2000000/, accessed 3 June 2024.

326 - *The Asahi Shimbun*, "Kansai Electric takes heat for half-truths over spent nuke fuel", 29 June 2023, see https://www.asahi.com/ajw/articles/14944345, accessed 15 May 2024.

327 - JAIF, "Kansai EP to Install Dry Spent Fuel Storage Facilities at All Its NPP Sites", 19 February 2024, op. cit.

328 - *NHK*, "関西電力「乾式貯蔵施設」　県が設置に向けた国への申請を了承 ["Fukui Prefecture approved that Kansai Electric Power will apply to the central government for building dry cask storage facilities"], 15 March 2024, see https://www3.nhk.or.jp/lnews/fukui/20240315/3050017306.html, accessed 31 July 2024.

This deal will bring the city more than ¥300 million (US$1.9 million) by March 2029 through a spent-fuel storage tax of ¥620/kg (US$4/kg).[329]

On 23 September 2023, the Mayor of Tshuhima City in Nagasaki, Naoki Hitakatsu, made it clear that the city will not accept a literature survey to determine whether it is suitable to host a final disposal site for high-level radioactive waste from nuclear power plants. He expressed concern that it may divide the citizens between "for" and "against" the plan.[330] In addition, he was also concerned that the project may harm their tourism, agricultural, and fishing industries.

On the other hand, according to *The Japan Times*, on 10 May 2024, Mayor Shintaro Wakiyama of Genkai Town, Saga Prefecture said that the town would accept a literature survey, after the town assembly approved a petition by a local business group.[331] On 10 June 2024, NUMO (Nuclear Waste Management Organization) started the survey in Genkai Town.[332] After the town of Suttsu and the village of Kamoenai, both in Hokkaido Prefecture, Genkai has become the third municipality in the country to accept such a survey, the first step in the process of selecting a final disposal site. Genkai Town is also host to Kyushu Electric Power's Genkai nuclear power plant, and it is the first municipality to accept a literature survey for HLW disposal. In order to facilitate literature surveys, the central government provides up to ¥2 billion (US$12.8 million) over two years to municipalities accepting a survey.[333]

329 - Yusuke Noda and Teruto Unuma, "Aomori governor OK nuclear waste storage first of its kind", *The Asahi Shimbun*, 29 July 2024, see https://www.asahi.com/ajw/articles/15366939, accessed 4 August 2024.

330 - *NHK*, ""核のごみ" 処分地調査受け入れず 長崎 対馬市長が表明" ["Mayor of Tshushima city of Nagasaki said, the City will not accept the survey"], 27 September 2023, see https://www3.nhk.or.jp/news/html/20230927/k10014207821000.html, accessed 13 July 2024.

331 - *The Japan Times*, "Genkai Mayor decides to accept nuclear waste site survey", 10 May 2024, see https://www.japantimes.co.jp/news/2024/05/10/japan/genkai-nuclear-waste-survey/, accessed 15 May 2024.

332 - Nanako Takehara, "NUMO Starts Literature Survey at Genkai Town for HLW Disposal", Japan Atomic Industrial Forum, 21 June 2024, see https://www.jaif.or.jp/en/news/7111, accessed 26 July 2024.

333 - *The Japan Times*, "Genkai Mayor decides to accept nuclear waste site survey", 10 May 2024, op. cit.

Table 7 · Official Reactor Closures Post-3/11 in Japan (as of 1 July 2024)

Operator	Reactor	Capacity MW	Startup Year	Closure Announcement[(a)] dd/mm/yy	Official Closure Date[(b)] dd/mm/yy	Last Production	Age[(c)]
TEPCO	Fukushima Daiichi-1 (BWR)	439	1970	-	19/04/12	2011	40
	Fukushima Daiichi-2 (BWR)	760	1973	-	19/04/12	2011	37
	Fukushima Daiichi-3 (BWR)	760	1974	-	19/04/12	2011	36
	Fukushima Daiichi-4 (BWR)	760	1978	-	19/04/12	2011	33
	Fukushima Daiichi-5 (BWR)	760	1977	19/12/13	31/01/14	2011	34
	Fukushima Daiichi-6 (BWR)	1 067	1979	19/12/13	31/01/14	2011	32
	Fukushima Daini-1 (BWR)	1 067	1981	31/07/19	30/09/19	2011	30
	Fukushima Daini-2 (BWR)	1 067	1983	31/07/19	30/09/19	2011	28
	Fukushima Daini-3 (BWR)	1 067	1984	31/07/19	30/09/19	2011	26
	Fukushima Daini-4 (BWR)	1 067	1986	31/07/19	30/09/19	2011	24
KEPCO	Mihama-1 (PWR)	320	1970	17/03/15	27/04/15	2010	40
	Mihama-2 (PWR)	470	1972	17/03/15	27/04/15	2011	40
	Ohi-1 (PWR)	1 120	1977	22/12/17	01/03/18	2011	34
	Ohi-2 (PWR)	1 120	1978	22/12/17	01/03/18	2011	33
KYUSHU	Genkai-1 (PWR)	529	1975	18/03/15	27/04/15	2011	37
	Genkai-2 (PWR)	529	1980	13/02/19	13/02/19	2011	31
SHIKOKU	Ikata-1 (PWR)	538	1977	25/03/16	10/05/16	2011	35
	Ikata- 2 (PWR)	538	1981	27/03/18	27/03/18	2012	30
JAEA	Monju (FBR)	246	1995	12/2016[(d)]	06/12/17	LTS[(e)] since 1995	-
JAPC	Tsuruga -1 (BWR)	340	1969	17/03/15	27/04/15	2011	41
CHUGOKU	Shimane-1 (PWR)	439	1974	18/03/15	30/04/15	2010	37
TOHOKU	Onagawa-1 (BWR)	498	1983	25/10/18	21/12/18	2011	27
TOTAL: 22 Reactors /15.5 GWe							

Sources: JAIF and JANSI, compiled by WNISR, 2024

Notes: This table only lists the 22 reactors closed after the Fukushima accidents, thus not including the Fugen Advanced Thermal Reactor (ATR), Japan Power Demonstration Reactor (JPDR), as well as Hamaoka-1 & -2 (Chubu Electric Power) and Tokai-1 (JAPC).

BWR: Boiling Water Reactor; **PWR**: Pressurized Water Reactor; **FBR**: Fast Breeder Reactor; **LTS**: Long-Term Shutdown (former IAEA category).

JAPC: Japan Atomic Power Company; **JAEA**: Japan Atomic Energy Commission.

(a) – Unless otherwise specified, all announcement dates from JANSI, "Licensing status for the Japanese nuclear facilities", Japan Nuclear Safety Institute, as of 15 September 2023, see http://www.genanshin.jp/english/facility/map/, accessed 13 July 2024.

(b) – Unless otherwise specified, all closure dates from individual reactors' page via JAIF, "NPPs in Japan", Japan Atomic Industrial Forum, as of 13 July 2024, see http://www.jaif.or.jp/en/npps-in-japan, accessed 13 July 2024.

(c) – Note that WNISR considers the age from first grid connection to last production day.

(d) – *The Mainichi*, "Japan decides to scrap trouble-plagued Monju prototype reactor", 21 December 2016.

(e) – The Monju reactor was officially in Long-Term Shutdown or LTS (former IAEA-Category) since December 1995. Officially closed in 2017.

Nuclear Energy in Japan in View of the Noto Peninsula Earthquake

The Noto Peninsula earthquake, which occurred on 1 January 2024, recorded magnitude 7.6 and caused enormous damage to the local community. Hokuriku Electric Power Company's Shika nuclear power station, which had been shut down since 2011, was also affected. Impacts included damaged transformers and external electricity supply interruption. The earthquake-induced events in this power plant once again highlight the particular problems of nuclear energy use in Japan.

The main issue is that the shaking exceeded anticipated levels, including in the vicinity of the Shika nuclear power plant. The recorded earthquake exceeded the "current reference seismic motion" of 600 gal for an instant (0.47 second) but remained below the reference seismic motion of 1,000 gal that the plant was to be protected against based on the new regulatory standards of 2014.[334]

Due to the earthquake's impact, two external power supply transformers for Units 1 and 2 at the Shika plant were damaged. Specifically, one transformer for Unit 2 was reported to have leaked approximately 19,800 liters of oil, although it was originally reported to be 3,500 liters, rendering that portion of the external power supply system inoperable.[335] Initially, the NRA said there was no safety problem as other power supply lines remained operable,[336] but an NRA committee member stated that the magnitude of the earthquake was extremely large and that the results of further expert research on the quake must be used in future assessments.[337]

Another serious problem is the approach to evacuation of residents when serious accidents occur. In the vicinity of this nuclear power plant, eleven national highways and prefectural roads have been designated as evacuation routes in the event that serious accidents such as leakages of radioactive substances occur. Of those, seven routes were closed following the Noto Peninsula earthquake due to collapses and cracks. The events placed doubts on the effectiveness of the evacuation plan. Reportedly, NRA is considering a "review of the guidelines".[338]

In the wake of the Noto Peninsula earthquake, ongoing discussions to restart TEPCO's Kashiwazaki-Kariwa nuclear power plant were met with concerns in the Niigata Prefecture, where local governments questioned the effectiveness of the evacuation plan in the event of a complex disaster such as a major earthquake.[339]

334 - Hokuriku Electric Power Company, "志賀原子力発電所に関するご質問、設備状況" ["Questions about the current situation of the Shika Nuclear Power Plant"], 2024 (in Japanese), see https://www.rikuden.co.jp/outline1/shika_qa.html, accessed 3 June 2024.

335 - Hokuriku Electric Power Company, "令和６年能登半島地震による志賀原子力発電所の影響について（第５報）" ["Effects of the 2024 Noto Peninsula Earthquake on Shiga Nuclear Power Station (5th Report)"], Press Release (in Japanese), 5 January 2024, see https://www.rikuden.co.jp/press/attach/24010599.pdf, accessed 26 July 2024.

336 - NRA, "原子力規制庁記者ブリーフィング", ["Nuclear Regulation Authority Press Briefing"], Nuclear Regulatory Authority, 1 January 2024, see https://www.nra.go.jp/data/000465073.pdf, accessed 26 July 2024.

337 - *The Japan News*, "Transformers Damaged at Shika N-Plant in Quake-Hit Area in Ishikawa Pref.; Watchdog to Request Operator to Investigate Cause", *The Yomiuri Shimbun*, 11 January 2024, see https://japannews.yomiuri.co.jp/society/noto-peninsula-earthquake/20240111-161313/, accessed 15 May 2024.

338 - *Kyodo News*, "志賀原発の避難道路、過半が寸断 能登地震で7路線、実効性揺らぐ", *47News*, 30 January 2024, op. cit.

339 - *NHK*, "柏崎刈羽原発の避難計画に 県内自治体から実効性問う声 相次ぐ" ["Kashiwazaki-Kariwa Nuclear Power Plant's Evacuation Plan Draws Questions from Local Governments in the Prefecture"], 23 February 2024 (in Japanese), see https://www3.nhk.or.jp/news/html/20240223/k10014368791000.html, accessed 15 May 2024.

The administration of evacuation plans in case of a nuclear accident in Japan is characterized by a dual system. The NRA establishes guidelines for evacuation plans but has no legal authority to approve specific plans as they are not covered by the licensing process. The local governments (town, villages, and prefecture) which host nuclear facilities prepare their own evacuation plans, which the Cabinet Office eventually approves but does not take responsibility for. Therefore, even if questions arise about the effectiveness of a given plan, as is the case in the aftermath of the Noto Peninsula earthquake, it is unclear who is responsible for leading a review of the disaster prevention plan.[340]

New Energy Policy and the Role of Nuclear Power

For Japan, 2024 is the year in which the Seventh Strategic Energy Plan will be formulated, and the role of nuclear power generation will be redefined. The current Sixth Strategic Energy Plan was approved by the Cabinet in October 2021, and the Energy Policy Basic Law mandates a review of the plan every three years or sometime within a year or so.

The central purpose of the Seventh Strategic Energy Plan will be to demonstrate a course of action toward the realization of carbon neutrality by 2050 and the reduction of greenhouse-gas emissions (GHGs) by 46 percent compared to 2013-levels by 2030. According to the 2030-target described in the Sixth Strategic Energy Plan, the respective shares of total generated electricity by power source are as follows: 36–38 percent renewable energies, 20–22 percent nuclear power, 20 percent LNG, 19 percent coal, about 10 percent hydrogen and ammonia, and 2 percent oil.[341]

On 31 May 2023, Japan's parliament passed the so-called "GX Decarbonization Power Supply Bill"—GX stands for Green Transformation—which includes amendments of the Nuclear Reactor Regulation Law, the Electricity Utility Industry Law, and the Atomic Energy Basic Law. Those three laws define the main feature of the new policy: Extension of the "licensing period" (until then generally 40 years and 60 years for exceptional cases) allowing operators to apply for an extension that takes into account "certain shutdown period due to 'non-technical' or 'unplanned' reasons", typically a part of the post 3/11 shutdown periods. This has become one of the most controversial aspects of the GX Basic Policy, because the licensed operational lifetime limitation was introduced after the Fukushima accidents.[342]

In addition, the development of innovative light-water reactors, Small Modular Reactors (SMR), fast reactors, and even nuclear fusion reactors, is also included in the GX implementation plan. The plan envisages the replacement and/or construction of new reactors for the first time since the Fukushima nuclear accidents. This is a major change from the current policy under the "Strategic Energy Plan" which says, "Japan will reduce the dependence on nuclear energy as much as possible." The new policy also emphasizes the unstable energy situation caused by the

340 - *The Mainichi Shimbun*, "「避難計画の責任どこに」柏崎刈羽原発の安全性、住民から質問相次ぐ" ["'Who is responsible for Evacuation Plan?' Questions arise from local citizens regarding safety of Kashiwazaki-Kariwa Nuclear Power Plant"], 15 November 2023, see https://mainichi.jp/articles/20231115/k00/00m/040/028000c, accessed 14 July 2024.

341 - METI, "エネルギー基本計画" ["Basic Energy Plan"], Government of Japan, 22 October 2021 (in Japanese), see https://www.meti.go.jp/press/2021/10/20211022005/20211022005-1.pdf, accessed 23 July 2024.

342 - Motoko Hasegawa, "Japan passes law to use nuclear reactors past 60 years", *Argus*, 31 May 2023, see https://www.argusmedia.com/en/news-and-insights/latest-market-news/2454628-japan-passes-law-to-use-nuclear-reactors-past-60-years, accessed 14 July 2024.

war in Ukraine. Securing a stable energy supply is thus mentioned as a major driver to promote nuclear energy.[343]

The Strategic Policy Committee, under the Ministry of Economy, Trade and Industry's (METI's) Advisory Committee for Natural Resources and Energy is expected to lead discussions around the Seventh Strategic Energy Plan, as the METI Minister is in charge of the Plan.[344] To further promote the shift to decarbonized energy sources and to guarantee energy security, the transition to renewables-based electricity will be accelerated and nuclear energy is expected to be re-emphasized.

On 28 March 2024, following the Diet's approval of the FY2024 budget, the prime minister Fumio Kishida stated that "We must change the present situation, wherein Japan imports energy and tens of trillions of yen flow out overseas. In order to shift to an energy system that contributes both to decarbonization while increasing the capability of domestic firms to earn profits, the implementation of a national strategy is absolutely necessary." Kishida announced his intention to start discussions toward revising the Strategic Energy Plan to be complemented by the GX National Policy.[345]

On 3 May 2024, Mr. Kingo Hayashi, President of Chubu Electric Power and Chairman of the Federation of Electric Power Companies (FEPCO), requested for the new Strategic Energy Plan "to create an environment that allows for the construction, replacement (rebuilding), and expansion of nuclear power plants."[346]

On 13 May 2024, the Japanese Government's GX Implementation Council, which was held for the first time in five months, presented its plan to "integrate activities for decarbonization and fundamental economic reform" and to issue a national strategy labelled the "GX 2040 Vision." By setting out a long-term outlook of the energy policy, the government aims to make it easier for companies to make investment plans. In preparation for investment projects that consume large amounts of electricity, such as data centers, it will compile measures to expand "decarbonized power sources.". The GX 2040 Vision will be reflected in the Strategic Energy Plan.[347]

On 15 May 2024, at the sub-committee on basic policy of its Advisory Council on Energy and Resources, METI published its policy to allow for the replacement of existing reactors

343 - Noriyuki Ishii, "Cabinet Approves Basic Policy Aimed at Implementing GX", Japan Atomic Industrial Forum, 13 February 2023, see https://www.jaif.or.jp/en/news/6350, accessed 29 June 2023; and METI, "Strategic Energy Plan", October 2021, see https://www.enecho.meti.go.jp/category/others/basic_plan/pdf/strategic_energy_plan.pdf, accessed 14 July 2024.

344 - Nanako Takehara, "Prime Minister: Strategic Energy Plan to Be Revised in New Fiscal Year", Japan Atomic Industrial Forum, 5 April 2024, see https://www.jaif.or.jp/en/news/6977, accessed 15 May 2024.

345 - Ibidem.

346 - *The Yomiuri Shimbun*, "電事連会長「原発の新設やリプレース、増設できる環境作りを」…電力安定供給に原発活用の必要性強調" ["President of Federation of Electric Power Co emphasizes the need for utilization of nuclear power in order to secure stable power supply, saying 'please establish business environment in which replacement and/or new construction of nuclear power plant is feasible'"], 3 May 2024, see https://www.yomiuri.co.jp/economy/20240502-OYT1T50221/, accessed 14 July 2024.

347 - Prime Minister's Office, "GX実行会議" ["GX Implementation Council"], Government of Japan, 13 May 2024 (in Japanese), see https://www.kantei.go.jp/jp/101_kishida/actions/202405/13gx.html; and Nanako Takehara, "Japanese Government to Issue GX 2040 Vision", 21 May 2024, see https://www.jaif.or.jp/en/news/7079; both accessed 14 July 2024.

on a given site.[348] This is the first time that METI defines its policy change to move towards newbuild since the Fukushima nuclear accidents.

Prospects for Nuclear Power

The new nuclear energy policies introduced under the GX Transformation laws represent a major shift as they allow for the construction of new reactors. They also amend the nuclear regulation laws to allow for lifetime extensions beyond 60 years. These new policies, which aim to maximize the use of nuclear power, are in fact inconsistent with the policy to "reduce the dependence on nuclear power as much as possible" as stated in the current Strategic Energy Plan.

A recent public-opinion survey suggests that support and opposition of restarting nuclear power plants are evenly divided,[349] in some polls, support outweighs opposition, and vice versa. Last year, support for the restart of existing reactors exceeded opposition to restarts for the first time since 3/11. However, some surveys suggest that the Noto Peninsula earthquake in January this year may have affected residents' perception of the safety of nuclear power generation. [350] It remains unclear how these new policies would change the conditions for utilities to restart reactors, and it is even less certain what the impact on the potential construction of new reactors could be. In addition, many issues associated with the decommissioning of the Fukushima Daiichi reactors remain unresolved (see Fukushima Status Report). Also, legal cases against reactor restarts and in favor of compensation for the impact of the Fukushima disaster continue. In short, the future of nuclear power in Japan is still far from certain.

Regarding activities around nuclear construction sites, on 13 May 2024, Chugoku Electric Power Co. announced that it aims to start operation of Unit 3 of the Shimane Nuclear Power Plant by FY2031. The company now aims to complete the implementation of safety measures by "approximately FY2029", when the previously announced target was the first half of FY2026.[351] Reportedly, in April 2024, Chugoku Electric Power had indicated that the target for commissioning was FY2030, marking the first time that the company had publicly specified when it intends to start operating Shimane-3.[352]

The Ohma Nuclear Power Plant (Aomori Prefecture) was designed to be the world's first commercial reactor to run with a full MOX core (uranium-plutonium mixed oxide fuel), with one of the largest power capacities in Japan at 1383 MW. The owner, J-POWER, aims to start

348 - METI, "エネルギーを巡る状況について" ["Regarding the current energy situation"], submitted to Sub-Committee on Basic Policy for Advisory Council on Energy and Resources, 15 May 2024, (in Japanese), see https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/2024/055/055_004.pdf, accessed 14 July 2024.

349 - *The Asahi Shimbun*, "原発再稼働賛成50% 反対35%を上回る 朝日世論調査" ["Asahi Poll: 50% in favor of restarting nuclear power plants, more than 35% opposed"], 19 February 2024, see https://www.asahi.com/articles/ASS2L7SJRS2HUZPS006.html, accessed 15 May 2024.

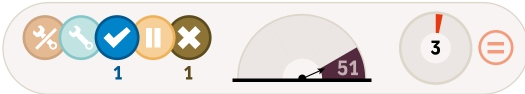
350 - *The Mainichii Shimbun*, "原発再稼働、「反対」45% 賛否が逆転 毎日新聞世論調査", 17 March 2024 (in Japanese), see https://mainichi.jp/articles/20240317/k00/00m/010/150000c, accessed 15 May 2024; and *The Mainichii Shimbun*, "More against restarting nuclear plants than for after Japan Noto quake: Mainichi poll"; 18 March 2024, see https://mainichi.jp/english/articles/20240318/p2a/00m/0op/004000c, accessed 14 July 2024.

351 - Chugoku Electric Power Co., "IR Investors Meeting for FY2024 Financial Results—Message from Top Management", 13 May 2024, see https://www.energia.co.jp/e/ir/info/pdf/ir6-69-01.pdf, accessed 22 August 2024.

352 - *TBS*, "島根原発3号機　2030年度までの運転開始目指す方針　中国電力が明らかに" [Shimane Nuclear Power Plant Unit 3 to begin operation by FY2030, Chugoku Electric Power Co."], 30 April 2024 (in Japanese), see https://newsdig.tbs.co.jp/articles/-/1145764?display=1, accessed 23 July 2024.

operations in 2030, but the NRA, which was created only in December 2014, has been reviewing the plant for a long time. The issuance of the updated construction license, prerequisite for the start of activities, has been postponed five times.[353] The latest deferral being when J-POWER announced in 2022 that they rescheduled the construction resumption to the latter part of 2024, due to delays in the licensing process.[354]

THE NETHERLANDS FOCUS



The Netherlands operates a single, over 50-year-old 482-MW PWR at Borssele—the oldest in the E.U.—that provided 3.8 TWh of electricity in 2023, just below the previous historic maximum of 4.0 TWh in 2009. This corresponded to 3.4 percent of the country's electricity, compared to the historic maximum of 6.2 percent in 1986, when the country also operated a 60-MW BWR at Dodewaard.

The Dodewaard unit operated from 1968 to 1997. Since April 2003, all the spent fuel has been removed, and the site entered its 40-year safe enclosure period in June 2005, after which the plant is to be dismantled[355] (see Decommissioning Status Report).

While Borssele's operating license is valid for an indefinite period, its initial safety report covered a 40-year operational lifetime, equating to the closure of the plant in 2013, but in late 2006, the owner, its shareholders, and the Dutch Government reached an agreement, formalized as the "Borssele Covenant", to allow the operation of the reactor to continue until 31 December 2033 provided certain conditions are met.[356] Amongst these conditions were enforced actions that Borssele "remain [...] amongst the 25% safest water-cooled and water-moderated power reactors in the E.U., the US, and Canada" and that then-shareholding utilities Delta and Essent invest over €100 million (US$$_{2006}$125.6 million) each into "sustainable energy management policies" and "additional innovative projects."[357] Today, Borssele is owned and operated by the Dutch nuclear utility Elektriciteits Produktiemaatschappij Zuid-Nederland (EPZ), which is

353 - *Sankei Shimbun*, "大間原発、令和１２年度の運転開始「私の与えられた使命」　Ｊパワーの菅野新社長" ["Oma Nuclear Power Plant to begin operation in FY2030 "My given mission," says J-Power's new president, Mr. Sugano"], 18 July 2023 (in Japanese), see https://www.sankei.com/article/20230718-JS2RTKZXTBO55AC3JHGQWKWHTE/, accessed 23 July 2023.

354 - Nihon Keizai Shimbun, "Jパワー、大間原発の稼働2年延期　審査長期化で5度目" ["J-Power postponed the startup plan for two years, fifth time postponement due to licensing delay"], 9 September 2022, see https://www.nikkei.com/article/DGXZQOUC092EB0Z00C22A9000000/, accessed 26 July 2024.

355 - IAEA, "Country Nuclear Power Profiles—2022 Edition—The Netherlands", Updated 2022, see https://www-pub.iaea.org/MTCD/publications/PDF/cnpp2022/countryprofiles/Netherlands/Netherlands.htm, accessed 15 June 2024.

356 - WNA, "Nuclear Power in the Netherlands", World Nuclear Association, April 2022, see https://www.world-nuclear.org/information-library/country-profiles/countries-g-n/netherlands.aspx, accessed 12 July 2022; and Authority for Nuclear Safety and Radiation Protection, "Borssele: Possible extension of nuclear power plant's operating life", Undated, see https://english.autoriteitnvs.nl/topics/borssele-possible-extension-of-nuclear-power-plant-s-operating-life; also State Secretary for Housing, Spatial Planning and the Environment, Minister of Economic Affairs, EPZ, Essent Energie, Delta Energy B.V., "Convenant Kerncentrale Borssele", *Staatscourant*, n. 136, p. 29 (in Dutch), 17 July 2006, see https://zoek.officielebekendmakingen.nl/stcrt-2006-136-p29-SC76083.pdf, both accessed 10 August 2022.

357 - Government of the Netherlands, "Convenant Kerncentrale Borssele", *Staatscourant*, No. 136, 17 July 2006 (in Dutch), see https://zoek.officielebekendmakingen.nl/stcrt-2006-136-p29-SC76083.pdf, accessed 11 August 2022.

co-owned by PZEM (70 percent) and German utility RWE (30 percent) via Energy Resources Holding (ERH).[358]

In July 2023, the conservative coalition government of Prime Minister Mark Rutte collapsed over disagreements on migration policy, and a snap election was called for November. Rutte withdrew from Dutch politics after the incoming administration took over and was appointed Secretary General of NATO in June 2024.[359] The election was won by far-right party Partij voor de Vreijheid (PVV) on an anti-immigration agenda, that, spear-headed by its leader Geert Wilders, announced on 16 May 2024 that it had reached an agreement to form a new coalition with Rutte's center-right party Volkspartij voor Vrijheid en Democratie (VVD), centrist party Nieuw Sociaal Contract (NSC), and so-called right-wing "Farmers' Party" BoerBurgerBeweging (BBB).[360] The agreement explicitly excludes Wilders from becoming Prime Minister, resulting in Dirk Schoof, a senior official of the Ministry of Justice and former head of the Dutch intelligence service, being presented as a compromise outside of party politics at the end of May 2024.[361] The new government under Prime Minister Schoof was sworn into office on 2 July 2024. Government plans on how to implement "a clampdown on immigration and exceptions on EU asylum and environmental rules" are to be presented in September.[362]

Regarding energy policy, the new government will increase its focus on offshore gas extraction and nuclear power, possibly exceeding the previous government's ambitions to increase the share of nuclear power in the coming decades.[363] There are ongoing evaluations regarding several newbuild options, including both large reactors as well as Small Modular Reactors (SMRs).

For the only operational reactor at Borssele, the possibility of further lifetime extensions had already been discussed by EPZ in November 2020. The idea was to extend the operational lifetime from 2033 by another 10 or 20 years.[364] As current legislation prohibits the regulator to even consider an application for further prolonged operation at Borssele,[365] in 2020 the

358 - European Commission, "State aid SA.107732 (2023/N) – The Netherlands - Aid for feasibility studies for lifetime extension of the Borssele nuclear power plant", October 2023, see https://ec.europa.eu/competition/state_aid/cases1/202343/SA_107732_C07A618B-0000-CCF7-9970-7C597B016E81_51_1.pdf, accessed 5 June 2024.

359 - *NOS*, "Rutte stopt als partijleider VVD en kondigt vertrek aan uit politiek", *Nederlandse Omroep Stichting*, 10 July 2023 (in Dutch), see https://nos.nl/collectie/13942/artikel/2482242-rutte-stopt-als-partijleider-vvd-en-kondigt-vertrek-aan-uit-politiek, accessed 5 June 2024; and NATO, "NATO Allies select Mark Rutte as next Secretary General", North Atlantic Treaty Organization, Press Release, 26 June 2024.

360 - Claire Moses, "Dutch Right-Wing Parties Reach Preliminary Deal to Form a Government", *The New York Times*, 15 May 2024, see https://www.nytimes.com/2024/05/15/world/europe/netherlands-government-geert-wilders.html, accessed 5 June 2024.

361 - Stephanie van den Berg and Bart H. Meijer, "Former intelligence chief Dick Schoof proposed as Dutch PM", *Reuters*, 28 May 2024, see https://www.reuters.com/world/europe/dutch-parties-propose-former-intelligence-chief-new-prime-minister-nos-news-2024-05-28/, accessed 5 June 2024.

362 - Bart Meijer, "Dutch right-wing government installed as Wilders' shadow looms large", *Reuters*, 2 July 2024, see https://www.reuters.com/world/europe/dutch-right-wing-government-installed-wilders-shadow-looms-large-2024-07-02/, accessed 26 August 2024.

363 - Toby Sterling, "New Dutch coalition aims for more offshore gas extraction, nuclear energy", *Reuters*, 16 May 2024, see https://www.reuters.com/business/energy/new-dutch-coalition-aims-more-offshore-gas-extraction-nuclear-energy-2024-05-16/, accessed 5 June 2024.

364 - EPZ, "Visie EPZ op kernenergie in Nederland na 2033", Elektriciteits Produktiemaatschappij Zuid-Nederland, November 2020 (in Dutch), see https://www.epz.nl/app/uploads/2023/10/Visie-EPZ-op-kernenergie-in-Nederland-na-2033.pdf, accessed 12 July 2022.

365 - ANVS, "Borssele: Possible Extension of Nuclear Power Plant's Operating Life", Autoriteit Nucleaire Veiligheid en Stralingsbescherming/Authority for Nuclear Safety and Radiation Protection, Undated, see https://english.autoriteitnvs.nl/topics/borssele-possible-extension-of-nuclear-power-plant-s-operating-life, accessed 1 August 2022.

Dutch Parliament decided to inquire into the legislative changes required to allow a lifetime extension[366] Further operation of Borssele would require the amendment of the Nuclear Energy Act and the Covenant, as well as a license renewal to update underlying safety report forms.[367]

In December 2022, operator EPZ applied for a grant to conduct technical feasibility studies on the operation of Borssele beyond 2033.[368] The up to €11.3 million (US$12.2 million) state aid to EPZ was approved by the European Commission in October 2023,[369] prompting the acting Dutch Energy and Climate Minister Rob Jetten to approve the feasibility study of Borssele's lifetime extension in December 2023. [370] An initial advance of €2 million [US$$_{2023}$2.2 million] was paid, while the remainder will be spread annually until 2033, when the current operational license of Borssele is due to end.[371] Additionally, in its draft agreement, the new coalition states that Borssele "will remain open,"[372] and in June 2024, while acknowledging that legislative amendments and further feasibility studies were necessary, acting Energy Minister Jetten called for the extended operation of Borssele beyond 2033 in a letter to Parliament. Additionally, he openly considered government purchase of a stake of EPZ to support the financing of this proposed lifetime extension.[373]

Until recently, nuclear newbuild was not considered a realistic option to decarbonize the Dutch energy system after Delta—then majority shareholder of EPZ— had put plans on ice "for at least two years" in 2012 (see previous WNISR editions).[374] While the 2016 Energy Report assessed that "under the current market conditions, there is no demand for a new nuclear power plant, however the cabinet does not rule out new nuclear technologies being deployed in the future, as long as they are safe,"[375] the 2019 Integrated National Energy and Climate Plan 2021-2030 mentions that "a number of studies reveal that for 2050, nuclear power could be a cost-effective option and that a positive business case could be one of the long-term

366 - IAEA, "Country Nuclear Power Profiles—2022 Edition—The Netherlands", Updated 2022, op. cit.

367 - ANVS, "Borssele: Possible extension of nuclear power plant's operating life", Undated, op. cit.

368 - EPZ, "EPZ is verheugd met voortvarende stappen kabinet", Press Release (in Dutch), Elektriciteits-Produktiemaatschappij Zuid-Nederland, 9 December 2022, see https://www.epz.nl/actueel/epz-is-verheugd-met-de-voortvarende-stappen-die-het-kabinet-zet-om-de-bouw-van-twee-nieuwe-kerncentrales-in-borssele-mogelijk-te-maken/, accessed 22 August 2023.

369 - European Commission, "State aid SA.107732 (2023/N) – The Netherlands - Aid for feasibility studies for lifetime extension of the Borssele nuclear power plant", October 2023, see https://ec.europa.eu/competition/state_aid/cases1/202343/SA_107732_C07A618B-0000-CCF7-9970-7C597B016E81_51_1.pdf, accessed 5 June 2024.

370 - Ministerie van Economische Zaken en Klimaat, "Subsidiebeschikking technische haalbaarheidsstudies bedrijfsduurverlenging kerncentrale Borssele", Dutch Economy and Climate Ministry, Government of the Netherlands, December 2023 (in Dutch), see https://open.overheid.nl/documenten/801c5ebd-cb2e-4cb1-b82a-d735f6d9f4d4/file, accessed 5 June 2024.

371 - European Commission, "State aid SA.107732 (2023/N) – The Netherlands - Aid for feasibility studies for lifetime extension of the Borssele nuclear power plant", October 2023, see https://ec.europa.eu/competition/state_aid/cases1/202343/SA_107732_C07A618B-0000-CCF7-9970-7C597B016E81_51_1.pdf, accessed 5 June 2024.

372 - PVV, VVD, NSC and BBB, "Hoofdlijnenakkoord tussen de fracties van PVV, VVD, NSC en BBB", Partij voor de Vrijheid/Party for Freedom, Volkspartij voor Vrijheid en Democratie/People's Party for Freedom and Democracy, Nieuw Sociaal Contract/New Social Contract and BoerBurgerBeweging/Farmer-Citizen's Movement, May 2024, see https://www.kabinetsformatie2023.nl/documenten/publicaties/2024/05/16/hoofdlijnenakkoord-tussen-de-fracties-van-pvv-vvd-nsc-en-bbb, accessed 5 June 2024.

373 - R.A.A. Jetten, "Kemerbrief verkennende gesprekken over de aandelen van EPZ", 2024 (in Dutch), see https://www.tweedekamer.nl/kamerstukken/detail, accessed 16 June 2024; and *WNN*, "Dutch state could buy share in Borssele plant", 5 June 2024, see https://www.world-nuclear-news.org/Articles/Dutch-state-could-buy-share-in-Borssele-plant, accessed 5 June 2024.

374 - *SPIEGEL ONLINE*, "Bau des Atomkraftwerks in Borssele verschoben", 24 January 2012 (in German), see https://www.spiegel.de/wissenschaft/technik/niederlande-bau-des-atomkraftwerks-in-borssele-verschoben-a-811010.html, accessed 12 July 2022; and *Uranium Intelligence Weekly*, "Netherlands", 23 January 2012.

375 - Ministry of Economic Affairs, "Energy Report—Transition to sustainable energy", Government of the Netherlands, 28 April 2022, see https://www.government.nl/binaries/government/documenten/reports/2016/04/28/energy-report-transition-tot-sustainable-energy/energy-report-transition-to-sustainable-energy.pdf, accessed 12 August 2022.

options. Given the lead times, additional nuclear power for 2030 does not seem likely in the Netherlands."[376] The plan targeted a 100-percent renewable electricity generation by 2050 with offshore wind delivering the lion's share.

In recent years however, the Dutch Government has been drawing closer attention to the possibility of continuing nuclear production beyond 2033. A few weeks after the publication of an Enco report on 1 September 2020, the then Minister of Economic Affairs and Climate Policy, Eric Wiebes—whose party, VVD, "want[ed] up to 10 new nuclear plants to be built" at the time—informed Parliament of the findings and the launch of procedures to allow a market consultation on nuclear newbuild.[377] The study concluded that nuclear "could play an important role in the future energy mix of the Netherlands" and argued that both large units and SMRs would be "cheaper" than renewable technologies.[378]

Another study commissioned by Minister Wiebes from Berenschot and Kalavasta concluded, on the contrary, that "nuclear energy is more expensive, except when nuclear power always takes precedence over the electricity grid and the government assumes a large part of the financial risks" as summarized by *Nuclear Engineering International* (*NEI*).[379]

In addition to its lifetime extension propositions made in 2020, EPZ also suggested newbuild as an option. According to the proposal, the government would have to invest in the construction of new nuclear reactors, the favored option being two Generation-III+ reactors of around 1.5 GW capacity each, increasing the currently installed capacity sixfold. This capacity would correspond to the European Pressurized Water Reactors (EPR) or the South Korean Advanced Pressurized Water Reactors (APR), "safe and reliable" technologies according to EPZ.[380] For this project, EPZ envisioned costs of €8–10 billion (US$$_{2020}$9.1–11.4 billion) and a construction duration of eight years per reactor, "if the project is properly implemented.".[381]

In a 2021 market consultation, commissioned by the House of Representatives prior to the last Rutte administration taking office, consulting firm KPMG stated that "private financing without extensive government guarantees would be difficult or impossible to achieve [as] a large nuclear power plant is too big an investment for many private investors, and has too long a horizon." [382] The report further states that "proven" technologies of Generation III+

376 - Ministry of Economic Affairs and Climate Policy, "Integrated National Energy and Climate Plan 2021-2030", Government of the Netherlands, September 2020, see https://energy.ec.europa.eu/system/files/2020-03/nl_final_necp_main_en_0.pdf, accessed 12 August 2022.

377 - *NEI Magazine*, "Netherlands considers more nuclear power", 28 September 2020, see https://www.neimagazine.com/news/newsnetherlands-pushes-for-more-nuclear-8153490, accessed 22 August 2023.

378 - Enco, "Possible Role of Nuclear in the Dutch Energy Mix in the Future", commissioned by Ministry of Economic Affairs and Climate Policy, Government of the Netherlands, September 2020, see https://www.tweedekamer.nl/downloads/document?id=66a4f4e8-5a8f-4638-a4c7-7a4225c8ecc9&title=Possible%20role%20of%20nuclear%20in%20de%20Dutch%20energy%20mix%20in%20the%20future.pdf, accessed 22 August 2023.

379 - *NEI Magazine*, "Netherlands considers more nuclear power", 28 September 2020, see https://www.neimagazine.com/news/newsnetherlands-pushes-for-more-nuclear-8153490; and *WNN*, "Dutch minister presents report on new nuclear", 28 September 2020, see https://world-nuclear-news.org/Articles/Dutch-minister-presents-report-on-new-nuclear; both accessed 12 August 2022.

380 - EPZ, "Visie EPS op kernenergie in Nederland na 2033", Elektriciteits Produktiemaatschappij Zuid-Nederland, November 2020 (in Dutch), see https://www.epz.nl/app/uploads/2021/04/Visie-EPZ-op-kernenergie-in-Nederland-na-2033.pdf, accessed 12 July 2022.

381 - Ibidem.

382 - KPMG, "Nuclear Energy Market Consultation", commissioned by the Ministry of Economic Affairs and Climate Policy, Government of the Netherlands, 1 July 2021, see https://www.government.nl/documents/reports/2021/07/01/market-consultation-nuclear-energy; and *NEI* Magazine, "KPMG Looks at Feasibility of New Build in Netherlands", 12 July 2021, see https://www.neimagazine.com/news/newskpmg-looks-at-feasibility-of-newbuild-in-netherlands-8893831, both accessed 12 August 2022.

designs, such as the EPR or APR would limit first-of-a-kind (FOAK) cost risks in comparison to implementing a completely new reactor design. Russian and Chinese technologies were placed "out of scope" at the request of the Ministry of Economic Affairs, thus pointing to EDF, Westinghouse, and KEPCO as "obvious options". Nonetheless, without consensus on the "best" design, and given that "a choice can only be made once a sufficient number of projects have actually been completed", it was expected that a choice would only be possible by 2023.

In late 2021, the Dutch Government followed EPZ's original proposal in their coalition agreement. An undefined lifetime extension for Borssele and the construction of two new reactors were included in the official governmental plans. A total of €5 billion (US$$_{2021}$5.9 billion) was planned to be spent by the state until 2030 to facilitate the construction of the new plants.[383]

Dutch newbuild plans took a new turn in December 2022, when it was announced that two reactors would be built near the Borssele plant with the government as co-investor. The plan is to begin construction in 2028 and complete both units by 2035 thanks to an "accelerated approach".[384] A second consultation issued by KPMG in February 2023, tasked with identifying financing options for newbuild confirmed that state involvement is considered indispensable and concluded that, in the Dutch context, existing financing schemes would have limited applicability. The KPMG study also stated that "market parties" expected a role for the government to limit licensing and political risks, and advance agreements on setting up a decommissioning fund. Construction duration was estimated at 11 to 15 years, calling the Dutch Government's envisioned "accelerated approach" into doubt.[385]

Meanwhile, Dutch company NRG Pallas, active in nuclear medicine and operator of the High Flux research Reactor (HFR) at Petten, and Belgian nuclear engineering company Tractebel, a subsidiary of the utility Engie, signed a Memorandum of Understanding in March 2023 to "cooperate to support the new-build of nuclear power plants in the Netherlands."[386]

On 12 April 2023, then Minister for Climate and Energy Rob Jetten renewed his pledge to stick with the coalition agreement of 2021 despite disagreement from the "Expert Team Energy System 2050", which he had appointed to outline recommendations for the country's Energy System Plan 2050.[387] In its report, submitted on the same day as the Minister's remarks, the team sees "no or a limited role" for nuclear power in the Dutch energy system and emphasized

383 - VVD, D66, CDA and ChristenUnie, "Omzien naar elkaar, vooruitkijken naar de toekomst - Coalitieakkoord 2021-2025", People's Party for Freedom and Democracy, Democrats 66, Christian Democratic Appeal and the Christian Union, 15 December 2021 (in Dutch), see https://www.parlement.com/9291000/d/pdfs/coalitieakkoord-2021-2025.pdf, accessed 12 July 2022.

384 - Bart Meijer, "Netherlands plans to build two nuclear power plants by 2035", *Reuters*, 9 December 2022, see https://www.reuters.com/business/energy/netherlands-plans-build-two-nuclear-power-plants-by-2035-2022-12-09/, accessed 31 July 2023; and *NEI Magazine*, "Borssele preferred site for two new reactors", 15 December 2022, see https://www.neimagazine.com/news/belgium-confirms-borssele-as-site-for-new-nuclear-plants-10439145/, accessed 15 June 2024.

385 - KPMG, "Onderzoek financieringsconstructies kernenergie", commissioned by the Ministry of Finances, Government of the Netherlands, 15 February 2023 (in Dutch), see https://www.rijksoverheid.nl/documenten/rapporten/2023/02/15/onderzoek-financieringsconstructies-kernenergie, accessed 22 August 2023.

386 - NRG, "Tractebel and NRG|PALLAS join forces to support nuclear new-build in the Netherlands", Press Release, 17 March 2023, see https://www.nrg.eu/en/news/tractebel-and-nrg-pallas-join-forces-to-support-nuclear-new-build-in-the-netherlands, accessed 7 November 2023.

387 - *NL Times*, "Cabinet moving forward with nuclear plant plans, despite experts seeing 'limited role'", 12 April 2023, see https://nltimes.nl/2023/04/12/cabinet-moving-forward-nuclear-plant-plans-despite-experts-seeing-limited-role; and Expertteam Energiesysteem 2050, "Energie door perspectief: rechtvaardig, robuust en duurzaam naar 2050", submitted 12 April 2023, see https://www.etes2050.nl/publicaties/outlookenergiesysteem2050/handlerdownloadfiles.ashx?idnv=2448181; both accessed 31 July 2023.

that new nuclear capacity would only be necessary if the Netherlands doubled or even tripled its current electricity demand and neighboring European countries started importing electricity from the Netherlands. They further questioned the possibility of having a new reactor online before 2040 and the potential choice of Borssele as a possible location for new capacity—as this could lead to system overload from the large amount of wind farms located nearby—all while noting that they had drawn their conclusion on nuclear power from other studies.[388] Minister Jetten indicated that the "final decision" on new nuclear capacity would be made towards the end of 2024.[389]

However, at the end of April 2023, the former administration stated its intent to reach a carbon-neutral electricity system by 2035 with nuclear mentioned as a potential contributor of up to 10 percent of the mix if two new reactors were built. Emphasis on SMR technologies in the statement contradicts the assumption of just two plants providing such a large portion of electricity.[390] Given the long lead time of nuclear newbuild in planning and construction experienced in other countries, it seems unlikely that the plans can be implemented in the targeted timeframe.

Dutch new nuclear policy gained further momentum when, also in April 2023, approx. €320 million (US$$_{2023}$346 million) were allocated to nuclear-associated funds in the draft document for the 2024 climate budget.[391] These expenditures exceed the planned budget of the 2021 coalition agreement by €199 million (US$$_{2023}$215.2 million). Included are €10 million (US$$_{2023}$10.8 million) for studies spanning from 2023 to 2025 on lifetime extension at Borssele and an additional €62 million (US$$_{2023}$67 million) for the local municipality and the province of Zeeland for efforts regarding newbuild projects and continued operation at Borssele. Further €117 million (US$$_{2023}$126.5 million) are allocated to newbuild feasibility studies and €65 million (US$$_{2023}$70.3 million) are to be spent on the development of knowledge and training of nuclear industry staff for the future operation of Dutch nuclear power plants.[392]

In December 2023, the Dutch Government announced that Korea Hydro & Nuclear Power (KHNP) had been contracted to carry out a technical feasibility study on the construction of two reactors at Borssele—expected to span at least six months starting in January 2024—with similar contracts with Westinghouse and EDF to follow "soon". On that occasion, the

388 - Expertteam Energisysteem 2050, "Energie door perspectief: rechtvaardig, robuust en duurzaam naar 2050", April 2023 (in Dutch), see https://etes2050.nl/publicaties/outlookenergiesysteem2050/HandlerDownloadFiles.ashx?idnv=2448181, accessed 22 August 2023.

389 - *NL Times*, "Cabinet moving forward with nuclear plant plans, despite experts seeing 'limited role'", 12 April 2023, see https://nltimes.nl/2023/04/12/cabinet-moving-forward-nuclear-plant-plans-despite-experts-seeing-limited-role; and Expertteam Energiesysteem 2050, "Energie door perspectief: rechtvaardig, robuust en duurzaam naar 2050" submitted 12 April 2023, see https://www.etes2050.nl/publicaties/outlookenergiesysteem2050/handlerdownloadfiles.ashx?idnv=2448181; both accessed 31 July 2023.

390 - Minister Rob A.A. Jetten, "Kamerbrief over voorjaarsbesluitvorming Klimaat", Ministry of Economic Affairs and Climate, addressed to the House of Representatives of the Netherlands (in Dutch), 26 April 2023, see https://www.rijksoverheid.nl/documenten/kamerstukken/2023/04/26/voorjaarsbesluitvorming-klimaat; and *WNN*, "Dutch government allocates funding for nuclear programme", 27 April 2023, see https://www.world-nuclear-news.org/Articles/Dutch-government-allocates-funding-for-nuclear-pro; both accessed 31 July 2023.

391 - Government of the Netherlands, "Ontwerp Meerjarenprogramma Klimaatfonds 2024", Rijksoverheid, 26 April 2023 (in Dutch), see https://www.rijksoverheid.nl/documenten/kamerstukken/2023/04/26/bijlage-2-ontwerp-meerjarenprogramma-klimaatfonds-2024, accessed 12 June 2023.

392 - *WNN*, "Dutch government allocates funding for nuclear programme", *World Nuclear News*, 27 April 2023, see https://www.world-nuclear-news.org/Articles/Dutch-government-allocates-funding-for-nuclear-pro, accessed 12 June 2023.

Dutch and South Korean Governments signed an MoU to "cooperate on nuclear energy".[393] In February 2024, Westinghouse followed with the announcement that it was also to conduct such a study for two AP-1000s, without divulging an estimated timeline.[394] However, according to *The Wall Street Journal* "Westinghouse said it learned from its U.S. experience during the 2010s and no longer takes on reactor construction."[395] That suggests that Westinghouse would provide the technology but not act as the main builder-contractor, who then remains to be identified.

As of June 2024, no contract with EDF had been made public. The government envisions a final site selection in 2025 as a second location, in addition to Borssele, might still come under consideration.[396]

In March 2024, the "Tweede Kamer", the lower house of the Dutch Parliament, adopted a resolution to extend newbuild plans from two to four new reactors.[397] The incoming government, in addition to the lifetime extension of the operational Borssele plant, indeed envisions the construction of four new nuclear power plants.[398] According to the coalition agreement, funding is to be increased from the current €4.5 billion to €14 billion (US$4.9 to US$15 billion), most of which is to be spent in the 2030s, by which time another policy shift might have happened.[399]

In the outgoing government's multi-annual climate fund budget, published in October 2023, an additional €65 million (US$$_{2023}$70 million) were earmarked for 2025 for the development of SMRs in the Netherlands.[400] In August 2022, Amsterdam-based ULC-Energy and British Rolls-Royce signed an exclusive agreement to cooperate on Dutch SMR development. ULC-Energy

393 - Rijsoverheid, "Haalbaarheidsonderzoek bouw kerncentrales in januari van start", Press Release (in Dutch), Government of the Netherlands, 13 December 2023, see https://www.rijksoverheid.nl/actueel/nieuws/2023/12/13/haalbaarheidsonderzoek-bouw-kerncentrales-in-januari-van-start, Government of the Netherlands and Government of the Republic of Korea, "Joint statement between the government of the Republic of Korea and the government of the Kingdom of the Netherlands", Diplomatic Statement, 13 December 2023, see https://www.government.nl/documents/diplomatic-statements/2023/12/13/joint-statement-between-the-government-of-the-republic-of-korea-and-the-government-of-the-kingdom-of-the-netherlands; both accessed 15 June 2024.

394 - Westinghouse, "Westinghouse Awarded Contract to Evaluate AP1000® Reactors in Support of Netherlands' Energy Future", Press Release, 20 February 2024, see https://info.westinghousenuclear.com/news/westinghouse-awarded-contract-to-evaluate-ap1000-reactors-in-support-of-netherlands-energy-future, accessed 15 June 2024.

395 - Kim Mackrael, James Marson, Nikita Nikolaienko and Jennifer Hiller, "The American Company Trying to Keep Ukraine's Nuclear Reactors Online", *The Wall Street Journal*, 7 June 2024, see https://www.wsj.com/world/the-american-company-trying-to-keep-ukraines-nuclear-reactors-online-e636917a, accessed 7 June 2024.

396 - *WNN*, "Feasibility for AP1000s at Borssele to be studied", 21 February 2024, see https://world-nuclear-news.org/Articles/Feasibility-for-AP1000s-at-Borssele-to-be-studiedhttps://world-nuclear-news.org/Articles/Feasibility-for-AP1000s-at-Borssele-to-be-studied, accessed 5 June 2024; and Rijksoverheid, "Projectprocedure nieuwe kerncentrales van start", Press Release (in Dutch), Government of the Netherlands, 19 February 2024, see https://www.rijksoverheid.nl/actueel/nieuws/2024/02/19/projectprocedure-nieuwe-kerncentrales-van-start, accessed 15 June 2024.

397 - *ANP*, "Dutch Cabinet must consider four large nuclear energy plants, not two, says Parliament", *NL Times*, 5 March 2024, see https://nltimes.nl/2024/03/05/dutch-cabinet-must-consider-four-large-nuclear-energy-plants-two-says-parliament, accessed 5 June 2024; and Tweede Kamer, "Motie van het lid Erkens over een scenario voor een groter aandeel kernenergie bestaande uit ten minste vier grote kerncentrales", Motion 32813-1358, introduced 28 February 2024, adopted 5 March 2024 (in Dutch), see https://www.tweedekamer.nl/kamerstukken/detail?id=2024Z03064&did=2024D07054, accessed 16 June 2024.

398 - PVV, VVD, NSC and BBB, "Hoofdlijnenakkoord Tussen de Fracties van PVV, VVD, NSC En BBB", May 2024, op. cit.

399 - Phil Chaffee, "Netherlands: New Government Commits to Expanded New Nuclear Role", *Energy Intelligence*, 17 May 2024, see https://www.energyintel.com/0000018f-82ee-dc18-a38f-a6ffod4f0000, accessed 21 May 2024; and PVV, VVD, NSC and BBB, "Budgettaire bijlage hoofdlijnenakkoord", 15 May 2024 (in Dutch), see https://www.kabinetsformatie2023.nl/binaries/kabinetsformatie/documenten/publicaties/2024/05/16/budgettaire-bijlage-hoofdlijnenakkoord/Budgettaire+bijlage+hoofdlijnenakkoord+15+mei+2024.pdf, accessed 16 June 2024.

400 - Ministry of Economic Affairs and Climate, "Meerjarenprogramma Klimaatfonds 2024", Government of the Netherlands, October 2023 (in Dutch), see https://open.overheid.nl/documenten/af2ace34-a505-4483-b8ae-7b33ceeaf535/file, accessed 2 July 2024.

hopes to apply for a license for its reactor in 2025, envisioning construction to begin in 2027.[401] In November 2023, Rolls-Royce signed an MoU with Dutch construction company BAM "to explore the opportunities for collaboration to support deployment of Rolls-Royce SMRs in the Netherlands."[402] The previously mentioned July 2021 KPMG report had considered SMRs as an "interesting option" to market parties but suggested waiting until "any FOAK issues have been resolved" to identify successful projects, deeming the start of such a process impossible before 2027–2033.[403] Moreover, in March 2024 acting Energy Minister Jetten in a letter to the "Tweede Kamer" acknowledged that there was, as of today, no SMR concept ready for deployment, while describing steps taken to prepare the potential deployment of SMRs in the future.[404]

Today's electricity mix in the Netherlands is dominated by natural gas, which supplied 37.7 percent of total electricity, 122.15 TWh (gross), in 2023. Wind energy (23.7 percent) and solar (17.3 percent) are next, followed by coal (6.9 percent) and bioenergy (6.8 percent). The contribution of "other fossil fuels" at 4.2 percent exceeds the nuclear share at 3.3 percent of total electricity generation.[405]

Renewables had strong growth rates in 2023 with wind turbines generating 35 percent and solar panels 24 percent more power than in the previous year. The Dutch National Energy and Climate Plan from June 2023 expects the share of renewable energies in gross electricity consumption to increase from 33.4 percent in 2021 to 86.2 percent in 2030 and 95.5 percent in 2040 (raising questions about the envisioned nuclear plans). This development is to be driven by the expansion of wind and solar power. The plan envisions capacity expansions of 28.3 GW for wind power by 2040, of which 21.2 GW are planned as offshore capacity.[406] 2023 marked the milestone of exceeding 10 GW of installed wind power, of which nearly 2 GW had been installed in the year including 1.4 GW offshore.[407] Solar is expected to grow from 23.9 GW at the end of 2023 to 42.6 GW by 2040.[408] The target seems realistic as in 2023 alone, solar capacities increased by 4.3 GW. In the E.U., the Netherlands lead the charts on installed solar capacity per capita at 1.3 kW, followed by Germany (0.9 kW) and Belgium (0.7 kW).[409]

401 - Darrell Proctor, "Dutch Officials Set Funding for Nuclear Power Program", *POWER Magazine*, 1 June 2023, see https://www.powermag.com/dutch-officials-set-funding-for-nuclear-power-program/, accessed 12 June 2023.

402 - BAM, "Rolls-Royce SMR and BAM Infra Nederland explore collaboration for the deployment of SMRs in the Netherlands", Press Release, 8 November 2023, see https://www.bam.com/en/press/press-releases/2023/11/rolls-royce-smr-and-bam-infra-nederland-explore-collaboration-for-the, accessed 5 June 2024.

403 - Karolin Schaps, "Netherlands has investor support for new nuclear plants", *Montel*, 8 July 2021, see https://www.montelnews.com/news/1237329/netherlands-has-investor-support-for-new-nuclear-plants, accessed 15 August 2022; and KPMG, "Nuclear Energy Market Consultation", 1 July 2021, op. cit.

404 - Minister for Climate and Energy, "Programma-aanpak Small Modular Reactors", Government of the Netherlands, 22 March 2024 (in Dutch), see https://open.overheid.nl/documenten/3d65a3bd-9bc8-4cc8-8c87-7a7592ff2d30/file, accessed 5 June 2024.

405 - Ember, "Electricity Data Explorer—Netherlands electricity generation by source", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 5 June 2024.

406 - Ministry of Economic Affairs and Climate Policy, "Draft update of the National Plan Energy and Climate 2021-2030", Draft INEK Update, Automated Translation, Government of the Netherlands, June 2023, see https://commission.europa.eu/system/files/2023-07/EN_NETHERLANDS%20DRAFT%20UPDATED%20NECP.pdf, accessed 22 August 2023.

407 - Eurobserv'Er, "Wind energy barometer 2024", March 2024, see https://www.eurobserv-er.org/wind-energy-barometer-2024/, accessed 5 June 2024.

408 - Ministry of Economic Affairs and Climate Policy, "Draft update of the National Plan Energy and Climate 2021-2030", 2023, op. cit.

409 - EurObserv'ER, "Photovoltaic barometer 2024", April 2024, see https://www.eurobserv-er.org/photovoltaic-barometer-2024/, accessed 5 June 2024.

POLAND FOCUS

For many decades, Poland has been planning the development of nuclear power plants. In the 1980s, construction of two VVER1000/320 reactors began in Żarnowiec on the Baltic coast, but both construction and further plans were halted following the Chornobyl accident in 1986.[410] Since then, there has been a long, expensive, and time-consuming series of attempts to restart the program. Refer to previous WNISR editions for a more detailed account of these various attempts, of which only the most recent ones are discussed below.

For example, in 2008, Poland announced that it was going to re-enter the nuclear arena.[411] In the "Polish Energy Policy until 2030", published in 2009, it was assumed that by 2030 three nuclear units (4.8 GW) would generate "over 10 percent" of the country's electricity, with the first unit put into operation "no[t] sooner than in 2020".[412] Five years later, the Polish Government adopted the Polish Nuclear Power Programme. The plan included proposals to build 6 GW of nuclear power capacity at an estimated cost of PLN40–60 billion ($US\$_{2014}$13–19 billion), with the first reactor starting up by 2024 and two units operating by 2035. A contract was to be concluded and a first site named by 2016.[413] That did not happen.

Instead, by January 2016, state-owned utility Polska Grupa Energetyczna's (PGE's) subsidiary PGE EJ1, which had been set up for the construction and operation of a nuclear power plant,[414] applied to the General Directorate for Environmental Protection (GDEP or GDOŚ) to launch Environmental Assessment procedures at Lubiatowo-Kopalino and Żarnowiec, both close to the Baltic coast in the northern province of Pomerania.[415] In March 2017, environmental and site selection surveys started at both sites.[416]

Following this, in November 2018, the government published a draft strategic energy development program, which called for the construction of up to four reactors (providing 4–6 GW of capacity) by 2040, with the first in operation by 2033, and another two reactors by 2043, bringing total nuclear capacity to 6–9 GW.[417] In May 2019, the Ministry of Energy

410 - Council of Ministers, "Uchwała nr 204 Rady Ministrów z dnia 17 grudnia 1990 r. w sprawie postawienia inwestycji Elektrownia Jądrowa 'Żarnowiec' w budowie w stan likwidacji", Government of Poland, 17 December 1990 (in Polish), see https://isap.sejm.gov.pl/isap.nsf/download.xsp/WMP19900490373/O/M19900373.pdf, accessed 1 August 2023.

411 - *WNN*, "Poland looks to nuclear to replace coal", with *Bloomberg* and *AFP*, see https://www.world-nuclear-news.org/Articles/Poland-looks-to-nuclear-to-replace-coal, accessed 1 August 2023.

412 - Ministry of Economy, "Energy Policy of Poland until 2030", adopted by the Council of Ministers, Government of Poland, 10 November 2009.

413 - Ministry of Economic Affairs, "Polish Nuclear Power Programme", Government of Poland, January 2014, see https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Umweltpruefungen/polnische_kernenergie_programm_en_bf.pdf; and *The Economist*, "Going Nuclear", 31 January 2014, see https://www.economist.com/eastern-approaches/2014/01/31/going-nuclear; both accessed 1 August 2023.

414 - *WNN*, "Polish cabinet approves new nuclear plan", 29 January 2014, see https://www.world-nuclear-news.org/Articles/Polish-cabinet-approves-new-nuclear-plan, accessed 23 August 2023.

415 - PEJ, "Site characterisation related to the construction of the first Polish NPP will be performed in the „Lubiatowo-Kopalino" and „Żarnowiec" sites. PGE EJ 1 leaves the „Gąski" site.", 30 June 2016, see https://ppej.pl/en/news/site-characterisation-related-to-the-construction-of-the-first-polish-npp-will-be-performed-in-the-lubiatowo-kopalino-and-zarnowiec-sites.-pge, accessed 10 June 2024.

416 - *NEI Magazine*, "Site Studies begin for Poland's first NPP", 12 April 2017, see https://www.neimagazine.com/news/site-studies-begin-for-polands-first-npp-5784946/, accessed 10 June 2024.

417 - Gary Peach, "Newbuild: Power Demand in Poland Bolsters Case for Nuclear", *Nuclear Intelligence Weekly*, Vol. 12, No. 47, 26 November 2018.

envisaged the site selection for the first plant in 2020 and technology selection the following year.[418]

In October 2020, the Council of Ministers adopted a revised long-term Polish Nuclear Power Programme.[419] It maintained the objective to build and commission nuclear power plants in Poland with a total installed capacity of approximately 6–9 GW based on Generation III (+) pressurized water reactors, with the start of operation during the 2030s, while the share of nuclear power in the electricity mix was predicted to reach about 20 percent by 2045.[420]

In the same month, the U.S. and Polish Governments signed an agreement on the "cooperation towards the development of a civil nuclear power program and the civil nuclear power sector in [...] Poland." The agreement includes cooperation plans on the development of financing regulations and schemes, technological knowledge transfer, and the "development, construction, and financing of the first [nuclear power plant] project, intended to be operational during 2033." The agreement came into force in February 2021.[421] In June 2021, a first grant was issued by the U.S. Trade and Development Agency to fund a front-end engineering and design study for Polskie Elektrownie Jądrowe (PEJ).[422]

PEJ is the direct descendant of PGE EJ1. In March 2021, the four owners PGE (70 percent of shares), Enea, Tauron, and KGHM (10 percent each) sold ownership to the Polish State Treasury "'in preparation for realisation' of the Polish nuclear power programme." Negotiations had begun in October 2020, and the transaction cost the Treasury around PLN531 million (US$$_{2021}$137.5 million).[423] In June 2021, "PGE EJ1" was renamed "Polskie Elektrownie Jądrowe", or "PEJ".[424]

The Pomeranian Project

In late December 2021, PEJ announced it had chosen the village of Choczewo in Pomerania for the first reactor.[425] Bids for the construction of the first Polish nuclear power plant were

418 - *WNN*, "Poland already preparing for nuclear plant, says energy minister", 16 May 2019, see https://www.world-nuclear-news.org/Articles/Poland-already-preparing-for-nuclear-plant,-says-e, accessed 1 May 2021.

419 - Republic of Poland, "Polish Nuclear Power Programme", adopted 2 October 2020, promulgated 16 October 2020, see https://www.gov.pl/attachment/4cddd10a-5e8b-414d-bb95-670f6507d73e, accessed 1 August 2023; and Government of the Republic of Poland, "PAA in the Polish Nuclear Power Programme", Undated, see https://www.gov.pl/web/paa-en/Polish-Nuclear-Power-Program, accessed 10 June 2024.

420 - Ibidem.

421 - Government of the United States of America and Government of the Republic of Poland, "Agreement Between the Government of the United States of America and the Government of the Republic of Poland on Cooperation Towards the Development of a Civil Nuclear Power Program and the Civil Nuclear Power Sector in the Republic of Poland", Signed on 19 and 22 October 2020, Enforced 24 February 2021, as release by U.S. Department of State, see https://www.state.gov/wp-content/uploads/2021/05/21-224-Poland-Nuclear-Energy.pdf, accessed 23 August 2023.

422 - U.S. Trade and Development Agency, "USTDA Advances Poland's Civil Nuclear Energy Program by Funding U.S. Industry-Led Study", Press Release, 30 June 2021, see https://www.ustda.gov/ustda-advances-polands-civil-nuclear-energy-program-by-funding-u-s-industry-led-study/, accessed 7 November 2023.

423 - *NEI Magazine*, "Polish state takes over nuclear company in preparation for NPP construction", 30 March 2021, see https://www.neimagazine.com/news/newspolish-state-takes-over-nuclear-company-in-preparation-for-npp-construction-8635299, accessed 23 August 2023.

424 - PEJ, "New company name: Polskie Elektrownie Jądrowe sp. z o.o.", Press Release, Polskie Elektrownie Jądrowe, 7 July 2021, see https://ppej.pl/en/news/new-company-name-polskie-elektrownie-jadrowe-sp.-z-o.o, accessed 23 August 2023.

425 - PEJ, "Preferred site of the first Polish nuclear power plant indicated by investor", Polskie Elektrownie Jądrowe, 22 December 2021, see https://ppej.pl/en/news/preferred-site-of-the-first-polish-nuclear-power-plant-indicated-by-investor, accessed 10 June 2024.

submitted between October 2021 and September 2022. They consisted of Korea Hydro & Nuclear Power's (KHNP's) proposal to build six APR-1400s (8.4 GW) for US$26.7 billion, Westinghouse's proposal to build six AP-1000 (6.7 GW) for US$31.3 billion, and EDF's preliminary offer of four to six EPRs (6.6–9.9 GW) for US$33–48.5 billion.[426]

Despite its bid costing more for less capacity, Westinghouse was formally appointed in November 2022 to deliver three reactors to the Pomeranian project at a price of around US$20 billion.[427] Four East German states (Brandenburg, Saxony, Mecklenburg-Vorpommern, and Berlin) opposed the project during the consultation period of the Environmental Impact Assessment (EIA) process.[428] Nonetheless, cooperation agreements were signed between Westinghouse and PEJ in December 2022.[429] These were further advanced when in February 2023, a contract covering front-end engineering, early procurement work, and program development was signed between Westinghouse and PEJ.[430] On 13 April 2023, PEJ applied to the Ministry of Climate for a "decision-in-principle" on the project,[431] which was granted in July 2023, allowing for further administrative applications to proceed.[432] In September 2023, Westinghouse, PEJ, and Bechtel signed an 18-month Engineering Services Contract (ESC) that shall provide, by the end of the period, the design documentation for the first nuclear plant in Poland.[433] At this stage, construction work was planned to begin in 2026, with electricity generation to commence in 2033.[434]

In the meantime, general elections have resulted in a Polish leadership change with the nationalist party "Law and Justice" (Prawo i Sprawiedliwość, PiS) losing their mandate and being replaced by a pro-European, center-right government under Donald Tusk, who had already been Polish Prime Minister from 2007 to 2014. The new cabinet was sworn into

426 - *NEI Magazine*, "Westinghouse and KHNP may both build NPPs in Poland", *Nuclear Engineering International*, 3 November 2022, see https://www.neimagazine.com/news/newswestinghouse-and-khnp-may-both-build-npps-in-poland-10144809, accessed 1 August 2023.

427 - Alan Charlish, Anna Wlodarczak-Semczuk, Anna Koper and Marek Strzelecki, "Poland's first nuclear power plant to cost around $20 bln - PM", *Reuters*, 2 November 2022, see https://www.reuters.com/business/energy/polands-first-nuclear-power-station-cost-around-20-bln-says-pm-2022-11-02/; and Prime Minister's Office, "Uchwała w sprawie budowy wielkoskalowych elektrowni jądrowych w Rzeczypospolitej Polskiej", Press Release (in Polish), Government of Poland, 2 November 2022, see https://www.gov.pl/web/premier/uchwala-w-sprawie-budowy-wielkoskalowych-elektrowni-jadrowych-w-rzeczypospolitej-polskiej; both accessed 1 August 2023.

428 - MSGIV, "Geplantes Kernkraftwerk in Polen: Einwände auch aus Brandenburg", Press Release Nr 538/2022 (in German), Ministerium für Soziales, Gesundheit, Integration und Verbraucherschutz Brandenburg/Ministry for Social Issues, Health, Integration and Consumer Protection of Brandenburg, 13 December 2022, see https://msgiv.brandenburg.de/sixcms/media.php/9/538_22_MSGIV_Einwaende_KKW_Polen_20221213.pdf, accessed 1 August 2023.

429 - PEJ, "Polskie Elektrownie Jądrowe and Westinghouse Electric Company have signed an agreement defining principles of cooperation in the preparation of the construction process of the first nuclear power plant in Poland", 15 December 2022, see https://ppej.pl/en/news/polskie-elektrownie-jadrowe-and-westinghouse-electric-company-have-signed-an-agreement-defining-principles-of-cooperation-in-the-preparation-of-the, accessed 10 June 2024.

430 - Westinghouse, "Westinghouse and Polskie Elektrownie Jądrowe Advance Poland's Nuclear Energy Program with Contract Signing", Press Release, 22 February 2023, see https://info.westinghousenuclear.com/news/wec-pej-poland-contract-signing, accessed 1 August 2023.

431 - PEJ, "Polskie Elektrownie Jądrowe company submits an application for a decision-in-principle for the first Polish nuclear power plant", Press Release, Polskie Elektrownie Jądrowe, 13 April 2023, see https://ppej.pl/en/news/polskie-elektrownie-jadrowe-company-submits-an-application-for-a-decision-in-principle-for-the-first-polish-nuclear-power-plant, accessed 1 August 2023.

432 - PEJ, "The Polskie Elektrownie Jądrowe company with a decision-in-principle for the first nuclear power plant in Poland", Press Release, Polskie Elektrownie Jądrowe, 12 July 2023.

433 - Westinghouse, "Historic Contract Paves the Way for Site Work on Poland's First Nuclear Power Plant", Press Release, 27 September 2023, see https://info.westinghousenuclear.com/news/historic-contract-paves-the-way-for-site-work-on-polands-first-nuclear-power-plant, accessed 19 January 2024.

434 - Sonal Patel, "Westinghouse, Bechtel Form Consortium to Design and Build Poland's First Nuclear Plant", *POWER Magazine*, 25 May 2023, see https://www.powermag.com/westinghouse-bechtel-form-consortium-to-design-and-build-polands-first-nuclear-plant/, accessed 6 June 2023.

office in December 2023.[435] While clearly in favor of nuclear power, before the election, Tusk reportedly agreed that the Polish nuclear power construction plan was "not based on a robust economic analysis and lacks a business plan."[436] The new administration announced that it was considering the implementation of a "Contracts for Difference" scheme together with the European Commission to "efficiently develop a business and financing model",[437] and also prompted an investigation into whether the target of first nuclear operations by 2033 was still achievable. New Climate and Environment Minister Paulina Hennig-Kloska said in February 2024 that the government doubted the ambitious target was achievable given the substantial delays that had already occurred during the previous government's legislative period.[438] Industry Minister Marzena Czarnecka stated in a radio interview in May 2024 that the earliest completion date of the Pomerania project would be in 2039 or 2040.[439] She also pointed out that the preceding government had been overly optimistic "without having much on the table".[440] After concerns were raised that the delay could lead to "an energy disaster", Czarnecka reiterated her statements saying that the target date of 2039 or 2040 referred to the whole plant's completion and that the first reactor was to come online by 2035 with construction to begin in 2028.[441]

The Polish Government seems to remain committed to the plant being built, with Deputy Climate and Environment Minister Meciej Bando affirming there was "a clear decision" to pursue, and that there was "no way today for us [the Polish Government] to stop the nuclear project."[442] In April 2024, PEJ's authorized representative Jan Chadam said that the final cost of the project was still not confirmed, but that current estimates now ranged at around PLN150 billion (US$ 37.9 billion),[443] a 90-percent increase over the figure indicated in November 2022.[444] In a meeting with Westinghouse CEO Patrick Fragman in April 2024,

435 - Andrew Higgins, "Who Is Donald Tusk, the Man Who Retook Power From Poland's Right-Wing Leaders?", *The New York Times*, 12 December 2023, see https://www.nytimes.com/2023/12/12/world/europe/donald-tusk-poland-prime-minister.html, accessed 31 May 202 .

436 - Grzegorz Adamczyk, "Polish opposition wants to potentially withdraw from Polish-US nuclear power deal if it comes to power", *Remix News*, 4 October 2023, see https://rmx.news/poland/polish-opposition-wants-to-potentially-withdraw-from-polish-us-nuclear-power-deal-if-it-comes-to-power/, accessed 31 May 2024.

437 - Kamen Kraev, "Poland / Government Considering Contracts For Difference Financing For First Nuclear Plant, Reports Say", *NucNet*, 24 January 2024, see https://www.nucnet.org/news/government-considering-contracts-for-difference-financing-for-first-nuclear-plant-reports-say-1-2-2024, accessed 30 May 2024.

438 - Marek Strzelecki, "Poland analyzes if nuclear plant will be ready by 2033 amid delays", *Reuters*, 13 February 2024, see https://www.reuters.com/business/energy/poland-analyzes-if-nuclear-plant-will-be-ready-by-2033-amid-delays-2024-02-13/, accessed 14 May 2024.

439 - Grzegorz Adamczyk, "Polish industry minister announces massive delay in nuclear power plant project", *Remix News*, 9 May 2024, see https://rmx.news/article/polish-industry-minister-announces-massive-delay-in-nuclear-power-plant-project/, accessed 30 May 2024.

440 - Marek Strzelecki, "Poland's first nuclear plant seen starting operations in 2040, minister says", *Reuters*, 7 May 2024, see https://www.reuters.com/world/europe/polands-first-nuclear-plant-seen-starting-operations-2040-minister-says-2024-05-07/, accessed 14 May 2024.

441 - Grzegorz Adamczyk, "Polish industry minister announces massive delay in nuclear power plant project", *Remix News*, May 2024, op. cit.

442 - Sung-woo Park and Su-hyeon Park, "Poland's new nuclear plant to boost S. Korean industry in Europe", *The Chosun Daily*, 5 March 2024, see https://www.chosun.com/english/industry-en/2024/03/05/C6F4HGDSHNC65ADSWNAUPXCWXY/ , accessed 30 May 2024.

443 - *PAP*, "Poland's first nuclear plant to cost approx. PLN 150 bln", *Market Insider*, 18 April 2024, see https://biznes.pap.pl/en/news/all/info/3578950,poland-s-first-nuclear-plant-to-cost-approx--pln-150-bln, accessed 30 May 2024.

444 - *Reuters*, "Poland's first nuclear power plant to cost around $20 bln - PM", 2 November 2022, op. cit.

Minister Hennig-Kloska emphasized "the importance of timely project implementation" while reiterating nuclear's essential role in her country's future energy mix.[445]

The distribution of roles in the project—especially that of Westinghouse—remains unclear. In early June 2024, the *Wall Street Journal* reported: "Westinghouse said it learned from its U.S. experience during the 2010s and no longer takes on reactor construction. (…) In Ukraine, Westinghouse said Energoatom will be responsible for construction of the new reactors […]"[446] In Bulgaria, South Korean company Hyundai is the main contractor, and Westinghouse is providing the technology and engineering. In Poland, Westinghouse has partnered up with U.S. construction giant Bechtel and the Polish state-owned PEJ, but who will actually sign up as the project management entity remains unclear, just as the financing package is yet to be established.

The Łódź Project

In parallel to the developments in Pomerania, in April 2022, KHNP submitted a bid for six APR-1400 reactors with a total of 8.4 GW and a first grid connection scheduled for 2033 in Pątnów, in the Łódź region of central Poland, at the site of a lignite power plant.[447] Polish utility Zespół Elektrowni Pątnów-Adamów-Konin (ZE PAK), PGE, and KHNP signed a letter of intent in October 2022 to develop plans for the project. On the same day, Poland's then-Minister of Assets, the former Deputy Prime Minister, and South Korea's Minister of Trade, Industry and Energy also signed an MoU "to support the nuclear energy project in [Pątnów] and tighten cooperation in the scope of necessary information exchange."[448]

This nuclear plant would constitute the second phase of the 6–9 GW nuclear capacity deployment envisioned in Poland's 2021 Nuclear Power Program. The project might come under E.U. investigation due to possible noncompliance with competition regulation that requires multiple equally treated bidders to be allowed to compete for such large infrastructure projects.[449] Regardless, ZE PAK and PGE announced in March 2023 that they would establish a joint venture to "represent the Polish side at all stages of the [Pątnów] project", then planned with at least two APR-1400 reactors to be delivered by KHNP and scheduled to be on the

445 - Ministry of Climate and Environment, "First nuclear power plant on schedule – meeting between Minister of Climate and Environment and Westinghouse Chief Executive Officer", Government of Poland, 11 April 2024, see https://www.gov.pl/web/climate/first-nuclear-power-plant-on-schedule--meeting-between-minister-of-climate-and-environment-and-estinghouse-chief-executive-officer, accessed 16 June 2024.

446 - Kim Mackrael Hiller James Marson, Nikita Nikolaienko and Jennifer, "The American Company Trying to Keep Ukraine's Nuclear Reactors Online", *The Wall Street Journal*, 7 June 2024, see https://www.wsj.com/world/the-american-company-trying-to-keep-ukraines-nuclear-reactors-online-e636917a, accessed 8 June 2024.

447 - Polski Atom, "Koreańska spółka KHNP złożyła polskiemu rządowi ofertę na budowę elektrowni jądrowych w Polsce", Government of Poland, 21 April 2022, see https://www.gov.pl/web/polski-atom/koreanska-spolka-khnp-zlozyla-polskiemu-rzadowi-oferte-na-budowe-elektrowni-jadrowych-w-polsce, accessed 12 June 2024.

448 - *WNN*, "South Korea's KHNP signs letter of intent on Polish nuclear", 31 October 2022, see https://www.world-nuclear-news.org/Articles/South-Korea-s-KHNP-signs-letter-of-intent-on-Polis; and ZE PAK, "ZE PAK, PGE and KHNP signed a letter of intent", Press Release, 31 October 2022, see https://www.zepak.com.pl/en/about-us/press-office/news/14036-ze-pak-pge-and-khnp-signed-a-letter-of-intent.html; both accessed 11 June 2024.

449 - WNA, "Nuclear Power in Poland", World Nuclear Association, Updated May 2023, see https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/poland.aspx, accessed 6 June 2023.

grid by 2035.[450] In April 2023, the 50-50 joint venture, named PGE PAK Energia Jądrowa, was established. In August 2023, it applied to the Polish Ministry of Climate for a "decision-in-principle" for two APR-1400 reactors,[451] which was granted in November 2023 by the acting Ministry of Climate and Environment, as it considered the project to be "in line with the public interest and the policies pursued by the state." This approval marks a first step in the Polish licensing process for nuclear facilities.[452]

Investment decision "very far away"

In January 2024, KHNP president Jooho Wang visited Warsaw for the grand opening of a three-person office. He announced that an agreement for a feasibility study for the project was to be signed by the end of March 2024 and that the financing scheme and EIA would conclude by 2025, allowing for an "ambitious but achievable" beginning of commercial operation of the first reactor by 2035.[453]

In late May 2024 however, ZE PAK president Dariusz Marzec said that the company was "very far away" from making an investment decision, given that the currently ongoing pre-feasibility studies would require several years to conclude. To begin with, the above-mentioned commissioning of a full-scale feasibility study had not happened.[454]

In an apparent attempt to force a legal declaration that KHNP's bid is based on Westinghouse technology, Westinghouse filed a lawsuit against KHNP and its owner Korea Electric Power Corporation (KEPCO) before the U.S. District Court for the District of Columbia[455] in October 2022.[456] The claim covered two major issues.

First, Westinghouse argued that KHNP was in contempt of U.S. nuclear technology export control requirements because, second, KHNP in its current design of nuclear reactors still uses

450 - ZE PAK, "PGE and ZE PAK will establish a company to implement a nuclear power plant construction project", 8 March 2023, see https://www.zepak.com.pl/en/about-us/press-office/news/14521-pge-and-ze-pak-will-establish-a-company-to-implement-a-nuclear-power-plant-construction-project.html; both accessed 6 June 2023.

451 - ZE PAK, "Establishment of PGE PAK Energia Jądrowa – construction of a nuclear power plant in Konin/Pątnów in the Greater Poland region", 13 April 2023, see https://www.zepak.com.pl/en/about-us/press-office/news/14646-establishment-of-pge-pak-energia-jadrowa-construction-of-a-nuclear-power-plant-in-koninpatnow-in-the-greater-poland-region.html; and *WNN*, "Approval sought for second large Polish nuclear power plant", 17 August 2023, see https://world-nuclear-news.org/Articles/Approval-sought-for-second-large-Polish-nuclear-po; both accessed 11 June 2024.

452 - Ministry of State Assets,"Minister Jacek Sasin: Przygotowaliśmy dobry program energetyki jądrowej, który powinny kontynuować kolejne rządy", Government of Poland, 27 November 2023 (in Polish), see https://www.gov.pl/web/aktywa-panstwowe/minister-jacek-sasin-przygotowalismy-dobry-program-energetyki-jadrowej-ktory-powinny-kontynuowac-kolejne-rzady; and *WNN*, "Second large Polish nuclear plant gets approval", *World Nuclear News*, 27 November 2023, see https://www.world-nuclear-news.org/Articles/Second-large-Polish-nuclear-plant-gets-approval, accessed 14 December 2023.

453 - *PAP*, "Koreański dostawca reaktorów urządza się w Polsce. Otworzył biuro w Warszawie", *Business Insider*, 18 January 2024 (in Polish), see https://businessinsider.com.pl/biznes/koreanski-dostawca-reaktorow-urzadza-sie-w-polsce-otworzyl-biuro-w-warszawie/2wgosql, accessed 30 May 2024.

454 - Robert Kędzierski, "Prezes PGE o elektrowni jądrowej: Decyzja o budowie z Koreańczykami jeszcze długo nie zapadnie", *Money.pl*, 28 May 2024 (in Polish), see https://www.money.pl/gospodarka/prezes-pge-o-elektrowni-jadrowej-decyzja-o-budowie-z-koreanczykami-jeszcze-dlugo-nie-zapadnie-7032465122233024a.html, accessed 31 May 2024.

455 - *NEI Magazine*, "Westinghouse tries to exclude South Korea from Poland's NPP project", 27 October 2022, see https://www.neimagazine.com/news/newswestinghouse-tries-to-exclude-south-korea-from-polands-npp-project-10122581, accessed 2 May 2023.

456 - Westinghouse, "Westinghouse Electric Company LLC, vs. Korea Electric Power Corp. and Korea Hydro & Nuclear Power Co. Ltd.—Complaint", Case 1:22-cv-03228-APM, before the United States District Court for the District of Columbia, filed 21 October 2022, as released on Jus Mundi, see https://jusmundi.com/en/document/other/en-korea-hydro-nuclear-power-co-ltd-and-korea-electric-power-corporation-v-westinghouse-electric-company-llc-complaint-friday-21st-october-2022#other_document_29139, accessed 11 June 2024.

technology it originally licensed from Westinghouse.[457] This regards ownership of "System 80 reactor technology" that was originally held by Combustion Engineering, a company that was taken over by Westinghouse in 2000.[458] Arguably, KHNP would require permission to export this technology, to which KHNP states that all necessary regulations had been followed.[459]

In January 2023, an attempt to reach an out of court settlement on technology licensing revolved around KHNP and KEPCO splitting their potential profits from a nuclear project with Westinghouse. [460] The parties had until 17 March 2023 to come to an agreement, but that did not happen.[461] In August 2023, the Korean Commercial Arbitration Board began assessing damages claimed by both sides, possibly amounting to several hundred millions of U.S. dollars.[462]

Regarding U.S. technology export regulations, in September 2023, the U.S. District Court of the District of Columbia ruled that export control enforcement lied solely with the U.S. Government, thus dismissing the case. Westinghouse filed a notice of appeal the following month and subsequently submitted a series of further documents to back their argumentation.[463]

The second issue, that of technology licensing, was not affected by this ruling. For this, the arbitration panel said a final ruling could be expected towards the end of 2025.[464] With the Czech Republic booting Westinghouse from their Dukovany II project (see Czech Republic Focus), rumors have emerged that the lawsuit might be dropped if Westinghouse were to be compensated accordingly.[465]

457 - David Dalton, "Westinghouse / Company Confirms Plans To Appeal US Court Ruling On South Korea Dispute", *NucNet*, 20 September 2023, see https://www.nucnet.org/news/company-confirms-plans-to-appeal-us-court-ruling-on-south-korea-dispute-9-3-2023, accessed 31 May 2024.

458 - *NEI Magazine*, "BNFL buys ABB's nuclear business", 28 January 2000, see https://www.neimagazine.com/news/newsbnfl-buys-abb-s-nuclear-business, accessed 1 August 2023.

459 - Jessica Sondgeroth, "Newbuild: Dispute Unresolved on Eve of Washington-Seoul Summit", *Energy Intelligence*, 14 April 2023, see https://www.energyintel.com/00000187-7bf7-dc4f-a7e7-7bf7b6b50000, accessed 6 June 2023.

460 - *NEI Magazine*, "South Korea seeks to end dispute with Westinghouse", 12 January 2023, see https://www.neimagazine.com/news/newssouth-korea-seeks-to-end-dispute-with-westinghouse-10511335, accessed 23 August 2023.

461 - Ibidem; and Westinghouse Electric Company, and Korea Electric Power Corp. and Korea Hydro & Nuclear Power Co., Ltd., "Joint Motion to Stay Proceedings Pending Settlement Negotiations", Case No. 1:22-cv-03228-APM, before the United States District Court for the District of Columbia, filed 10 January 2023, as released on *Jus Mundi*, see https://jusmundi.com/en/document/pdf/other/en-korea-hydro-nuclear-power-co-ltd-and-korea-electric-power-corporation-v-westinghouse-electric-company-llc-joint-motion-to-stay-proceedings-pending-settlement-negotiations-tuesday-10th-january-2023, accessed 7 November 2023; also *NEI Magazine*, "US stalls South Korea's NPP export plans", 11 April 2023, see https://www.neimagazine.com/news/newsus-stalls-south-koreas-npp-export-plans-10747925, accessed 23 August 2023.

462 - Jin-Seong Kim and Han-Shin Park, "Westinghouse, KHNP seek licensing dispute arbitration", *The Korea Economic Daily*, 2 August 2023, see https://www.kedglobal.com/energy/newsView/ked202308020008, accessed 29 August 2023.

463 - Westinghouse, "Notice of Appeal", Case No. 1:22-cv-03228, before the United States District Court for the District of Columbia, filed 16 October 2023, as published on *Jus Mundi*, see https://jusmundi.com/en/document/other/en-korea-electric-power-corporation-and-korea-hydro-nuclear-power-co-ltd-v-westinghouse-electric-company-llc-notice-of-appeal-monday-16th-october-2023#other_document_34882, accessed 11 June 2024.

464 - David Dalton, "Westinghouse / Company Confirms Plans To Appeal US Court Ruling On South Korea Dispute", *NucNet*, September 2023, op. cit.

465 - 김동현 기자, "美웨스팅하우스, 체코 원전입찰 탈락 뒤에도 한수원과 계속 소송 ["US Westinghouse continues litigation with Hansoo after losing Czech nuclear bid»]", *Yonhap News Agency* with *Reuters*, 27 February 2024 (in Korean), see https://www.yna.co.kr/view/AKR20240227014300071, accessed 31 May 2024.

Perspectives for Small Modular Reactor (SMR) Deployment

Plans for a third high-capacity power plant were being discussed until at least August 2023,[466] but are currently supposedly on hold.[467] However, in addition to negotiations regarding potential orders of large reactors, Poland is eyeing the possibility of investing into the deployment of Small Modular Reactors (SMRs). In a 2023 study by the Polish Economic Institute, 47 "experts" were interviewed regarding the potential future role of SMRs in Poland. A majority said that SMRs might be relevant for heat production, and 42 percent believe that more than 5 GW of SMR capacity will have been installed in Poland by 2045, all while acknowledging that this "is too little [to be considered] a [...] significant contribution to the energy trawnsition."[468]

Meanwhile, various cooperation agreements have been signed. In September 2021, SMR developer NuScale signed an MoU with Polish mining company KGHM and engineering firm Piela Business Engineering (PBE).[469] In July 2023, the project was granted first approval by the responsible Climate and Environment Ministry, theoretically allowing the project to move to the next administrative steps, including siting decisions and building permits.[470] Although the administrative procedures are ongoing[471] and KGHM stated that cooperation with NuScale continues as planned,[472] the termination of NuScale's Utah project in November 2023 increases uncertainty about the project's viability (see United States in chapter on SMRs).

In June 2022, Polish state-owned company Enea S.A. and U.S. SMR developer Last Energy agreed to cooperate on the deployment of SMRs.[473] In March 2023, after contracting power purchase agreements with industrial partners of Poland's Katowice Special Economic Zone and in the U.K., totaling over US$4.3 billion in electricity sales and US$1 billion in infrastructure investments, Last Energy felt optimistic enough to announce the deployment of ten 20 MWe "Micro Modular Nuclear Power Plants" with the (extremely unlikely) target of commissioning

466 - *Money.pl*, "Trzecia elektrownia atomowa w Polsce. Wiceminister zabiega głos ws. lokalizacji", 17 August 2023 (in Polish), see https://www.money.pl/gospodarka/trzecia-elektrownia-atomowa-w-polsce-wiceminister-zabiega-glos-ws-lokalizacji-6931565804112800a.html, accessed 31 May 2024.

467 - Robert Kędzierski, "Prezes PGE o elektrowni jądrowej: Decyzja o budowie z Koreańczykami jeszcze długo nie zapadnie", *Money.pl*, 28 May 2024, op. cit.

468 - Adam Juszczak, "Prospects for the use of SMRs in Poland's energy transition", Polish Economic Institute, August 2023, see https://pie.net.pl/wp-content/uploads/2023/09/Reaktory-SMR-ENG.pdf, accessed 2 July 2024.

469 - NuScale, "NuScale Power Signs Memorandum of Understanding with KGHM and PBE to Explore SMR Deployment in Poland", Press Release, 23 September 2021, see https://nuscale-prod-mamkgy89m-nuscale-power.vercel.app/news/press-releases/2021/nuscale-signs-mou-with-kghm-and-pbe, accessed 24 July 2024.

470 - KGHM, "KGHM has received the basic decision regarding the construction of a small modular reactor (SMR) power plant", Press Release, 13 July 2023, see https://media.kghm.com/en/news-and-press-releases/kghm-has-received-the-basic-decision-regarding-the-construction-of-a-small-modular-reactor-smr-power-plant, accessed 24 July 2024.

471 - PAA, "Second opinion of the President of the PAA on the application of KGHM Polska Miedź S.A.", Państwowa Agencja Atomistyki/National Atomic Energy Agency of Poland, 26 April 2024, see https://www.gov.pl/web/paa-en/second-opinion-of-the-president-of-the-paa-on-the-application-of-kghm-polska-miedz-sa, accessed 12 June 2024.

472 - KGHM, "KGHM categorically denies media reports which allege that cooperation with the company NuScale has been terminated", Press Release, 10 November 2023, see https://media.kghm.com/en/news-and-press-releases/kghm-categorically-denies-media-reports-which-allege-that-cooperation-with-the-company-nuscale-has-been-terminated, accessed 24 July 2024.

473 - *WNN*, "Poland expands cooperation on SMRs and large reactors", 23 June 2022, see https://www.world-nuclear-news.org/Articles/Poland-expands-cooperation-on-SMRs-and-large-react, accessed 23 June 2022; and Last Energy, "Last Energy, Enea Group to Develop Small Modular Nuclear Reactors, As Polish Government Prioritizes Energy Security and Net-Zero Goals", Press Release, as published on *GlobeNewswire*, 23 June 2022, see https://www.globenewswire.com/news-release/2022/06/23/2468500/0/en/Last-Energy-Enea-Group-to-Develop-Small-Modular-Nuclear-Reactors-As-Polish-Government-Prioritizes-Energy-Security-and-Net-Zero-Goals.html, accessed 11 June 2024.

a first plant by 2026 to provide customers with electricity and heat.[474] The reactor design is not licensed anywhere yet.

In April 2023, the U.S. Export-Import Bank and the U.S. International Development Finance Corporation both signed letters of interest to provide loans, up to US$3 billion and US$1 billion, respectively, to the ORLEN Synthos Green Energy (OSGE) project that as of April 2023 envisioned the construction of up to 20 GE Hitachi (GEH) BWRX-300 reactors in Poland, with the startup of the first one ambitiously scheduled for 2029.[475] The BWRX-300 design is not licensed anywhere in the world and is currently in the pre-licensing phase in Poland.[476]

In September 2023, OSGE was also selected to receive funds from the U.S. Department of State for "Coal-to-SMR" feasibility studies under "Project Phoenix".[477] On 7 December 2023, six projects at Włocławek, Stawy Monowskie, Stalowa Wola, Ostrołęka, Nowa Huta, and Dąbrowa Górnicza, envisioning up to 24 individual reactors on the grid by 2030, received approval-in-principle from the Climate and Environment Ministry, only a few days before the new government came into power.[478]

Then in May 2024, the Ministry of Climate and Environment granted a "decision-in-principle" for Polish state-owned Industria's plans to use a Rolls-Royce SMR at their "Central Hydrogen Cluster", a cooperation that had been announced in February 2023.[479] In March 2024, a letter of intent had also been signed between Industria and U.K. company Chiltern Vital Group to collaborate on the project.[480]

This decision brings the total number of SMR-based initiatives with principal government approval to three, none of them licensed anywhere in the world:

474 - Last Energy, "Last Energy Announces Fleet of 34 Micro Modular Nuclear Power Plants Across UK and Poland, Supporting Industry With Zero Carbon Baseload Power", Press Release, 20 March 2023, see https://www.lastenergy.com/news-press/last-energy-announces-fleet-of-34-micro-modular-nuclear-power-plants-across-uk-and-poland-supporting-industry-with-zero-carbon-baseload-power, accessed 10 September 2024.

475 - Monika Scislowska, "US ready to lend Poland $4 billion for nuclear energy plan", *The Associated Press*, 17 April 2023, see https://apnews.com/article/nuclear-energy-us-poland-221e7fcbe13bba60bd872929a9c822aa; and EXIM, "Export-Import Bank of the United States Issues a $3B Letter of Interest for U.S. Nuclear Exports to Poland", Press Release, Export-Import Bank of the United States, 17 April 2023, see https://www.exim.gov/news/export-import-bank-united-states-issues-3b-letter-interest-for-nuclear-exports-poland; also OSGE, "US government financial institutions indicate willingness to support ORLEN Synthos Green Energy with its GE Hitachi BWRX-300 small modular reactor deployment program in Poland", ORLEN Synthos Green Energy, Press Release, 17 April 2023, see https://osge.com/en/us-government-financial-institutions-indicate-willingness-to-support-osge/; all accessed 11 June 2024.

476 - Monika Scislowska, "US ready to lend Poland $4 billion for nuclear energy plan", *The Associated Press*, 17 April 2023, see https://apnews.com/article/nuclear-energy-us-poland-221e7fcbe13bba60bd872929a9c822aa, accessed 19 April 2023.

477 - U.S. Department of State, "Special Presidential Envoy for Climate Kerry Announces Project Phoenix Participants and the Nuclear Expediting the Energy Transition (NEXT) Program", Press Release, 7 September 2023, see https://www.state.gov/special-presidential-envoy-for-climate-kerry-announces-project-phoenix-participants-and-the-nuclear-expediting-the-energy-transition-next-program/; and OSGE, "OSGE selected to the Project Phoenix by the U.S. Department of State", 9 November 2023, see https://osge.com/en/osge-selected-to-the-project-phoenix-by-the-u-s-department-of-state/; both accessed 12 June 2024.

478 - Alan Charlish, "Poland approves construction of SMR nuclear units at six sites", *Reuters*, 7 December 2023, see https://www.reuters.com/sustainability/climate-energy/poland-approves-construction-smr-nuclear-units-six-sites-2023-12-07/, accessed 30 May 2024; and OSGE, "OSGE obtained six decisions-in-principle", 7 December 2023, see https://osge.com/en/osge-obtained-six-decisions-in-principle/, accessed 11 June 2024.

479 - Ministerstwo Klimatu i Środowiska, "Decyzja zasadnicza MKiŚ dot. budowy elektrowni jądrowej z zastosowaniem reaktorów modułowych typu SMR", Ministry of Climate and Energy, 13 May 2024 (in Polish), see https://www.gov.pl/web/klimat/decyzja-zasadnicza-mkis-dot-budowy-elektrowni-jadrowej-z-zastosowaniem-reaktorow-modulowych-typu-smr; and Rolls-Royce SMR, "Industria selects Rolls-Royce SMR for use in Polish green energy projects", Press Release, 8 February 2023, see https://www.rolls-royce-smr.com/press/industria-selects-rolls-royce-smr-for-use-in-polish-green-energy-projects; both accessed 11 June 2024.

480 - Central Hydrogen Valley, "CVG and INDUSTRIA: Polish-British cooperation to implement Rolls-Royce SMR technology", Industria, 13 March 2024, see https://h2cluster.eu/cvg-and-industria-polish-british-cooperation-to-implement-rolls-royce-smr-technology/, accessed 11 June 2024.

- July 2023: Mining company KGHM Polska Miedź SA plans to construct a six-module NuScale VOYGR as of 2029 (~ 460 MW);
- December 2023: OSGE project envisions the construction of 24 GEH BWRX-300 reactors at six sites by 2030 (~ 7.2 GW);
- May 2024: Industria plans to deploy up to three 470 MW Rolls-Royce SMR in the 2030s.

Polish SMR proponents envision a vast expansion of capacities. In February 2023, ORLEN reportedly announced it was planning to install a total of 79 GEH BWRX-300 reactors at 26 locations by 2038.[481] As of June 2024, three sites of the OSGE project, namely Stawy Monowskie, Włocławek, and Ostrołęka, totaling up to 4.6 GW or 15 reactors, had entered environmental proceedings with GDOŚ to establish the required scope of Environmental Impact Assessment (EIA) Reports, while applications had yet to be filed for the remaining three sites.[482] Applications for Włocławek and Ostrołęka have been under GDOŚ-review since August and September 2023, respectively, while Stawy Monowskie is the only site that received a decision on the required scope of its environmental report.[483] Upon its issuance in February 2024, OSGE announced it was starting to carry out "environmental and location studies at [the] Stawy Monowskie site necessary for the preparation of the Environmental Impact Assessment Report." According to the company, about two years can be expected to pass until completion of the EIA report.[484]

Additionally, the Polish Atomic Energy Agency (PAA) announced it would be joining the Joint Early Review of the French Nuward SMR project.[485] In July 2024 however, EDF announced that the Nuward project would be scrapped and a whole new design would be drafted (see France in chapter on SMRs).[486]

These expansive newbuild ambitions stand against a Polish electricity system dominated by coal, which contributed 61 percent to the electricity mix in 2023, followed by wind (13.7 percent), natural gas (8.7 percent), and solar (7.3 percent). The remainder was generated through various other fossil and renewable sources such as bioenergy and hydro. A total of 168.8 TWh were produced that year.[487]

481 - *WNN*, "Polish universities launching nuclear courses, as PKN Orlen plans 79 SMRs", 2 February 2023, see https://www.world-nuclear-news.org/Articles/Polish-universities-launching-courses-ahead-of-rap, accessed 4 February 2023.

482 - OSGE, "Three enviromnental proceedings in progress", 1 September 2023, see https://osge.com/en/three-enviromnental-proceedings-in-progress/, accessed 11 June 2024; and BMUV, "Grenzüberschreitende Umweltverträglichkeitsprüfungen (UVP) zum Bau von Small Modular Reactors (SMR) in Polen- BMUV - Meldung", Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz/Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection of Germany, March 2024, see https://www.bmuv.de/ME10946, accessed 31 May 2024.

483 - GDOŚ/GDEP, "Zawiadomienie Generalnego Dyrektora Ochrony Środowiska z 1 lutego 2024 r., znak: DOOŚ-WDŚZOO.420.23.2023.AKA.24", 1 February 2024, see https://www.gov.pl/web/gdos/zawiadomienie-generalnego-dyrektora-ochrony-srodowiska-z-1-lutego-2024-r-znak-doos-wdszoo42023202 3aka24, accessed 11 June 2024.

484 - OSGE, "OSGE with the scope of the environmental report for the first SMR project", 2 February 2024, see https://osge.com/en/osge-with-the-scope-of-the-environmental-report-for-the-first-smr-project/, accessed 12 June 2024.

485 - PAA, "National Atomic Energy Agency joins JER Phase 2 of NUWARD SMR project", Państwowej Agencji Atomistyki/National Atomic Energy Agency of Poland, 21 December 2023, see https://www.gov.pl/web/paa-en/national-atomic-energy-agency-joins-jer-phase-2-of-nuward-smr-project, accessed 31 May 2024.

486 - America Hernandez, "France's EDF to redraft small modular reactor design amid cost, technology concerns", *Reuters*, 1 July 2024, see https://www.reuters.com/business/energy/frances-edf-drops-plans-develop-its-own-small-nuclear-reactor-technology-2024-07-01/, accessed 1 July 2024.

487 - Ember, "Electricity Data Explorer—Poland electricity generation by source", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 31 May 2024.

The extension of onshore wind capacities ceased in 2016 when restrictive distance laws ("10H legislation") essentially brought onshore newbuild to a standstill. By 2022, only a total of about 8 GW had been installed. A 2022-amendment of the law might foster some project development; an additional 1.4 GW were installed in 2023, bringing total onshore wind capacity to 9.3 GW.[488] The previous government's target had lain at only 14 GW by 2030 and 20 GW by 2040. The first offshore wind farm is expected to come online in 2026, and a total of 12 GW of offshore capacity is planned.[489]

In comparison, solar energy is rapidly gaining significance. Throughout 2023, solar capacity grew from 12.17 GW in 2022, to 15.8 GW, a 30 percent increase.[490] In 2023, solar contributed 7.3 percent to the national power consumption, a 17-fold increase of the solar share in four years.[491] Estimates from November 2023 expect 27 GW of solar capacity to be reached as early as 2025.[492] Coincidentally, a few months earlier, per provisional government announcements, this was to be the target featured in the Polish Energy Strategy for… 2030.[493]

In March 2024, the new government published a draft for the update of Poland's National Energy and Climate Plan (NECP) and is currently working on reversing regulatory hurdles put in place by its predecessors.[494] It now aims to achieve at least 50 percent of renewables in the 2030 electricity mix, with Prime Minister Tusk having promised 68 percent during his election campaign.[495] Meanwhile, on 19 June 2022, renewables already covered 67 percent of the electricity demand in Poland.[496]

488 - WWEA, "WWEA Annual Report 2023", World Wind Energy Association, April 2024, see https://wwindea.org/ss-uploads/media/2024/3/1711538106-40ab83f2-3e01-4c0a-9d28-e0a21bff72e6.pdf, accessed 24 July 2024.

489 - Polish Wind Energy Association, TPA Poland, Baker Tilly Poland and DWF, "Wind Energy in Poland 2023", May 2023, see http://psew.pl/wp-content/uploads/2023/06/Energetyka-wiatrowa-w-Polsce_2023_internet.pdf, accessed 24 August 2023.

490 - IRENA, "Renewable Capacity Statistics 2024", International Renewable Energy Agency, March 2024, op. cit.

491 - Ember, "Electricity Data Explorer", 2024.

492 - Emilliano Bellini, "Poland's grid-connected PV project pipeline hits 18 GW", *pv magazine*, 9 November 2023, see https://www.pv-magazine.com/2023/11/09/polands-grid-connected-pv-project-pipeline-hits-18-gw/, accessed 31 May 2024.

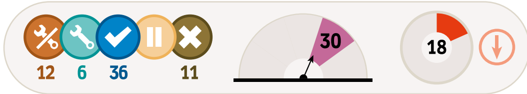
493 - IEO, "Photovoltaic Market in Poland 2023 - Summary", Instytut Energetyki Odnawialnej/Institute for Renewable Energy, 2023, see https://ieo.pl/en/pv-report/pv-report-2023, accessed 21 July 2023.

494 - Ministry of Climate and Environment of Poland, "National Plan in the field of energy and Climate by 2030 (2019 update of NECPs)", Preliminary Version, February 2024, see https://commission.europa.eu/document/download/5118b15e-d380-49ae-b8bb-41cc81a28e15_en?filename=PL_NECPupdate_Projekt_EN.pdf, accessed 31 May 2024.

495 - Nathan Canas, "Departing from coal: Poland's new energy roadmap", *Euractiv*, 7 March 2024, see https://www.euractiv.com/section/energy/news/departing-from-coal-polands-new-energy-roadmap/, accessed 31 May 2024.

496 - Alicja Ptak, "Renewables met record 67% of Poland's power demand on Sunday", *Notes From Poland*, 22 June 2022, see https://notesfrompoland.com/2022/06/22/renewables-met-record-67-of-polands-power-demand-on-sunday/, accessed 17 June 2024.

RUSSIA FOCUS



"Russia is one of the few countries without a populist energy policy favoring wind and solar generation; the priority is unashamedly nuclear"

World Nuclear Association, March 2024[497]

In 1954, Russia was the first country to produce nuclear electricity for the grid. Since then, Russia has significantly influenced the global industry and turned into the largest exporter of reactors, currently constructing 26 units (20 outside the country) of the world's total of 59 projects in active building, as of 1 July 2024.

In 2023, nuclear energy contributed 18.4 percent of the country's power mix, generating 204 TWh of electricity, down from a record 209.5 TWh in 2022. With no additional reactor startups in 2023, as of mid-2024, 36 reactors were operating, with eleven permanently closed, the latest being Kursk-2, which generated its last kWh on 31 January 2024.[498]

Russia has the fourth largest nuclear power fleet, with 36 reactors across six classes: the RBMK, a graphite-moderated reactor of the Chornobyl type (7 units); VVER-440 (5 units); VVER-1000 (13 units); VVER-1200 (4 units); EGP-6, a Light-Water Gas-cooled Reactor (3 units); the KLT-40 (2 units); and FBRs (2 units). (See Annex 4.)

Russia is also one of the world's largest producers of fossil fuels and a significant exporter of oil, coal, and gas globally. Russia's economy is highly dependent on its fossil fuel exports and is consequently significantly impacted by fossil fuel prices on the global market. Europe, primarily the E.U., was Russia's largest customer and has sought to rapidly reduce its dependency following Russia's full-scale invasion of Ukraine in 2022, with the E.U. pledging to no longer import any gas by 2027.[499] Prior to 2022, Russia had provided around 40 percent of the E.U.'s gas imports. While Russia has relatively easily found new markets for its oil and coal to make up for shrinking demand from the E.U., it has struggled to divert its gas supply to new customers, leading to a fall in domestic production. Due to a lack of infrastructure, Russian gas exports to the E.U. will likely not be able to find new offtakes for the next five to ten years, according to some estimates.[500] The expansion of the nuclear sector was partly driven by a desire to substitute gas as a domestic electricity supply source, in turn making larger volumes available for export.

Russia is the fourth largest producer of greenhouse gas emissions, and in its approach to COP26 (2021), Russia adopted a net zero target by 2060. However, the Climate Analytics institute stated that the short-term climate change mitigation target would "not represent an increase in ambition as government projections show Russia will achieve this target under current

497 - WNA, "Nuclear Power in Russia", World Nuclear Association, March 2024, see https://world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power, accessed 12 July 2024.

498 - Rosenergoatom, "Power unit No. 2 of the Kursk NPP was taken out of power generation mode after 45 years of successful operation", 1 February 2024, see https://www.rosenergoatom.ru/en/for-journalists/highlights/45620/, accessed 6 August 2024.

499 - European Commission, "REPowerEU Actions", May 2022, see https://ec.europa.eu/commission/presscorner/api/files/attachment/873247/FS%20RePower%20EU%20Actions_EN.pdf, accessed 6 August 2024.

500 - Kamila Godzinska and Maria Pastukhova, "Russia's Climate Action and Geopolitics of Energy Transition: The Uncertain and Unsettling Outlook following Russia's Invasion of Ukraine", Istituto Affari Internazionali, 2022, see https://www.iai.it/sites/default/files/iaip2221.pdf, accessed 12 July 2024.

unambitious policies."[501] Moreover, the use of solar and wind is extremely low accounting for only 0.45 percent of the electricity mix, which is "significantly below the global average of 13%" per Ember.[502] This approach has been praised by some in the nuclear industry (see WNA quote above).

Nuclear Newbuild

There are six reactors under construction in or for Russia, including a barge built in China to house two reactors destined for Russia.

Two large units are under construction at Kursk II, which are to replace the four RBMK reactors at the site, two of which have already closed, and the last one is to close by 2031. These will be the first of the latest Russian designs (Generation III+), the VVER-TOI (VVER-V-510) with a capacity of 1200 MW, which are also earmarked for export. When construction started on Unit 1 in April 2018, completion was scheduled for 2022, a deadline which has already been breached, as certainly will the expected budget of around US$3.5 billion.[503] In November 2022, plant director Alexander Uvakin said, "We hope that 2024-2025 will see the physical startup and commercial operation of the first and then the second unit of the Kursk-II NPP."[504] In June 2024, it was reported that the first turbine of Unit 1 was being installed, which is a "key operation" of commissioning[505] and usually takes 1–2 years altogether,[506] and the first batch of fuel was delivered.[507] The grid connection of the power plant is expected in March 2025. In February 2023, public hearings began on the planned construction of Units 3 and 4.[508]

Construction of an innovative SMR fast reactor design using liquid lead as a coolant and uranium-plutonium nitride for fuel started in June 2021.[509] The objective for the BREST-

501 - Climate Analytics, "What is Russia's pathway to limit global warming to 1.5°C?", 1 June 2021, see https://1p5ndc-pathways.climateanalytics.org/countries/russia/, accessed 13 July 2024.

502 - Ember, "Russia | Electricity Trends", Updated May 2024, see https://ember-climate.org/countries-and-regions/countries/russia/, accessed 12 July 2024.

503 - WNISR, "Construction Start at the First Unit of Kursk-II in Russia", 11 May 2018, see https://www.worldnuclearreport.org/Construction-Start-at-the-First-Unit-of-Kursk-II-in-Russia.html, accessed 8 August 2024; and *Power Technology*, "Kursk II Nuclear Power Plant", 5 June 2023, see https://www.power-technology.com/projects/kursk-ii-nuclear-power-plant/, accessed 16 July 2023.

504 - *NEI* Magazine, "Russia's Kursk unit 2 to be permanently closed in 2024", *Nuclear Engineering International*, 9 November 2022, see https://www.neimagazine.com/news/newsrussias-kursk-unit-2-to-be-permanently-closed-in-2024-10280637, accessed 12 July 2024.

505 - *NEI Magazine*, "Turbine installation begins at unit 1 of Kursk-II NPP", 7 June 2024, see https://www.neimagazine.com/news/turbine-installation-begins-at-unit-1-of-kursk-ii-npp/, accessed 12 July 2024.

506 - Eberhard Grauf, "Commissioning Phase", Se-engineering GmbH, in Agustín Alonso et. al, "Infrastructure and Methodologies for the Justification of Nuclear Power Programmes", *Woodhead Publishing*, 2012, see https://www.sciencedirect.com/topics/engineering/commissioning-phase, accessed 12 July 2024.

507 - Rosenergoatom, "The first batch of nuclear fuel for the replacement station under construction was delivered to the site of the operating Kursk NPP", 18 June 2024, see https://www.rosenergoatom.ru/en/for-journalists/news/46532/, accessed 8 August 2024.

508 - *NEI Magazine*, "Public hearings to begin on construction Kursk-II NPP units 3&4", 17 February 2023, see https://www.neimagazine.com/news/public-hearings-to-begin-on-construction-kursk-ii-npp-units-34-10604904/, accessed 12 July 2024; and Rosatom, "Прошли общественные обсуждения материалов обоснования лицензии на размещение в регионе энергоблоков № 3 и № 4 Курской АЭС-2", Press Release (in Russian), 15 March 2023, see https://rosatom.ru/journalist/news/proshli-obshchestvennye-obsuzhdeniya-materialov-obosnovaniya-litsenzii-na-razmeshchenie-v-regione-en/? , accessed 8 August 2024.

509 - TVEL "Rosatom starts construction of unique power unit with BREST-OD-300 fast neutron reactor", Press Release, Rosatom, 8 June 2021, see https://www.tvel.ru/en/press-center/news/?ELEMENT_ID=8787, 10 July 2021.

OD-300 reactor is to start up in 2027,[510] and it is said to cost RUB100 billion (US$$_{2021}$1.4 billion).[511] If achieved, that would be an impressive performance given that it is the first of its kind, but the project is not there yet.

In June 2020, Rosatom announced that preparation work had begun for the construction of four new reactors, Units 3 and 4 at Leningrad II (also referred to as Leningrad NPP Units 7 and 8 when including the existing reactors) as well as two reactors at Smolensk II, all four meant to replace existing RBMK reactors nearby.[512] In December 2022, concrete was poured for the first buildings of the future units at Leningrad.[513] The construction of Unit 7 formally began with the concreting of the reactor building's foundation in March 2024, slightly ahead of schedule.[514] Construction on Unit 8 is scheduled to start in May 2025, with startups planned for Unit 7 in 2030 and Unit 8 in 2032. Reportedly, the Smolensk units are expected to be built later, with the concreting of the reactor buildings only scheduled for March 2027.[515]

In August 2022, Rosatom announced the keel-laying ceremony—considered as construction start for floating reactors—in China of the first Arctic-type Nuclear Floating Power Unit (NFPU) to be equipped with two RITM-200C reactors and to be deployed in Russia in the framework of the Cape Nagloynyn project.[516] The completed barge was supposed to be delivered to Russia before the end of 2023,[517] but no information on the project's progress has been published over the past two years.

In June 2023, Rosatom signed an agreement with TSS Group (a Russian oil and gas construction group) to jointly build floating reactors for export to the Middle East, Asia, and Africa.[518]

In March 2021, in its strategic review, Rosatom said that nuclear energy should provide 25 percent of the country's electricity by 2045.[519] Russian President Vladimir Putin reiterated this target at the launch of construction of the most recent Leningrad unit.[520] According to

510 - Rosatom, "Росатом Госкорпорация «Росатом» ядерные технологии атомная энергетика АЭС ядерная медицина", 8 June 2021, see https://rosatom.ru/journalist/smi-about-industry/glava-magate-nazval-stroitelstvo-reaktora-brest-prodvizheniem-mirovoy-atomnoy-industrii/?sphrase_id=5794674, accessed 10 August 2024.

511 - Gary Peach, "Construction Starts on Lead-Cooled Fast Reactor", *Nuclear Intelligence Weekly*, 11 June 2021.

512 - Rosatom, "Four New NPP Units Will be Built in Russia", Press Release, 26 June 2020, see https://rosatom-europe.com/en/press-centre/news/four-new-npp-units-will-be-built-in-russia/, accessed 8 August 2024.

513 - Rosatom, "Ленинградская АЭС: на стройплощадке энергоблоков № 7 и № 8 приступили к заливке фундамента насосной станции", Press Release (in Russian), 21 December 2022, see https://www.rosatom.ru/journalist/news/leningradskaya-aes-na-stroyploshchadke-energoblokov-7-i-8-nachato-sooruzhenie-nasosnoy-stantsii/?, accessed 8 August 2024.

514 - Rosatom, "Main construction stage started at Leningrad NPP Unit 7", Press Release, 15 March 2024, see https://www.rosatom.ru/en/press-centre/news/-main-construction-stage-started-at-leningrad-npp-unit-7/, accessed 19 March 2024; and *NEI Magazine*, "Leningrad NPP units 7&8 to start construction in 2024/5", June 2022, see https://www.neimagazine.com/news/leningrad-npp-units-78-to-start-construction-in-20245-9759028/, accessed 8 August 2024.

515 - *NEI Magazine*, "New units planned for Russia's Smolensk NPP", *Nuclear Engineering International*, 10 February 2023, see https://www.neimagazine.com/news/new-units-planned-for-russias-smolensk-npp-10584756/, accessed 12 July 2024.

516 - Rosatom, "Keel-laying ceremony for the first Arctic-type Floating Power Unit with RITM-200 transport reactor vessels", Press Release, 30 August 2022, see https://rosatom-mena.com/press-centre/news/keel-laying-ceremony-for-the-first-arctic-type-floating-power-unit-with-ritm-200-transport-reactor-v/, accessed 12 July 2024.

517 - *PortNews,* "Keel-laying of first Arctic floating power unit with RITM-200 reactors held in China", 30 August 2022.

518 - Rosatom, "ROSATOM will establish a joint venture for the construction of energy fleet based on nuclear floating power units for overseas markets", 15 June 2023, see https://rosatom.ru/en/press-centre/news/rosatom-will-establish-a-joint-venture-for-the-construction-of-energy-fleet-based-on-nuclear-floatin/, accessed 8 August 2024.

519 - Rosatom, "К 2045 году доля атомной энергетики в энергобалансе России должна достичь 25%", Страна РОСАТОМ, 9 March 2021, see https://strana-rosatom.ru/2021/03/09/k-2045-godu-dolya-atomnoj-energetiki-v-ener/, accessed 14 August 2024.

520 - Rosatom, "Main Construction Stage Started at Leningrad NPP Unit 7", 15 March 2024, op. cit.

Rosatom CEO Alexey Likhachev, this will require the commissioning of 24 blocks, including at new sites and in new regions. Rosatom reiterated these intentions in May 2022. According to the World Nuclear Association (WNA), the list of sixteen new reactors in the official plan up to 2035 includes:

- Baimsky GOK: four modernized FNPP units (RITM-200 reactors);
- Beloyarsk: Unit 5 (BN-1200M fast reactor);
- Kola-II: Unit 1 (VVER-S or VVER-600 reactor);
- Kursk-II: Units 1–4 (VVER-TOI reactors);
- ODEK in Seversk: BREST-OD-300;
- Leningrad-II: Units 3 & 4 (VVER-1200 reactors);
- Smolensk-II: Units 1 & 2 (VVER-TOI reactors); and
- a Small Modular Reactor in Yakutia: Unit 1 (RITM-200 reactor).[521]

A number of these will be at or close to existing nuclear power plant sites but also at three new sites: Baimsky and Yakutia in the far East and the proposed Seversk facility in the Tomsk Oblast, a closed city and site of military nuclear facilities. It is also important to note the range of reactor designs being considered, a strategy that makes it significantly more challenging to reach economies of scale.

Russia has closed eleven power-generating reactors: Beloyarsk-1 and -2, Bilibino-1, Leningrad-1 and -2, Kursk-1 and 2, Novovoronezh-1–3, and Obninsk-1, with a further ten units to potentially close by 2030 without operating lifetime extensions,[522] which will make it more difficult to meet the target of generating 25 percent of power from nuclear by 2030.

The Russian reactor fleet is aged 30.5 years on average as of mid-2024, with two-thirds of its reactors being 31 years or older, of which 10 operated for 41 years or more and 2 for 51 years or more (see Figure 40). Therefore, a vital issue for the industry is managing its aging units. For example, Rosatom has proposed to extend the operating lives of the 2nd generation of RBMK reactors from 45 to 50 years.[523]

However, aging is not just a problem for the nuclear sector; the average age of the country's 68 coal plants stood at 41 years in 2020.[524]

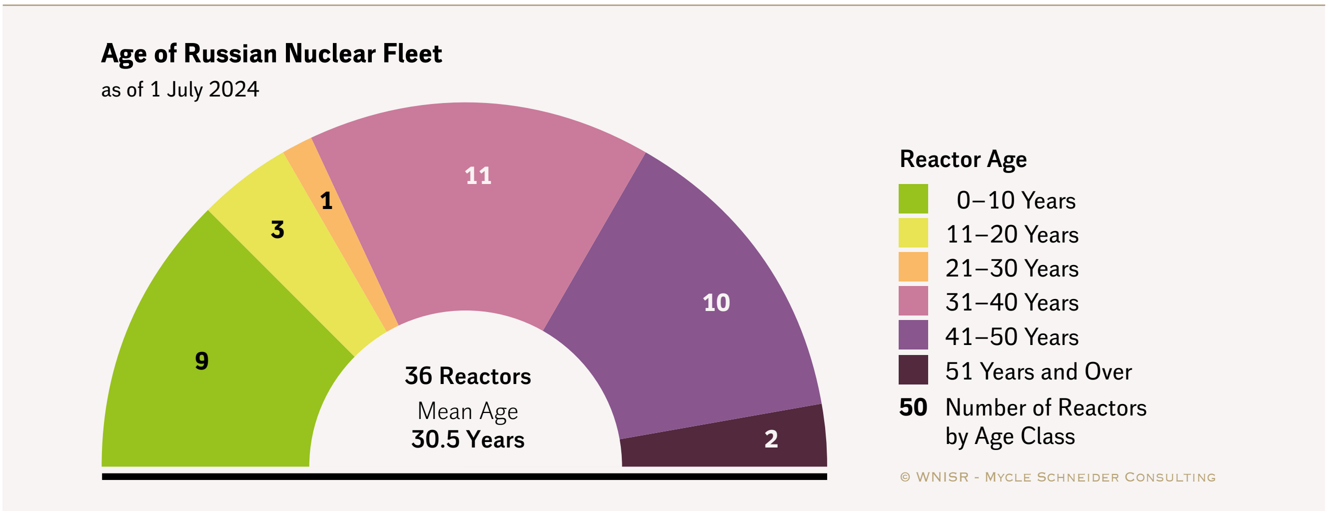
521 - WNA, "Nuclear Power in Russia", Updated March 2024, see https://world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-powerhttps://world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power, accessed 8 August 2024.

522 - Ibidem.

523 - *NEI Magazine*, "Life extension for Russia's second generation RBMK reactors", 12 July 2024, see https://www.neimagazine.com/news/life-extension-for-russias-second-generation-rbmk-reactors/, accessed 21 July 2024.

524 - IEA, "Average age of existing coal power plants in selected regions in 2020", International Energy Agency, Updated 13 October 2021, see https://www.iea.org/data-and-statistics/charts/average-age-of-existing-coal-power-plants-in-selected-regions-in-2020, accessed 12 July 2024.

Figure 40 · Age Distribution of the Russian Nuclear Fleet



Sources: WNISR, with IAEA-PRIS, 2024

Reactor Exports

Russia is an aggressive exporter of nuclear power technology. Rosatom's website claims that there are 33 projects abroad in various stages of advancement.[525] These claims must be taken with some skepticism; as of mid-2024, Rosatom is involved as the main contractor in the following projects abroad which are in various stages of active construction:

- **Rooppur, Bangladesh.** Construction started on two VVER-1200 reactors at Rooppur in 2017 and 2018, which were expected to begin operation in 2023 and 2024, respectively;[526] commissioning is now expected to start in December 2024, and the project's completion deadline was moved to 2027.[527] The first fuel load shipment was delivered in October 2023;[528] see Bangladesh in Potential Newcomer Countries.
- **Tianwan and Xudapu, China.** Two VVER-1200s each at Tianwan and Xudapu (or Xudabao) are being built. Construction of the respective first units (Tianwan-7 and

525 - Rosatom, "Projects", Undated, see https://www.rosatom.ru/en/investors/projects/index.php?, accessed 12 July 2024.

526 - Rosatom, "First concrete poured at the constructed Rooppur NPP site (Bangladesh)", 30 November 2017, see https://rosatomafrica.com/en/press-centre/news/first-concrete-poured-at-the-constructed-rooppur-npp-site-bangladesh/, accessed 29 July 2023; and Rosatom, "Main construction of the 2nd Unit of Rooppur NPP begins with the 'First Concrete' ceremony", Press Release, 14 July 2018, see https://rosatom-mena.com/press-centre/news/main-construction-of-the-2nd-unit-of-rooppur-nuclear-power-project-begins-with-the-first-concrete-ce/, accessed 1 August 2024.

527 - Ahmed Humayun Kabir Topu, "Rooppur Nuclear Power Plant: First unit to start production in December", *The Daily Star*, 27 April 2024, see https://www.thedailystar.net/news/bangladesh/news/rooppur-nuclear-power-plant-first-unit-start-production-december-3596116, accessed 3 May 2024.

528 - Rosatom, "The first batch of nuclear fuel has been delivered to Rooppur NPP", Press Release, 5 October 2023, see https://www.rosatom.ru/en/press-centre/news/the-first-batch-of-nuclear-fuel-has-been-delivered-to-rooppur-npp/, accessed 8 August 2024.

Xudapu-3) started in 2021 and that of the second units (Tianwan-8 and Xudapu-4) in 2022.[529] See China Focus.

- **El Dabaa, Egypt.** Four VVER-1200s are under construction at El Dabaa; the most recent started in January 2024. The construction of the reactors is scheduled to be completed between 2028 and 2031. The cost is given as US$30 billion, facilitated by a US$25 billion loan from Russia.[530] See Egypt in Potential Newcomer Countries.

- **Kudankulam, India.** Four VVER-1000s are under construction at Kudankulam. Construction started on the first units in 2017 and the most recent ones in 2021. The first of these units is now supposed to be completed in November 2026, and the subsequent reactors are scheduled to be fully operational by 2027. In December 2023, Russia and India signed preliminary agreements for additional units at Kudankulam[531], while negotiations on building another plant are also ongoing.[532] See India in Annex 1.

- **Bushehr, Iran.** Construction of Bushehr-2 (also called Busheer-2) was initially started in February 1976 by the German company KWU-Siemens and was suspended in 1978. Work resumed in 1996, with Rosatom subsidiary ASE as the nuclear island provider. Construction work began on this unit and a third reactor at the site in 2017. Concrete pouring for Bushehr-2 took place in 2019, and its commissioning is expected in 2028—whereas the third reactor is not under-construction according to the IAEA.[533] See Iran in Annex 1.

- **Mochovce, Slovakia.** Mochovce-4, a Russian VVER design, which originally started construction in 1985, is being completed by an international consortium and is scheduled to be commissioned in 2025.[534] See Slovakia in Annex 1.

529 - Rosatom MENA, "Start of new unit construction at China's Tianwan and Xudapu Nuclear Power Plants", Rosatom, 19 May 2021, see https://www.rosatom-mena.com/press-centre/news/start-of-new-unit-construction-at-china-s-tianwan-and-xudapu-nuclear-power-plants/; WNISR, "Russian Nuclear Industry Starts Nuclear Reactor Construction in China—Anyways", 26 February 2022, see https://www.worldnuclearreport.org/Russian-Nuclear-Industry-Starts-Nuclear-Reactor-Construction-in-China-Anyways.html; and WNISR, "Second Russian Nuclear Reactor Construction Start in China This Year—Anyways 2", 20 May 2022, see https://www.worldnuclearreport.org/Second-Russian-Nuclear-Reactor-Construction-Start-in-China-This-Year-Anyways-2.html; all accessed 8 August 2024.

530 - *Daily News Egypt*, "Dabaa nuclear plant project progresses according to schedule: Minister of Electricity", 14 June 2023, see https://www.dailynewsegypt.com/2023/06/14/dabaa-nuclear-plant-project-progresses-according-to-schedule-minister-of-electricity/, accessed 22 August 2023, and NPPA, "بعد أولى الصبة الخرسانية لأعمال الوحدة النووية الرابعة عن قرب بمشروع محطة الضبعة النووية بمشاركة فخر الرئيس التنفيذي للمؤسسة الرئيس التنفيذي لروساتوم الطاقة يزور من", Nuclear Power Plants Authority, 23 January 2024 (in Arabic), see https://nppa.gov.eg/News/Details?id=2121; and Asma Alsharif, "Russia to lend Egypt $25 billion to build nuclear power plant", *Reuters*, 19 May 2016, see https://www.reuters.com/article/us-egypt-russia-nuclear/russia-to-lend-egypt-25-billion-to-build-nuclear-power-plant-idUSKCN0YA1G5/; both accessed 8 August 2024.

531 - Ministry of External Affairs, "Press Conference of EAM Dr. S. Jaishankar with FM Sergey Lavrov of Russia (December 27, 2023)", Government of India, 27 December 2023, see https://www.mea.gov.in/Speeches-Statements.htm?dtl/37483/Press_Conference_of_EAM_Dr_S_Jaishankar_with_FM_Sergey_Lavrov_of_Russia_December_27_2023; and *The Hindu*, "India, Russia ink pacts on construction of future power units of Kudankulam nuclear plant", 27 December 2023, see https://www.thehindu.com/news/national/india-russia-ink-pacts-on-construction-of-future-power-units-of-kudankulam-nuclear-plant/article67677964.ece; both accessed 8 August 2024.

532 - Governments of India and the Russian Federation, "Joint Statement following the 22nd India-Russia Annual Summit", 9 July 2024, see https://www.mea.gov.in/bilateral-documents.htm?dtl/37940/Joint+Statement+following+the+22nd+IndiaRussia+Annual+Summit, accessed 8 August 2024.

533 - WNISR, "Iran: Construction Restart of Busheer-2", 14 November 2019, see https://www.worldnuclearreport.org/Iran-Construction-Restart-of-Busheer-2.html, accessed 14 November 2019.

534 - *The Slovak Spectator*, "Slovakia breaks its record in electricity generated from nuclear power", 6 February 2024, see https://spectator.sme.sk/c/23278787/slovakia-breaks-its-record-in-electricity-generated-from-nuclear-power.html, accessed 31 May 2024.

- **Akkuyu, Türkiye.** Four VVER-1200s are being built at Akkuyu. Construction started on the first unit in 2018 and Unit 4 in 2022. Unit 1 is expected to begin operation in 2025.[535] See Türkiye Focus.

In addition, in Hungary preparation work is underway at Paks II where construction is expected to start by end of the year.[536] The European Commission approved the contract in May 2023 despite the ongoing conflict between Europe and Russia on energy and the war in Ukraine.[537] The June 2024 E.U. Foreign Affairs Council's 14th sanctions package against Russia included provisions against LNG import.[538] As *Nuclear Engineering International* reported: "Hungary had agreed to the EU's latest package of sanctions, which provides for restrictions on supplies of liquefied natural gas, in exchange for assurances that no current or future measures will threaten Paks II, which is being built by Rosatom."[539] The Hungarian Minister of Foreign Affairs and Trade commented "We've reached the objective of having it stated in this directive that the construction of the new Paks nuclear power plant and all its processes, stages and elements are completely exempted from sanctioning measures."[540]

It remains clear that Rosatom is the primary constructor and exporter of reactors, building 26 out of the 59 units under construction worldwide as of mid-2024 (see Figure 10 and Table 2).

Nuclear Interdependencies and Sanctions

For details see dedicated chapter Russia Nuclear Dependencies.

Since its illegal, full-scale invasion of Ukraine in February 2022, Russia is facing sanctions from forty-five countries—mainly in Europe and North America, but also from countries like Australia, Japan, New Zealand, and South Korea.[541]

535 - Mustafa Ercan, "Türkiye'nin ilk nükleer güç santrali! Çalışmalar sürüyor gözler 2025'te", *Demirören News Agency* as published by *Milliyet*, 18 May 2024, (in Turkish), see https://www.milliyet.com.tr/ekonomi/turkiyenin-ilk-nukleer-guc-santrali-calismalar-suruyor-gozler-2025te-7128920, accessed 19 June 2024.

536 - Rosatom, "ROSATOM head Alexey Likhachev meet Hungary's minister of foreign affairs and trade Péter Szijjártó", Press Release, 12 March 2024, see https://www.rosatom.ru/en/press-centre/news/rosatom-head-alexey-likhachev-meet-hungary-s-minister-of-foreign-affairs-and-trade-p-ter-szijj-rt-/, accessed 8 August 2024.

537 - *WNN*, "EC outlines approval grounds for Paks II contract amendments ", 30 May 2023, see https://world-nuclear-news.org/Articles/EC-outlines-approval-grounds-for-Paks-II-contract, accessed 14 July 2024.

538 - European Commission, "EU adopts 14th package of sanctions against Russia for its continued illegal war against Ukraine, strengthening enforcement and anti-circumvention measures", Press Release, 24 June 2024, see https://ec.europa.eu/commission/presscorner/detail/en/ip_24_3423; and European Council, "Russia's war of aggression against Ukraine: comprehensive EU's 14th package of sanctions cracks down on circumvention and adopts energy measures", Council of the European Union, Press Release, 24 June 2024, see https://www.consilium.europa.eu/en/press/press-releases/2024/06/24/russia-s-war-of-aggression-against-ukraine-comprehensive-eu-s-14th-package-of-sanctions-cracks-down-on-circumvention-and-adopts-energy-measures/; both accessed 8 August 2024.

539 - *NEI Magazine*, "EU exempts Hungary's Paks II nuclear project from Russia sanctions", *Nuclear Engineering International*, 3 July 2024, see https://www.neimagazine.com/news/eu-exempts-hungarys-paks-ii-nuclear-project-from-russia-sanctions/, accessed 14 July 2024.

540 - *About Hungary*, "FM: Paks has received a full exemption from EU sanctions", Cabinet Office of the Prime Minister, Government of Hungary, 25 June 2024, see https://abouthungary.hu//news-in-brief/fm-paks-has-received-a-full-exemption-from-eu-sanctions, accessed 22 August 2024.

541 - Peter Piatetsky, "What are countries doing to counter Russia's War ?", Castellum.AI, Undated, see https://www.castellum.ai/insights/which-countries-are-taking-action-on-ukraine, accessed 14 July 2024.

The European Union

The E.U.'s 14 sanctions packages—given the importance of energy to the Russian economy—have included energy products and equipment, notably[542]:

- the prohibition of the import of seaborne crude oil and refined products;
- price caps which prevent E.U. operators from providing transport or insurance services for the transport of Russian oil above the cap;
- an import ban on all forms of coal;
- an import ban on liquefied petroleum gas;
- a ban on future investment in LNG projects under construction in Russia and a ban on the use of E.U. ports for the transshipment of LNG;
- a far-reaching ban on new investment across the Russian energy sector, with limited exceptions for civil nuclear energy.

There is no sanction specifically against the import of piped gas from Russia, but in 2022, the European Commission's RePower E.U. proposed that the bloc would end reliance on fossils by 2027. The dependency on gas has significantly diminished, from 45 percent in 2021 to 15 percent in 2023.[543] However, given differing political support, there remains considerable doubt if the 2027 deadline will be met.[544]

Also primarily excluded from the sanctions are nuclear equipment and fuel as a result of concern and political pressure from some Member States, including France and Hungary[545], that have strong nuclear links with Russia. Hungary continues to develop Paks II, while France appears determined to maintain its nuclear relationship with Russia be it through the import of enriched uranium or numerous projects with Rosatom.[546] In Germany, officials in the state of Lower Saxony are considering a request from Framatome to produce VVER fuel in a joint venture with Rosatom.[547] Furthermore, a report by Greenpeace alleges that Framatome and Siemens Energy are (through export of technologies, software, and expertise) supporting Rosatom in its global trade.[548]

542 - European Commission, "Sanctions on energy", Undated, see https://eu-solidarity-ukraine.ec.europa.eu/eu-sanctions-against-russia-following-invasion-ukraine/sanctions-energy_en, accessed 14 July 2024.

543 - European Commission, "REPowerEU Actions", May 2022, see https://ec.europa.eu/commission/presscorner/api/files/attachment/873247/FS%20RePower%20EU%20Actions_EN.pdf, accessed 6 August 2024; and Kate Abnett, "EU countries to discuss hurdles to quitting Russian natural gas, document shows", *Reuters*, 21 May 2024, see https://www.reuters.com/business/energy/eu-countries-discuss-hurdles-quitting-russian-natural-gas-document-shows-2024-05-21/, accessed 14 July 2024.

544 - Marcin Czekanski, "EU unlikely to ban Russian gas by 2027 – experts", *Montel*, 19 April 2024, see https://montelnews.com/news/b6d38ff1-27aa-408d-8b5f-0a581df19e5a/eu-unlikely-to-ban-russian-gas-by-2027-experts, accessed 14 July 2024.

545 - Victor Jack, "French-Russian nuclear relations turn radioactive", *Politico*, 20 April 2023, see https://www.politico.eu/article/french-russian-nuclear-relations-radioactive-rosatom-sanctions/, accessed 21 July 2024; and Henry Foy, "Why Hungary is again blocking the latest round of Russia sanctions", *The Financial Times*, 15 February 2024, see https://www.ft.com/content/53f2e696-5ff2-4be9-bcf0-f6a144fbdbff, accessed 29 May 2024.

546 - Grace Symes, "France: Nuclear Industry Retains Ties With Rosatom", *Energy Intelligence*, 1 March 2024, see https://www.energyintel.com/0000018d-f041-d9ab-adff-f26da88c0000, accessed 31 May 2024.

547 - Frank Jordans, "Germany criticizes Russian role in French nuclear fuel plant", *The Associated Press*, 30 March 2023, see https://apnews.com/article/germany-france-russia-nuclear-power-rosatom-framatome-ce470270053495803o6d55553c7f1142, accessed 21 July 2024.

548 - Shaun Burnie and Jan Vande Putte, "Russia's Atomic Partners: Framatome, Siemens Energy and Rosatom—How European Companies are Supporting a Criminal Russian State Nuclear Company – and Why EU Sanctions Are Needed to Stop it", Greenpeace, 2023, see https://www.greenpeace.de/publikationen/Rosatom_Report_G.pdf, accessed 21 July 2024.

In February 2023, the European Parliament passed a resolution that called for expanding the sanctions to include individuals and entities, including Rosatom.[549] However, despite initially suggesting it would propose sanctions against the Russian commercial nuclear sector, the European Commission abandoned such plans in February 2023 and none have subsequently been applied.[550] The Euratom Supply Agency stated in their 2022 annual report (published in 2024) that "EU Stakeholders took measures to reduce their reliance on Russian nuclear fuel supplies."[551]

Analysis undertaken by the Norwegian organization Bellona has uncovered that in 2023 Slovakia and the Czech Republic significantly increased their uranium imports from Russia to such an extent that, in total, the E.U. more than doubled its collective payment from €280 to €686 million. This was in part because new reactors (Mochovce-4) and new fresh fuel storage facilities (Czech Republic) were commissioned.[552]

Furthermore, as there are five E.U. countries—Bulgaria, Czech Republic, Finland, Hungary, and Slovakia—operating 19 Soviet-designed VVER reactors, fuel supply diversification is more complex. Westinghouse has become a fuel supplier in Ukraine, and Framatome is set to start fabricating VVER fuel. (See Russia Nuclear Dependencies).

The United States

Rosatom is also a significant supplier of nuclear material to the U.S. covering 14 percent of its natural uranium consumption and 28 percent of the enriched uranium in 2021. As a result, the introduction of sanctions against Rosatom and the wider Russian nuclear sector has been slow; thus, the March 2022 Executive Order on the prohibition of energy imports from Russia focused on the fossil fuel sector.[553] In 2023, further sanctions were introduced, which included ten subsidiaries of Rosatom, including Rusatom Overseas, which is—or at least was—in charge of implementing the construction projects of nuclear power plants in other countries (see section above), and activities related to shipping and defense co-operation, but not those relating to fuel services.[554]

549 - European Parliament, "European Parliament resolution of 2 February 2023 on the preparation of the EU-Ukraine Summit (2023/2509(RSP))", 2 February 2023, see https://www.europarl.europa.eu/doceo/document/TA-9-2023-0029_EN.html, accessed 8 February 2023.

550 - Leonie Kijewski and Jacopo Barigazzi, "EU Commission scratches Russia nuclear sanctions plans", *Politico*, 16 February 2023, see https://www.politico.eu/article/rosatom-russia-ukraine-volodymyr-zelenskyy-vladimir-putin-eu-executive-scratches-russia-nuclear-sanctions-plans/, accessed 14 July 2024.

551 - ESA, "EURATOM Supply Agency - Annual Report 2022", Euratom Supply Agency, January 2024, see https://euratom-supply.ec.europa.eu/document/download/416f638d-1928-44b6-a9d9-d9180b6eb2ad_en?filename=ESA%20Annual%20Report%202022%20-%20Final%20%28website%29_2.pdf, accessed 12 July 2024.

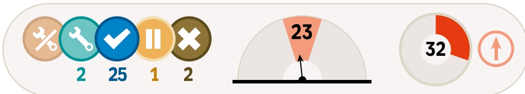
552 - Charles Digges, "Europe doubled its import of Russian nuclear fuel for 2023, data say", Bellona, 15 March 2024, see https://bellona.org/news/nuclear-issues/2024-03-europe-russian-nuclear-fuel, accessed 16 July 2024.

553 - The White House, "FACT SHEET: United States Bans Imports of Russian Oil, Liquefied Natural Gas, and Coal", United States Government, 8 March 2022, see https://www.whitehouse.gov/briefing-room/statements-releases/2022/03/08/fact-sheet-united-states-bans-imports-of-russian-oil-liquefied-natural-gas-and-coal/, accessed 16 July 2024.

554 - Ihor Moshenets, "Can the EU and US end their dependence on Russia's nuclear energy industry?", *Energy Post*, 18 January 2024, see https://energypost.eu/can-the-eu-and-us-end-its-dependence-on-russias-nuclear-energy-industry/, accessed 16 April 2024.

However, in May 2024 a new law was introduced that banned the import of uranium from Russia, which came into force on 11 August 2024.[555] Given the significance of Russian supply, a caveat allows for waivers until 2027 if the Department of Energy judges that no alternative supply is available. Tenex, the subsidiary of Rosatom primarily targeted by the legislation, has responded by sending a note to its clients in the U.S. saying it would stop enriching and delivering uranium unless it received a guarantee that it would receive payment regardless of if a waiver was granted.[556] The industry in the U.S. has been preparing for the ban, with uranium mining taking place in the U.S. for the first time in eight years in 2024 and the startup of a small enrichment facility in Ohio. The legislation also unlocks $US 2.7 billion in federal support for domestic enrichment.[557] (See United States Focus.)

SOUTH KOREA FOCUS



South Korea (the Republic of Korea) has the world's fifth-largest nuclear power program at 25.8 GW (including one reactor in LTO), not far behind fourth-place Russia. South Korea has been generating nuclear power since 1977, when its first nuclear plant, Kori-1, was connected to the grid. It now has 25 operating reactors and one reactor in LTO, all run by a market-based public corporation, Korea Hydro & Nuclear Power (KHNP), subsidiary of Korea Electric Power Corporation (KEPCO). As of mid-2024, there were two reactors—Saeul-3 and Saeul-4—under construction, and two units—Kori-1 and Wolsong-1—that were closed. In April 2023, then the oldest operating reactor in the country, Kori-2, was closed after 40 years of operation; however, as it is expected to be restarted, it is considered in LTO.

According to IAEA-PRIS, in 2023, nuclear power produced a record 171.6 TWh in South Korea. The share of nuclear power in electricity generation in 2023 was 31.5 percent compared to the historic peak of 53.3 percent in 1987.

Continued Pro-nuclear Policy of the Yoon Administration

On 31 May 2024, the Ministry of Trade, Industry and Energy (MOTIE) released the working draft of the 11th Basic Plan for Long-term Electricity Supply and Demand (BPE).[558] The BPE is a plan established every two years in accordance with Article 25 of the Electricity Business Act and Article 15 of the Enforcement Decree of the same Act to stabilize the country's mid- to long-term electricity supply and demand. The plan includes the basic direction of electricity supply and demand for the 15-year period from 2024 to 2038, as well as long-term forecast,

555 - U.S. Government, "Public Law 118–62—Prohibiting Russian Uranium Imports Act—An Act To prohibit the importation into the United States of unirradiated low-enriched uranium that is produced in the Russian Federation, and for other purposes.", 13 May 2024, see https://www.congress.gov/118/plaws/publ62/PLAW-118publ62.pdf, accessed 8 August 2024.

556 - Mary Catherine Hancock and William Freebairn, "US DOE issues process for utility waivers of Russian enriched uranium ban", S&P Global, 22 May 2024, see https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/052224-us-doe-issues-process-for-utility-waivers-of-russian-enriched-uranium-ban, accessed 23 May 2024.

557 - Jennifer T. Gordon, "The US is banning the import of Russian nuclear fuel. Here's why that matters.", Atlantic Council, 16 May 2024, see https://www.atlanticcouncil.org/blogs/new-atlanticist/the-us-is-banning-the-import-of-russian-nuclear-fuel-heres-why-that-matters/, accessed 16 July 2024.

558 - MOTIE, "｢제11차 전력수급기본계획｣ 실무안 공개", Press Release (in Korean), Ministry of Trade, Industry and Energy, Government of South Korea, 31 May 2024, see https://www.motie.go.kr/kor/article/ATCL3f49a5a8c/169132/view#, accessed 9 August 2024.

power generation facility planning, and electricity demand management. The working draft released in 2024 will be finalized through consultations with related ministries, public hearings, reports to the Trade, Industry, Energy, SMEs [Small and Midsize Enterprises] and Startups Committee (TIESSC) of the National Assembly, and deliberations within the Electric Power Policy Council.

According to the working draft of the 11th BPE, total power generation is expected to increase to up to 641.4 TWh by 2030, which is slightly more than estimates from the 10th BPE.[559] The nuclear power generation projection for 2030 has also increased by 2.5 TWh in the 11th plan compared to the 10th plan, while the share of nuclear in the electricity mix of 2030 has decreased from 32.4 to 31.8 percent as shown in Table 8 below. However, the nuclear share is planned to increase to 35.6 percent by 2038.

Table 8 · Government Plan for Electricity Mix in South Korea

Plan	Production / Share of Electricity	Nuclear	Coal	LNG	NRE[(a)]	Hydrogen & Ammonia	Other	Total
Actual Electricity Mix in 2023	TWh	180.5	184.9	157.7	56.6	-	8.3	588.0
	Share	*30.7%*	*31.4%*	*26.8%*	*9.6%*	-	*1.4%*	
10th Basic Plan on Electricity supply and demand - Electricity Mix Targets								
Target for 2030	TWh	201.7	122.5	142.4	134.1	13.0	8.1	621.8
	Share	*32.4%*	*19.7%*	*22.9%*	*21.6%*	*2.1%*	*1.3%*	
Target for 2036	TWh	230.7	95.9	62.3	204.4	47.4	26.6	667.3
	Share	*34.6%*	*14.4%*	*9.3%*	*30.6%*	*7.1%*	*4.0%*	
11th Basic Plan on Electricity supply and demand - Electricity Mix Targets								
Target for 2030	TWh	204.2	111.9	160.8	138.4	15.5	10.6	641.4
	Share	*31.8%*	*17.4%*	*25.1%*	*21.6%*	*2.4%*	*1.7%*	
Target for 2038	TWh	249.7	72.0	78.1	230.8	38.5	32.5	701.7
	Share	*35.6%*	*10.3%*	*11.1%*	*32.9%*	*5.5%*	*4.6%*	

Sources: KEPCO, MOTIE, 2023 and 2024[560]

Notes:
(a) **NRE**: New and Renewable Energy. New Energy in South Korea includes Integrated Gasification Combined Cycle (IGCC) and fuel cells. Renewable Energy includes solar, wind, hydro, marine, geothermal, and bio energy.

The peak electricity demand in 2038 is projected to be 129.3 GW. Including reserve capacity (22 percent), the required capacity by 2038 is estimated to reach 157.8 GW, and the target capacity is 147.2 GW when considering the renewable energy deployment plan (120 GW in 2038). Therefore, the draft concluded that an additional 10.6 GW of power generation capacity was needed. The gap is proposed to be met by large nuclear power plants, SMRs, and LNG cogeneration.

Regarding nuclear energy, the draft proposes to build three additional 1400-MW reactors, 4.2 GW total, but unlike past plans, it does not specify where they would be built. Also, the

559 - MOTIE, "(참고자료) 「제10차 전력수급기본계획(2022~2036)」 확정", Government of South Korea, 12 January 2023, see https://www.korea.kr/briefing/pressReleaseView.do?newsId=156547521, accessed 1 October 2023.

560 -KEPCO, "한국전력통계", Korea Electric Power Corporation, 31 May 2024; and MOTIE, "(참고자료) 「제10차 전력수급기본계획(2022~2036)」 확정", Ministry of Trade, Industry and Energy, Government of South Korea, 12 January 2023; also MOTIE, "「제11차 전력수급기본계획」 실무안 공개", Press Release, 31 May 2024, op. cit.

draft includes the construction of the very first SMRs in the country. According to government announcements as well as media coverage, the plan includes a first SMR-project with 0.7 GW.[561] The announced SMR would be a so-called "innovative SMR" or "i-SMR" that KHNP is developing as a four-module plant, each unit with a 170 MW capacity.[562] Therefore, in fact the plan is to build not one but four SMRs with a total capacity of 680 MW (i.e., about 0.7 GW).

The incumbent Yoon administration has taken for granted that the lifetime of all operating nuclear power plants will be extended, despite the fact that the decision to continue operation of a nuclear power plant must be based on the independent Nuclear Safety and Security Commission (NSSC)'s assessment of safety, as well as economic analysis and public acceptance. In addition, President Yoon amended the Enforcement Decree of the Nuclear Safety Act in December 2022 to expand the application period for extending the lifetime of a nuclear power plant from two to five years before the expiration of the existing operational license to five to ten years before.[563]

Since 2015, starting with Saeul-1, the first APR-1400 to be commissioned, the NSSC has provided the monopoly nuclear operator, KHNP, a 60-year operating license at a time.[564] This system, together with the Yoon administration's pro-nuclear legislation and policies, facilitates stable business opportunities for the foreseeable future for the Korean nuclear industry.

The current administration also showed its support by increasing the budget for nuclear power in the 2024 government budget plan.[565] It newly allocated KRW100 billion (US$72.65 million) to finance the nuclear ecosystem and KRW25 billion (US$18 million) for nuclear export guarantees. The budget for building the export infrastructure for the nuclear power industry also increased from KRW6.9 billion (US$\$_{2023}$5 million) in 2023 to KRW8.5 billion (US$6.2 million) in 2024. The budget for the i-SMR technology development project (R&D) was KRW3.9 billion (US$\$_{2023}$3 million) in 2023 but increased nearly 10 times to KRW33.3 billion (US$24.2 million) in 2024. The budget for the construction of the Wolseong Low- and Intermediate-Level Radioactive Waste Disposal Center increased significantly from KRW52.8 billion (US$\$_{2023}$40.4 million) in 2023 to KRW81.8 billion (US$59.4 million) in 2024, and the R&D project to strengthen nuclear power plant decommissioning competitiveness increased from KRW33.7 billion (US$25.8 million) to KRW43.3 billion (US$31.5 million) in 2024.

561 - Michael Herh, "Korean Gov't to Install 3 Additional Large Nuclear Reactors, 1 SMR by 2038", *BusinessKorea*, 3 June 2024, see https://www.businesskorea.co.kr/news/articleView.html?idxno=218297, accessed 19 August 2024.

562 - KHNP, "i-SMR—Innovative Small Modular Reactor", Brochure, Korea Hydro and Nuclear Power Co., 2023, see https://i-smrkr.com/data/file/brochure/20231123_i-SMR_e-Brochure.pdf, accessed 9 August 2024.

563 - NSSC, "원자력안전법 시행령 일부개정령안 재입법예고", Nuclear Safety and Security Commission, as published by the Ministry of Government Legislation, November 2022 (in Korean), accessed 18 August 2024; and Law Viewer, "Enforcement Decree of the Nuclear Safety Act", Korea Law Translation Center, 2023, see https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=63367&type=part&key=18, accessed 27 August 2024.

564 - IAEA, "Status report 83 - Advanced Power Reactor 1400 MWe (APR1400)", 11 April 2011, see https://aris.iaea.org/PDF/APR1400.pdf, accessed 26 August 2024.

565 - 이만섭 기자, "2024년 산업부 예산 작년보다 4452억 늘어난 11조5188억원...경제활력 회복, 원전 생태계 복원에 집중", *Skenews*, 1 January 2024, see https://www.skenews.kr/news/articleView.html?idxno=37459, accessed 4 June 2024; and MOEF, "2024 년도 나라살림 예산개요—Summary of Budget for FY 2024", Ministry of Economy and Finance, Government of South Korea, 5 February 2024, see https://www.moef.go.kr/com/cmm/fms/FileDown.do?atchFileId=ATCH_000000000025193&fileSn=3, accessed 9 August 2024 .

The World's Largest Nuclear Power Plant Got Another Reactor

After over 10 years of construction, Shin-Hanul-2, a Korean pressurized water reactor (APR-1400) was first connected to the grid in December 2023 and began commercial operation in April 2024.[566] With the startup of Shin-Hanul-2, Hanul Nuclear Power Plant (NPP) located in Ulchin-gun, Gyeongsangbuk-do, became one of only two NPPs in the world hosting eight units, along with Canada's Bruce NPP in Ontario, which is the largest number of reactors at a single site.

The total installed electrical capacity of the eight Hanul units is 8678 MW (net), 1.5 times larger than Europe's largest nuclear power plant, Zaporizhzhia in Ukraine with six units totaling 5700 MW (currently occupied by the Russian army, and in LTO). The implications of Russia's seizure by force and military use of the Zaporizhzhia NPP are of great significance to South Korea, which is still technically at war with North Korea.

Construction of Saeul-3 and -4

Two APR-1400 reactors, Saeul-3 and -4, previously named Shin-Kori-5 and -6, are being constructed. These are the only reactors under construction in South Korea. Yet, with the exception of Türkiye that is building four units, South Korea and the U.K. have the largest number of nuclear reactors (two each) under construction among the OECD member countries. This illustrates the limited scope of nuclear power plant construction in industrialized countries.

Saeul-3 and -4 were first included in the 4th BPE issued in 2008, with expected commissioning by December 2018 and 2019.[567] The construction licenses for the two reactors were approved by the NSSC on 23 June 2016,[568] and construction of Saeul Unit 3 began in April 2017. However, on 27 June 2017, former President Moon's administration decided to suspend the construction of these two reactors and leave the decision to a public deliberation. The public debate committee recommended, based on the deliberation by the citizen task force, that the construction of the two reactors be resumed, but while enforcing the outcome of the consultation, the government decided to pursue an energy policy reducing the share of nuclear power generation in the long term.[569] According to the latest projection from May 2024 by KPX (Korea Power Exchange), a quasi-governmental agency under the MOTIE responsible for operating the electricity market

566 - KHNP, "[보도] 신한울2호기, 최초 계통연결 성공", Press Release (in Korean), 22 December 2023, see https://www.khnp.co.kr/main/selectBbsNttView.do?key=2289&bbsNo=71&nttNo=50464&searchCtgry=&searchCnd=all&searchKrwd=&integrDeptCode=&pageIndex=15; and KHNP, "Shin-Hanul Unit 2 begins commercial operation", 8 April 2024, see https://www.khnp.co.kr/eng/selectBbsNttView.do?key=565&bbsNo=84&nttNo=52347&searchCtgry=&searchCnd=all&searchKrwd=&integrDeptCode=&pageIndex=3; both accessed 10 August 2024.

567 - Government of South Korea, "The 4th Basic Plan of Long-Term Electricity Supply and Demand (2008–2022)", translated by Korea Power Exchange, December 2008, see https://new.kpx.or.kr/boardDownload.es?bid=ATT&list_no=72220OOO17129071088536&seq=6, accessed 10 August 2024.

568 - NSSC, "Meeting Grants Construction Permit for Shinkori Units 5 and 6", Press Release, Nuclear Safety and Security Commission, 23 June 2016, see https://www.nssc.go.kr/ajaxfile/FR_SVC/FileDown.do?GBN=X01&BOARD_SEQ=1&SITE_NO=3&BBS_SEQ=36864&FILE_SEQ=18462, accessed 10 August 2024.

569 - Jung In-hwan and Kim Sung-hwan, "Construction to be suspended on fifth and sixth Shin-Kori nuclear reactors", *The Hankyoreh*, 28 June 2017, see https://english.hani.co.kr/arti/english_edition/e_business/800632.html; and Yoon Sojung, "Nuclear plant public consultation embodies perfect democracy: president", *Korea.net*, Ministry of Culture, Sports and Tourism, Government of South Korea, 23 October 2017, see https://www.korea.net/NewsFocus/policies/view?articleId=150360 ; both accessed 10 August 2024.

and the power system in South Korea, the construction of Saeul-3 and -4 are scheduled to be completed by October 2024 and 2025, respectively.[570]

Construction of Shin-Hanul-3 and -4

The Yoon administration is also pushing ahead with the construction of Shin-Hanul-3 and -4, two APR-1400 units, which are to be the ninth and tenth nuclear reactor at the world's densest and largest nuclear power plant, Hanul in Uljin (see The World's Largest Nuclear Power Plant Got Another Reactor, above). KHNP has submitted documents for the construction license to the NSSC, and the Korea Institute of Nuclear Safety (KINS) has now completed the review of the construction license application, which will be reviewed and is expected to be approved by the NSSC. According to a recent media report, the NSSC is expected to discuss the construction license for Shin-Hanul-3 and -4 at a meeting to be held in August or September 2024.[571]

Even though the construction licenses for Shin-Hanul-3 and -4 have not been issued by the regulator yet, in March 2023, the sole operator for South Korea's NPPs, KHNP, signed a KRW2.9 trillion (US$$_{2023}$2.2 billion) contract with the monopolistic provider of main equipment for nuclear power plants in South Korea, Doosan Enerbility, for the supply of components including the nuclear reactors, steam generators, and turbine generators.[572] Doosan Enerbility has commenced production of the main components since May 2023.[573] Also, in December 2023, KHNP signed another KRW3.2 trillion (US$$_{2023}$2.45 billion) contract with a consortium led by Hyundai Engineering & Construction together with Doosan Enerbility and POSCO Engineering & Construction for the construction of the main facilities at Shin-Hanul-3 and -4.[574]

It has been argued that this practice of pre-manufacturing equipment before a construction license has been granted is problematic and could be illegal under the nuclear safety regulations. After the commencement ceremony in May 2023, Korean environmental NGOs raised concerns, arguing that even if a design problem is found during the safety review for the construction license, safety may not be prioritized because a huge amount of money would have already been spent. Alternatively, if the permit is not granted, KHNP (after all, the government) that approved the prefabrication will have to compensate for it, most likely with taxpayers' money.[575] During the 2023 National Audit, a congressman also claimed that the 'pre-manufacturing' is illegal. MOTIE responded that it has been general practice for the main

570 - KPX, "Progress of Power Plant Construction Project in Q1 2024", Korea Power Exchange, 30 May 2024, see https://www.kpx.or.kr/board.es?mid=a10403040000&bid=0040&act=view&list_no=72656&tag=&nPage=1, accessed 4 June 2024.

571 - *Newsis*, "Shin-Hanul-3 & -4 to start digging in October...NSSC's construction license discussion imminent", 6 August 2024, see https://www.newsis.com/view/NISX20240805_0002838853, accessed 6 August 2024.

572 - Doosan Enerbility, "Doosan Enerbility Signs Supplier Agreement for Shin Hanul Units 3 & 4", 29 March 2023, see https://www.doosanenerbility.com/en/about/news_board_view?id=21000570&page=4&pageSize=9, accessed 10 August 2024.

573 - Doosan Enerbility, "Doosan Enerbility Commences Manufacturing of Main Components for Shin Hanul 3 and 4", 15 May 2023, see https://www.doosanenerbility.com/en/about/news_board_view?id=21000546&page=0&pageSize=9, accessed 4 June 2024.

574 - KHNP, "[보도] 한국수력원자력, 신한울 3,4호기 주설비공사 계약 체결", Press Release (in Korean), 22 December 2023, see https://www.khnp.co.kr/main/selectBbsNttView.do?key=2289&bbsNo=71&nttNo=50503&searchCtgry=&searchCnd=all&searchKrwd=&integrDeptCode=&pageIndex=15, accessed 10 August 2024.

575 - *KBS*, "[이슈대담] 신한울 3·4호기 절차 문제 없나?", 22 May 2023 (in Korean), see https://news.kbs.co.kr/news/pc/view/view.do?ncd=7681393, accessed 25 August 2024.

equipment supplier to send a proposal to KHNP before a construction license is secured. Once KHNP approves the proposal, manufacture of the main equipment begins on an out-of-pocket basis, in order to meet the production schedule agreed between KHNP and the supplier.[576]

Originally, Shin-Hanul-3 & -4 were included in the 4th BPE for the first time in 2008 to be constructed by June 2020 and 2021, respectively.[577] However, the two units were excluded in the 8th BPE in 2017 under the Moon administration (2017–2022) in compliance with its policy to phase out nuclear by the 2080s and later re-included in the 10th BPE established in 2023 by the Yoon administration (2022–2027).[578] According to the latest projection by KPX, the construction of Shin-Hanul-3 and -4 are scheduled to be completed by October 2032 and 2033, respectively.[579]

If the two reactors become operational as planned and the lifetimes of Hanul-1 and -2 are extended as planned (see Lifetime Extensions, below), the Hanul site would become the world's first nuclear power plant with 10 operational reactors with around 11.5 GW of capacity.

Lifetime Extensions

According to the Nuclear Safety Act, to extend the lifetime of a nuclear power plant, the operator, KHNP, must submit a Periodic Safety Review (PSR) report to the regulator, NSSC, collect opinions from residents through public notices and hearings on the Radiological Environmental Impact Assessment report, and submit an application for a license to change operations to the NSSC for license review.[580]

There are a total of 10 nuclear reactors whose licenses expire before 2030, and the Yoon administration is seeking to extend all of them by ten years. On 8 April 2023, Kori-2, the country's third nuclear reactor, which began operation on 9 April 1983, stopped generating electricity due to the expiration of its 40-year operating license. KHNP has announced a plan to restart the reactor by June 2025 by accelerating the scheduled activities as much as possible, including safety inspections for continued operation, and improving facilities.[581]

The fourth reactor, Kori-3, can only operate until 28 September 2024. NPPs with expiring operating licenses are waiting in line. Those of Kori-4 and Hanbit-1 are scheduled to expire

576 - 안희민 기자, "[2023 국감] 김성환 "건설허가 전 신한울 3,4호기 주기기 제작 착수 위법 소지"", *Hankooki.com*, 26 October 2023 (in Korean), see https://www.hankooki.com/news/articleView.html?idxno=113161, accessed 10 June 2024.

577 - Government of South Korea, "The 4th Basic Plan of Long-Term Electricity Supply and Demand (2008–2022)", December 2008, op. cit.

578 - MOTIE, "(참고자료) 「제10차 전력수급기본계획(2022~2036)」 확정", Ministry of Trade, Industry and Energy, Government of South Korea, 12 January 2023, see https://www.korea.kr/briefing/pressReleaseView.do?newsId=156547521, accessed 1 October 2023.

579 - KPX, "2024년도 1분기 발전소 건설사업 추진현황", Korea Power Exchange, 30 May 2024 (in Korean), see https://www.kpx.or.kr/board.es?mid=a10403040000&bid=0040&act=view&list_no=72656&tag=&nPage=1, accessed 4 June 2024.

580 - Government of South Korea, "Act No. 14839—Nuclear Safety Act", 26 July 2017, as published by the Korea Legislation Research Institute, Updated 7 November 2017, see https://elaw.klri.re.kr/eng_service/lawView.do?hseq=45486&lang=ENG, accessed 10 August 2024.

581 - *Yonhap New*, "40년만에 전원 끈 고리2호기…2025년 6월 재가동 목표", 9 April 2023 (in Korean), see https://www.yna.co.kr/view/AKR20230408039300003, accessed 25 August 2024.

next year, and those of Hanbit-2 and Wolsong-2 in 2026. In 2027, the licenses for Hanul-1 and Wolsong-3 will expire, followed by Hanul-2 in 2028 and Wolsong-4 in 2029.[582]

SMR Support and Demonstration Reactor Construction Plan

On 3 July 2024, at the SMR Alliance's first anniversary general meeting, MOTIE announced its strategy to become a "leading SMR country."[583] The main ambitions include expanding private sector participation in the nuclear power market, supporting the construction and operation of Korean i-SMRs, promoting private businesses utilizing SMRs, establishing foundries, and maintaining infrastructure.

The ministry plans to promote 'demonstration support projects' for the construction and operation of the first reactor of the innovative SMR design (i-SMR) currently under development, establish a commercialization corporation in the form of a private joint venture (tentatively titled 'i-SMR Holdings'), and create a KRW80 billion (US$58 million) policy fund for investments in the nuclear power industry, including SMRs. Nam-ho Choi, Vice Minister of MOTIE, stated that the government will "actively support the strengthening of flexible and efficient private sector capabilities while maintaining safety as the top priority."[584]

On 17 June 2024, less than a month after the announcement that the 11th BPE would pursue SMR development, Daegu Metropolitan City and KHNP signed a Memorandum of Understanding (MoU) on the commercialization of the country's first SMRs at the New Airport Advanced Industrial Complex. According to KHNP, the MoU includes cooperation on "feasibility studies such as site suitability and economic feasibility" for the commercialization and construction of SMRs, "commercialization efforts and cooperation in creating a SMR Smart Net-Zero City (SSNC)", and "enhancing residents' acceptance" among others.[585]

In a press release, Daegu Metropolitan Government also revealed that discussions with MOTIE, the Korea Atomic Energy Research Institute (KAERI), and the i-SMR Technology Development Project to build the country's first SMR had been ongoing for two years.[586] However, according to a media report, an information disclosure request revealed that there is no written MoU between Daegu Metropolitan City and KHNP. The media report by *Newsmin* quotes an official from the city's Energy Industry Division as saying "Not all business agreements are made in writing. It can also be discussed verbally and in person. This MoU was also discussed over the phone and in person, and there was no formalized MoU." Indeed, according to the publications' information, the city's ledger contained only six documents, including the internal approval for the purchase of banners intended for the signing ceremony. Leading *Newsmin* to conclude:

582 - *Newsis*, "체코 수주 따낸 'K-원전', 국내선 놀릴 판…계속운전 골든타임 놓치나", 25 July 2024 (in Korean), see https://www.newsis.com/view/NISX20240724_0002824365, accessed 31 July 2024.

583 - MOTIE, "민간 주도로 소형모듈원전(SMR) 조기 사업화에 박차, 내년 'SMR 얼라이언스'는 정식 협회로 전환 추진", Press Release (in Korean), Government of South Korea, 3 July 2024, see https://www.motie.go.kr/kor/article/ATCL3f49a5a8c/169273/view, accessed 10 August 2024.

584 - Ibidem.

585 - KHNP, "한국수력원자력-대구시, 혁신형 SMR 협력", Press Release (in Korean), 17 June 2024, see https://www.khnp.co.kr/main/selectBbsNttView.do?key=2289&bbsNo=71&nttNo=55261, 10 August 2024.

586 - Daegu Metropolitan City, "대구광역시, 신공항 첨단산단에 4조 원 규모 SMR 건설", Press Release (in Korean), 17 June 2024, see https://info.daegu.go.kr/newshome/mtnmain.php?mtnkey=articleview&mkey=scatelist&aid=266270&bpage=1&stext=, accessed 27 August 2024.

"This means that even the coordination of the agreement was done verbally, with no written evidence."[587]

Dr. Kwang-hoon Seok, a Policy Consultant at the Energy Transition Forum, said in an interview, "The MoU between Daegu City and KHNP is a cost-effective noise marketing scheme. KHNP is trying to secure government subsidies, and Daegu's Mayor is using it as a show-off for the next election."[588]

South Korea has previously tried and failed to commercialize the SMART (System-integrated Modular Advanced Reactor). This has led to some skepticism about the revival of SMR development in the 2020s. SMART was a project that began development in 1997; in 2012, it was claimed that the 100-MW reactor obtained the world's first standard design approval, and in 2015, it was heavily promoted in the media as being jointly developed with Saudi Arabia. However, to date, not a single SMART has been built either in South Korea or abroad. The latest attempts are strictly early agreements yet again: In April 2023, KAERI and the Government of Alberta signed an MoU to cooperate on the deployment of SMR technology in Alberta, Canada, including the SMART.[589] Also, in December 2023, KAERI signed another MoU with Hyundai Engineering to collaborate on the commercialization and export of the SMART overseas.[590]

KEPCO/KHNP vs. Westinghouse

The legal battle between Westinghouse Electric Company and KHNP (subsidiary of KEPCO) centers around the alleged unauthorized transfer of nuclear technology in breach of U.S. regulations. This case has significant implications for international nuclear technology transfers and regulatory compliance. The lawsuit was filed on 21 October 2022 by Westinghouse to ensure that KHNP and KEPCO adhere to U.S. regulations governing the transfer of nuclear technology, specifically under Part 810 of the Atomic Energy Act.[591]

Westinghouse, a leading U.S. nuclear power company, brought this action to seek a declaration that KEPCO and KHNP's transfer of APR-1400 reactor technology to countries like Poland, Saudi Arabia, and the Czech Republic would require authorization from the U.S. Department of Energy (DOE). Westinghouse argued that KHNP and KEPCO's actions were in violation of Part 810, which mandates U.S. entities to obtain specific authorization before transferring certain nuclear technologies to foreign entities. Westinghouse emphasized that the APR-1400 design, developed by KHNP and KEPCO, is based on technology originally licensed from Westinghouse, thus falling under the purview of Part 810.[592]

587 - 장은미, "대구시-한수원 SMR 업무협약, 공문 한 장 없이 논의해 체결", *Newsmin*, 26 July 2024 (in Korean), see https://www.newsmin.co.kr/news/106623/, accessed 28 July 2024.

588 - 장은미, ""대구시-한수원 SMR 업무협약, 가성비 좋은 노이즈 마케팅"", *Newsmin*, 11 July 2024 (in Korean), see https://www.newsmin.co.kr/news/105714/, accessed 28 July 2024.

589 - KAERI, "Korea and Alberta will pave a way together towards SMR and a cleaner energy future", 19 April 2023, accessed 25 August 2024.

590 - *WNN*, "Hyundai, KAERI team up for export of SMART SMR", 11 December 2023, see https://world-nuclear-news.org/Articles/Hyundai,-KAERI-team-up-for-export-of-SMART-SMR, accessed 25 August 2024.

591 - Westinghouse Electric Power Company, "Complaint vs. Korea Electric Power Corp. and Korea Hydro & Nuclear Power Company", filed with the United States District Court for the District of Columbia, as published by Jus Mundi, 21 October 2022, see https://jusmundi.com/en/document/other/en-korea-hydro-nuclear-power-co-ltd-and-korea-electric-power-corporation-v-westinghouse-electric-company-llc-complaint-friday-21st-october-2022#other_document_29139, accessed 28 July 2024.

592 - Ibidem.

On the other side, KHNP and KEPCO contended that they had independently developed the APR-1400 reactor and that their technology transfers were not subject to the restrictions of Part 810. They argued that their actions did not constitute a violation of U.S. regulations as claimed by Westinghouse. Furthermore, KHNP and KEPCO asserted that any disputes arising from the 1997 License Agreement, which originally facilitated the transfer of technology from Westinghouse's predecessor to the Korean entities, should be resolved through arbitration as stipulated in their contract.[593]

In their defense, KHNP and KEPCO filed a motion to dismiss the lawsuit or, alternatively, to compel arbitration. They maintained that Westinghouse lacked a private right of action to enforce Part 810 regulations and that the proper avenue for resolving disputes related to the 1997 License Agreement was through arbitration before the Korean Commercial Arbitration Board. They emphasized that Westinghouse's claim should be dismissed as it failed to state a claim under the Declaratory Judgment Act (DJA).[594]

The court's ruling focused on whether Westinghouse had a private right of action to enforce Part 810. On 18 September 2023 the court concluded that Westinghouse did not possess such a right, as the Atomic Energy Act (AEA) vests enforcement authority with the U.S. Attorney General. The court noted that the AEA clearly indicates that only the Attorney General can seek injunctions or enforcement actions for violations of the Act or its implementing regulations. Thus, the court granted the motion to dismiss filed by KHNP and KEPCO, stating that Westinghouse had no standing to seek declaratory relief under the DJA for alleged violations of Part 810.[595]

Furthermore, the court did not address the request to compel arbitration, as it was contingent upon Westinghouse seeking to enforce the 1997 License Agreement. Since Westinghouse explicitly stated that its claim was separate from the 1997 License Agreement, the court's decision focused solely on the regulatory obligations under Part 810. The ruling underscored that any such disputes over compliance with Part 810 must be pursued by the appropriate federal authorities, not through private litigation.[596]

In short, the court's decision highlights the limitations on private entities attempting to enforce federal regulatory compliance in the context of nuclear technology transfers. While Westinghouse raised legitimate concerns about the potential unauthorized transfer of sensitive technology, the court affirmed that enforcement authority rests with the federal government. This ruling sets a precedent for how similar disputes may be handled in the future, emphasizing the role of federal oversight in international nuclear technology transfers.

593 - Ibidem.

594 - United States District Court for the District of Columbia, "Westinghouse Electric Company LLC, v. Korea Electric Power Corp. et al.—Memorandum Opinion", Case No. 22-cv-3228 (APM), as published by Jus Mundi, 18 September 2023, see https://jusmundi.com/en/document/decision/en-korea-electric-power-corporation-and-korea-hydro-nuclear-power-co-ltd-v-westinghouse-electric-company-llc-memorandum-opinion-of-the-united-states-district-court-for-the-district-of-columbia-monday-18th-september-2023#decision_54807, accessed 28 July 2024.

595 - United States District Court for the District of Columbia, "Westinghouse Electric Company LLC v. Korea Electric Power Corp. et al.—Order", as published by Jus Mundi, 18 September 2023, see https://jusmundi.com/en/document/decision/en-korea-electric-power-corporation-and-korea-hydro-nuclear-power-co-ltd-v-westinghouse-electric-company-llc-order-of-the-united-states-district-court-for-the-district-of-columbia-monday-18th-september-2023#decision_54808, accessed 28 July 2024.

596 - Ibidem.

On 16 October 2023, Westinghouse filed a notice of appeal with the Court of Appeals for the Federal Circuit against the district court's summary judgment.[597,598]

KHNP as Preferred Bidder for the Czech's New NPP Project

In July 2024, KHNP was selected as the preferred bidder to supply new nuclear reactors to the Czech Republic. The project involves the construction of up to four new units at the Dukovany and Temelín sites.

Dukovany is an existing nuclear facility that has been operating since the 1980s. Two additional reactors would be built at an estimated cost of CZK400 billion (US$17.5 billion). KHNP's role includes supplying advanced nuclear technology and expertise for these new units. The new reactors are planned to replace aging infrastructure and significantly increase the plant's capacity. A contract for the construction of two APR-1000s at Dukovany is to be concluded by March 2025.

Negotiations will also address the possibility "to contract an option for up to five years, during which time it will be possible to decide on the construction of two more units at the Temelín site."[599]

The bidding process for the Czech nuclear project was highly competitive, with major international players, e.g. EDF from France and Westinghouse from Canada/U.S., vying for the contract. The Czech Minister of Industry and Trade stated that "It is clear that the preferred bidder [KHNP] offered a better price and more reliable guarantees of cost control, as well as the timetable of the entire project."[600] However, in fact, not only the Barakah project in the United Arab Emirates (see United Arab Emirates in Annex 1) but also KHNP's recent domestic projects were delayed by years.

With KHNP selected to supply the new reactors, the project will now advance to the next stages, including detailed planning and finalization of contractual agreements. This phase will involve working closely with Czech utility ČEZ, the main partner in the project, to finalize

597 - Counsel for Plaintiff Westinghouse Electric Company, LLC, "Westinghouse Electric Company LLC vs. Korea Electric Power Corp. and Korean Hydro & Nuclear Power Co. LTD.—Notice of Appeal", Case No. 1:22-cv-03228, filed 16 October 2023, as published by Jus Mundi, see https://jusmundi.com/en/document/other/en-korea-electric-power-corporation-and-korea-hydro-nuclear-power-co-ltd-v-westinghouse-electric-company-llc-notice-of-appeal-monday-16th-october-2023#other_document_34882, accessed 28 July 2024.

598 - In early August 2024, according to a media report citing an unnamed senior government official, a South Korean delegation including the MOTIE Minister and the CEOs of both KEPCO and KHNP held closed-door meetings with U.S. DOE and Westinghouse officials in the U.S. to seek a resolution, but they "returned home without any results." A member of President Yoon's office was also quoted in *The Korea Herald* describing efforts "through various channels to support the amicable resolution of the corporate dispute," ahead of a visit from a South Korean delegation led by President Yoon to the Czech Republic in September 2024; see *Chosun*, "[단독] 미국 태클에 걸린 K원전 체코 수출", 24 August 2024 (in Korean), see https://www.chosun.com/economy/industry-company/2024/08/24/NTC464SISNGZZGIS6KD7OSJ36U/?utm_source=naver&utm_medium=referral&utm_campaign=naver-news; and Son Ji-hyoung, "Seoul seeks to end KHNP-Westinghouse dispute", *The Korea Herald*, 25 August 2024, see https://news.koreaherald.com/view.php?ud=20240825050125; both accessed 25 August 2024.

599 - KHNP, "KHNP is ready to support to secure the energy needs of the Czech Republic", Press Release, 17 July 2024, see https://www.khnp.co.kr/eng/selectBbsNttView.do?key=565&bbsNo=84&nttNo=56342; and Government of the Czech Republic, "The Government Has Decided on a Preferred Supplier for the New Nuclear Power Source at Dukovany", Press Release, 17 July 2024, see https://vlada.gov.cz/en/media-centrum/aktualne/the-government-has-decided-on-a-preferred-supplier-for-the-new-nuclear-power-source--negotiations-on-the-construction-of-two-units-at-dukovany-will-be-214609/tmplid-81/; both accessed 11 August 2024.

600 - Ministry of Industry and Trade, "The Government Has Decided on a Preferred Supplier for the New Nuclear Power Source at Dukovany", Press Release, Government of the Czech Republic, 17 July 2024, see https://www.mpo.gov.cz/en/guidepost/for-the-media/press-releases/the-government-has-decided-on-a-preferred-supplier-for-the-new-nuclear-power-source-at-dukovany--282181/, accessed 11 August 2024.

technical specifications and project timelines. Regulatory approvals will be sought from Czech and international nuclear oversight bodies to ensure compliance with stringent safety and environmental standards, with a construction permit expected by 2029. Construction is anticipated to begin in the early 2030s, with the new reactors expected to reach commercial operation in 2038.[601]

The news has been greatly welcomed by the South Korean Government and parts of the media as another important milestone after the first nuclear export deal to the UAE in 2009.[602] In fact, following the 2009 UAE deal, then-President Lee Myung-bak's administration announced a plan to export a further nine nuclear reactors by 2012 and 80 by 2030.[603] In reality there has not been a single further export since 2009.

The Energy Transition Forum in South Korea published an issue briefing on 23 July 2024 to raise a number of major concerns around the nuclear export to the Czech Republic.[604]

The joint statement from the 2023 U.S.-Korea Summit in Seoul included the following unusual statement regarding nuclear exports—whose "weight" the Forum claims cannot be ignored—saying:

> Our two nations are committed to the peaceful use of nuclear energy. The two leaders [U.S. President Joseph R. Biden and President of South Korea Yoon Suk Yeol] affirmed the importance of nuclear energy as a key means for overcoming the energy security crisis and achieving their goal of net zero emissions. The Presidents reaffirmed that both countries are committed to engaging in global civil nuclear cooperation consistent with the International Atomic Energy Agency (IAEA) Additional Protocol, **while mutually respecting each other's export control regulations and intellectual property rights** [emphasis added]. They committed to promoting the responsible development and deployment of civil nuclear energy globally by leveraging financing tools, building capacity in recipient countries, and establishing a more resilient nuclear supply chain.[605]

Shortly after the Czech Government's announcement of the preferred bidder, Westinghouse claimed that KHNP did not have the legal authorization to supply nuclear power plants to the Czech Republic and that it "reserves its rights to challenge this in front of the relevant national and international jurisdictions."[606]

601 - Government of the Czech Republic, "The Government Has Decided on a Preferred Supplier for the New Nuclear Power Source at Dukovany", Press Release, 17 July 2024, op. cit.

602 - President of the Republic of Korea, "'올림픽 승전보와 체코 원전 수주, '팀 코리아' 파이팅!'", 30 July 2024 (in Korean), see https://www.president.go.kr/president/speeches/Wcq1hpkJ; and *The Hankyoreh*, "Undercutting competition on pricing could cost Korea in Czech nuclear plant bid", 19 July 2024, see https://english.hani.co.kr/arti/english_edition/e_national/1149870.html; both accessed 11 August 2024.

603 - *WNN*, "South Korea seeks to boost reactor exports", 13 January 2010, see https://www.world-nuclear-news.org/np-south_korea_seeks_to_boost_reactor_exports-1301104.html, accessed 11 August 2024.

604 - Energy Transition Forum, "[이슈브리핑] '체코 원전수주' 환호 속에 묻힌 4 대 문제와 진실", 23 July 2024 (in Korean), see https://www.energytransitionkorea.org/brief/?q=YToxOntzOjEyOiJrZXl3b3JkX3R5cGUiO3M6MzoiYWxsIjt9&bmode=view&idx=81059832&t=board, accessed 11 August 2024.

605 - The White House, "Leaders' Joint Statement in Commemoration of the 70th Anniversary of the Alliance between the United States of America and the Republic of Korea", 26 April 2023, see https://www.whitehouse.gov/briefing-room/statements-releases/2023/04/26/leaders-joint-statement-in-commemoration-of-the-70th-anniversary-of-the-alliance-between-the-united-states-of-america-and-the-republic-of-korea/, accessed 7 August 2024.

606 - Susanna Twidale, "Westinghouse says KHNP not authorised to use reactor for Czech nuclear tender", *Reuters*, as published by *MarketScreener*, 17 June 2024, see https://ca.marketscreener.com/quote/stock/WESTINGHOUSE-AIR-BRAKE-TE-14842/news/Westinghouse-says-KHNP-not-authorised-to-use-reactor-for-Czech-nuclear-tender-47401884/, accessed 11 August 2024.

As mentioned above, the U.S. court dismissed Westinghouse's lawsuit, but Westinghouse filed a notice of appeal in October 2023. According to the Forum, this dispute could pose a real threat to South Korea for the export of nuclear power plants to third parties. KHNP had requested approval from the U.S. Department of Energy in April 2023, but its filing was rejected as only U.S. entities are legally able to submit such applications.[607]

The Forum also claims that Europe's relatively stringent nuclear safety regulations are also likely to pose a challenge for KHNP. The Czech State Office for Nuclear Safety (SÚJB) has been sharing Western European nuclear safety standards for more than 20 years, which means that it may enforce a significantly different level of nuclear safety regulation than the UAE. European safety regulators have tightened safety regulations since the Fukushima nuclear disaster began in 2011, which contributed to extended construction times and cost overruns in Finland, France, and the U.K.

In particular, the core catcher and double containment design, which have become the standard for new nuclear power plants in Europe, is something that KHNP has never built before. In March 2023, the APR-1000 nuclear power plant design—which includes the new core catcher and double containment design—was certified by the European Utility Requirements (EUR) organization, an advisory organization for European electricity operators.[608] However, when it comes to the actual construction-permit process, the company will have to prove the safety of the equipment under the SÚJB's strict safety regulations. Furthermore, since the Dukovany site is located inland, rather than on the coast, it will require the construction of cooling towers, which is also a first for KHNP—the South Korean reactors are located on the coast—adding to construction time and cost.

Furthermore, the Czech labor standard is a 40-hour workweek, which is significantly different from KHNP's practice at home. The Forum's issue paper said that KHNP has been building nuclear power plants in Korea with a 69-hour workweek for decades and that it even raised concerns over the introduction of a 52-hour workweek in South Korea.[609] The Forum questioned whether KHNP could meet the construction timeline under conditions that differ as much from its home country.

Finally, the Energy Transition Forum pointed out that the most mysterious aspect of the Czech nuclear export appears to be the financing model. While the Czech Government has selected KHNP as the preferred bidder for two reactors, the financing plan, which was approved by the European Commission in April 2024, is limited to the first reactor at Dukovany.[610] Nuclear power plant investments in Europe are risky, and private investors are hard to find in the first place. The estimated construction cost of CZK400 billion (US$17.5 billion) is too much for

607 - Oh Seok-min, "S. Korea urges U.S. to resolve legal issue on nuclear reactor export to Czech Republic", *Yonhap News Agency*, 28 April 2023, see https://en.yna.co.kr/view/AEN20230428003600320, accessed 11 August 2024.

608 - KEPCO, "APR1000 acquires the European Utility Requirements (EUR Rev.E) Certification", 2 March 2023, see https://www.kepco-enc.com/board.es?mid=a20501000000&bid=0039&act=view&list_no=34938, accessed 11 August 2024.

609 - Energy Transition Forum, "[이슈브리핑] '체코 원전수주' 환호 속에 묻힌 4대 문제와 진실", 23 July 2024 (in Korean), op. cit.

610 - EU Commission, "Commission approves State aid to support construction of nuclear power plant in Czechia", European Commission, 30 April 2024, see https://ec.europa.eu/commission/presscorner/detail/en/ip_24_2366, accessed 6 May 2024; and Ministry of Industry and Trade, "The Government Has Decided on a Preferred Supplier for the New Nuclear Power Source at Dukovany", Press Release, Government of the Czech Republic, 17 July 2024, see https://www.mpo.gov.cz/en/guidepost/for-the-media/press-releases/the-government-has-decided-on-a-preferred-supplier-for-the-new-nuclear-power-source-at-dukovany--282181/, accessed 11 August 2024.

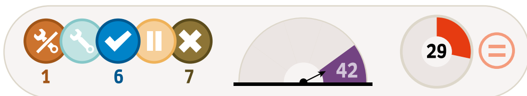
Czech governmental financing, so it will be interesting to see what financing model will be adopted. The only possible financing option for the Czech Government appears to be a loan from South Korea through the Export-Import Bank of Korea or equity participation from KHNP, and then selling power over several decades after construction to recover investment. However, there is still a great deal of uncertainty as to whether it would be beneficial for South Korea to finance a project with a payback period of maybe 30 years or more.

KEPCO's Continued Financial Crisis

According to KEPCO's Semi-annual Report[611], its total debt as of the end of June 2024 was approximately KRW202.9 trillion [US$147.4 billion]. This is about KRW440 billion [US$320 million] more than the KRW202.5 trillion at the end of last year. KEPCO's total debt has been rising since the end of June last year, when it surpassed KRW200 trillion for the first time.

KEPCO's growing debt is mainly due to its operating losses of more than KRW47 trillion [US$34 billion] since 2021, as international energy prices, which soared after the Russia-Ukraine war, were not reflected in the electricity tariff. KEPCO has raised residential electricity tariffs by 44 percent since 2022 and industrial rates by 63 percent since December 2020[612], and the decline in international energy prices has eliminated the company's reverse margin structure for electricity sales. Since the third quarter of last year, the company has posted four consecutive quarters of profitability. However, the accumulated deficit of KRW40 trillion (US$30 billion) for 2021–2023 remains unchanged due to the rising won/dollar exchange rate and the weakening effect of last year's increased electricity tariff.[613]

SWEDEN FOCUS



Sweden's nuclear fleet of six reactors generated 46.65 TWh in 2023, a 6.7 percent decrease compared to the previous year. Nuclear accounted for 28.6 percent of the country's total electricity production. The share of nuclear power in the country's electricity mix peaked in 1996 at 52.4 percent when 12 reactors were operating, while the fleet reached its highest output of over 75 TWh in 2004 with 11 units still on the grid.

The 1100-MW reactor Ringhals-4 was taken off the grid for routine maintenance work in August 2022. During tests, the reactor pressure vessel was damaged, pushing the restart back to November 2022, as Vattenfall had to first build a mock-up to train staff and test procedures and equipment for the repair of damaged components.[614] This replacement work proved to be

611 - KEPCO, "Semi-annual Report 2024", 14 August 2024, see https://dart.fss.or.kr/dsaf001/main.do?rcpNo=20240814004078, accessed 25 August 2024.

612 - *The Korea Economic Daily*, "High power bills drive Korean manufacturers out of country", 23 July 2024.

613 - 한국경제*TV*, "한전, 흑자에도 빚더미...반년 만에 4,400억원↑", 14 August 2024 (in Korean), see https://www.wowtv.co.kr/NewsCenter/News/Read?articleId=A202408140249&t=NN, accessed 25 August 2024.

614 - Nora Buli, Anna Ringstrom and Anne Kauranen, "Sweden's Ringhals 4 nuclear outage extends into winter months", *Reuters*, 13 September 2022, see https://www.reuters.com/business/energy/swedens-ringhals-4-nuclear-outage-extends-into-winter-months-2022-09-13/, accessed 8 September 2023.

more complex than initially imagined, prompting Vattenfall to push the restart date first to January, then February, and finally March 2023.[615] However, in late March, start-up activities were interrupted by leakage "from a small valve in a chemical sampling tube" adjacent to the reactor. The unit eventually came back online at full capacity on 12 April 2023.[616] Over the year, the reactor experienced continuous operational challenges, and an unplanned outage of Ringhals-4 that occurred in parallel with an unplanned outage at Finland's newest reactor Olkiluoto-3 (see Finland in Annex 1), sent Nordic wholesale electricity prices skyrocketing from around €20/MWh (US$$_{2023}$21.6/MWh) in mid-October 2023 to over €130/MWh (US$$_{2023}$140.6/MWh) in November 2023.[617] Prices remained elevated until at least January 2024.[618] During the same time, Swedish reactor Forsmark-3 also experienced an unplanned outage that lasted for three days.[619]

During the summer of 2023, another reactor, Oskarshamn-3, had to reduce power output for two weeks due to "a problem in the turbine system."[620] Operational problems reappeared at Forsmark-3 in March[621] and more recently in June 2024. Production was halted on 10 June 2024, with the plant expected to return to full capacity three days later.[622] However, it was then announced that further work was to be conducted that, as of end-July 2024, had not yet been completed.[623] Media reports speak of an "indefinite" delay.[624] Despite these challenges, all currently operational reactors are scheduled to operate for 60 years, with plans, announced in June 2024, to further extend tne operational lifetimes of all five reactors at Ringhals and Forsmark to 80 years.[625] Ongoing developments regarding reactor lifetime extensions in Sweden are further discussed below.

615 - *NEI Magazine*, "Restart of Ringhals 4 faces further delay", *Nuclear Engineering International*, 28 March 2023, see https://www.neimagazine.com/news/newsrestart-of-ringhals-4-faces-further-delay-10708332, accessed 8 September 2023.

616 - Vattenfall, "Ringhals 4 åter i full produktion", Press Release (in Swedish), 12 April 2023, see https://group.vattenfall.com/se/nyheter-och-press/nyheter/2023/ringhals-4-ater-i-full-produktion, accessed 8 September 2023.

617 - Terje Solsvik, "Operators extend Finnish, Swedish nuclear reactor outages", *Reuters*, 30 November 2023, see https://www.reuters.com/business/energy/operators-extend-finnish-swedish-nuclear-reactor-outages-2023-11-30/, accessed 11 June 2024; and Lars Paulsson, "Nuclear Outages Drive Nordic Power Prices to Highest Since March", *Bloomberg.com*, 29 November 2023, see https://www.bloomberg.com/news/articles/2023-11-29/swedish-reactor-goes-offline-amid-already-soaring-power-prices, accessed 29 November 2023.

618 - Per Karlsson et al., "Nordics | Increasing Volatility Fuels Uncertainty", S&P Global, February 2024, see https://www.spglobal.com/_assets/documents/ratings/research/101593187.pdf, accessed 7 August 2024.

619 - Terje Solsvik, "Operators extend Finnish, Swedish nuclear reactor outages", *Reuters*, 30 November 2023, op. cit; and Paulsson, op.cit; and Lars Paulsson, "Nuclear Outages Drive Nordic Power Prices to Highest Since March", *Bloomberg.com*, 29 November 2023, op. cit.; also Vattenfall, "Elproduktionen vid Forsmark 3 är tillfälligt stopped", 25 November 2023 (in Swedish), see https://group.vattenfall.com/se/nyheter-och-press/nyheter/2023/tillfalligt-produktionsstopp-pa-forsmark2, accessed 28 July 2024.

620 - Lars Paulsson, "Sweden's Biggest Nuclear Reactor Will Be Offline Until Sept. 15", *Bloomberg.com*, 30 August 2023, see https://www.bloomberg.com/news/articles/2023-08-30/sweden-s-biggest-nuclear-reactor-will-be-offline-until-sept-15, accessed 11 June 2024.

621 - Vattenfall, "Forsmark 3 utför planerat underhåll", Press Release (in Swedish), 15 March 2024, see https://group.vattenfall.com/se/nyheter-och-press/nyheter/2024/forsmark-3-utfor-planerat-underhall, accessed 7 August 2024.

622 - Vattenfall, "Tillfälligt produktionsstopp Forsmark 3", Press Release (in Swedish), 10 June 2024, see https://group.vattenfall.com/se/nyheter-och-press/nyheter/2024/snabbstopp-forsmark-3, accessed 7 August 2024.

623 - Vattenfall, "Tillfälligt produktionsstopp Forsmark 3", Press Release (in Swedish), 13 June 2024, see https://group.vattenfall.com/se/nyheter-och-press/nyheter/2024/tillfalligt-produktionsstopp-forsmark--3, accessed 7 August 2024.

624 - Wilhelm Zakrisson, "Vattenfall delays restart of Forsmark 3 (1.2 GW) reactor indefinitely", *Montel News, 20 June 2024, see* https://montelnews.com/news/0e51041c-0468-4e43-9ac5-e2b4f589d514/vattenfall-delays-restart-of-forsmark-3-1-2-gw-reactor-indefinitely, accessed 7 August 2024.

625 - Vattenfall, "Forsmark and Ringhals nuclear power plants aim for 80 years of operation of existing reactors", Press Release, 17 June 2024, see https://group.vattenfall.com/press-and-media/pressreleases/2024/forsmark-and-ringhals-nuclear-power-plants-aim-for-80-years-of-operation-of-existing-reactors, accessed 17 June 2024.

Reversing the Phaseout Policy

For more than four decades, a planned nuclear phaseout had been a central part of energy policy in Sweden. A 1980 public referendum set the target to end commercial utilization of nuclear power by 2010. Sweden retained the 2010 phaseout date until the middle of the 1990s, but an active debate on the country's nuclear future continued and led to a new inter-party deal to start the phaseout earlier but abandon the 2010 deadline. The first commercial reactors to close were Barsebäck-1 in 1999 and Barsebäck-2 in 2005. In June 2010, Parliament voted by a tight margin to abandon the phaseout legislation and aim for carbon neutrality by 2050. Following this decision, new reactors were allowed to be built, but only at pre-existing sites.[626] Later, the goal of carbon neutrality was pulled forward to 2045,[627] with the target of a "100% renewable" electricity system by 2040, though it was explicitly stressed that it did not automatically correspond to a nuclear phaseout.[628]

The cooperation agreement of Sweden's current center-right Government (a coalition of the Moderate Party, the Christian Democrats, and the Liberal Party) with the far-right party of the Sweden Democrats, signed on 14 October 2022, is referred to as the "Tidö Agreement". It contains a pledge to change the energy policy goal "from 100% renewable" to "100% fossil-free", thus paving the way for the inclusion and expansion of nuclear power in the future energy mix. The new government indicated it would also provide special credit guarantees for nuclear power investments "with more generous terms", totaling SEK400 billion (US$$_{2022}$39.5 billion).[629]

This rephrasing was approved by Parliament in June 2023. Consequently, Sweden now aims for "100% fossil-free" instead of "100% renewable" electricity generation by 2040.[630] The updated draft of the National Energy and Climate Plan (NECP) (finalized in June 2024, see below) was submitted to the European Commission in July 2023, officializing the newly adopted formulation.[631]

626 - WNA, "Nuclear Power in Sweden", World Nuclear Association, Updated 25 March 2024, see https://world-nuclear.org/information-library/country-profiles/countries-o-s/sweden.aspx, accessed 1 August 2024.

627 - Ministry of the Environment and Energy, "The Swedish climate policy framework", Government Offices of Sweden, 2017, see https://www.government.se/495f60/contentassets/883ae8e123bc4e42aa8d59296ebe0478/the-swedish-climate-policy-framework.pdf, accessed 14 July 2022.

628 - Ministry of Infrastructure, "Sweden's Integrated National Energy and Climate Plan", Government of Sweden, 16 January 2020, see https://energy.ec.europa.eu/system/files/2020-03/se_final_necp_main_en_0.pdf, accessed 8 September 2023.

629 - Sverigedemokraterna, Moderaterna, Kristdemokraterna and Liberalerna, "Tidöavtalet: Överenskommelse för Sverige", October 2023 (in Swedish), see https://www.liberalerna.se/wp-content/uploads/tidoavtalet-overenskommelse-for-sverige-slutlig.pdf, accessed 28 July 2024; and *WNN*, "New Swedish government seeks expansion of nuclear energy", 17 October 2022, see https://www.world-nuclear-news.org/Articles/New-Swedish-government-seeks-expansion-of-nuclear?feed=feed, accessed 17 October 2022.

630 - Simon Johnson, "Swedish parliament passes new energy target, easing way for new nuclear power", *Reuters*, 20 June 2023, see https://www.reuters.com/sustainability/climate-energy/swedish-parliament-passes-new-energy-target-easing-way-new-nuclear-power-2023-06-20/, accessed 8 September 2023.

631 - Ministry of Climate and Industry, "Draft updated National Energy and Climate Plan (NECP) for Sweden", Government Offices of Sweden, 11 July 2023, see https://commission.europa.eu/publications/sweden-draft-updated-necp-2021-2030_en, accessed 9 September 2023.

In mid-November 2023, the government presented a roadmap for the envisioned nuclear power expansion in Sweden which "clarifies the Government's objectives and provides long-term conditions for new nuclear power." This roadmap consists of four steps:[632]

- The government is to appoint a so-called "nuclear power coordinator" mandated to identify necessary measures, remove regulatory hurdles, coordinate all stakeholders, and promote new nuclear. Carl Berglöf, secretary general of the Swedish Atomic Forum (SAFO), was appointed to this role in January 2024, effective 1 February 2024. His final mission report is due by 31 December 2026.[633] Berglöf submitted his first report in June 2024, in which he calls for a dedicated project management organization as well as separate commissions to further develop concrete plans and regulations.[634]
- A financing scheme shall be developed that will split the financial risk between the state and private investors. The Swedish National Debt Office was tasked with developing "preparatory measures" for the issuance of state credit guarantees in compliance with EU regulations, as SEK400 billion (US$38 billion) in credit guarantees were included in the proposed 2024 Budget Bill.[635] An investigator was appointed to propose models for the government to take on further financial burdens and risks.[636]
- New policies shall allow for a minimum of 2.5 GW of new nuclear capacity to be connected to the grid by 2035.
- Regulatory and financial changes shall allow for the subsequent "massive expansion" of new nuclear that "could, for example, correspond to ten new large-scale reactors" by 2045. The exact composition and location of this new fleet has not yet been defined.

Many of these envisaged "new policies" or "changes" seem to disregard the fact that Sweden does not have its own reactor-building industry anymore. Construction of the most recent reactor started in the country in 1980 with grid connection in 1985; no other projects were carried out in the past 40 years. This means that Sweden—just as most of the other countries making newbuild plans—will depend on the same handful of potential builders.

632 - Regeringskansliet, "Regeringen lanserar en färdplan för ny kärnkraft i Sverige", Press Release (in Swedish), Government Offices of Sweden, 16 November 2024, see https://www.regeringen.se/pressmeddelanden/2023/11/regeringen-lanserar-en-fardplan-for-ny-karnkraft-i-sverige/, accessed 28 July 2024; and WNN, "Sweden plans 'massive' expansion of nuclear energy", *World Nuclear News*, 17 November 2023, see https://www.world-nuclear-news.org/Articles/Roadmap-launched-for-expansion-of-nuclear-energy-i, accessed 17 November 2023.

633 - Regeringskansliet, "Carl Berglöf utses till nationell kärnkraftssamordnare", Press Release (in Swedish), Government Offices of Sweden, 4 January 2024, see https://www.regeringen.se/pressmeddelanden/2024/01/carl-berglof-utses-till-nationell-karnkraftssamordnare/, accessed 28 July 2024; and David Dalton, "Sweden / Gov't Appoints Nuclear Coordinator As Plans To Deploy New Reactors Gather Pace", *NucNet*, 5 January 2024, see https://www.nucnet.org/news/gov-t-appoints-nuclear-coordinator-as-plans-to-deploy-new-reactors-gather-pace-1-5-2024, accessed 10 June 2024.

634 - Ministry of Climate and Enterprise, "Kärnkraftssamordnaren lämnar sina första förslag till regeringen", Press Release (in Swedish), Government Offices Of Sweden, 18 June 2024, see https://www.regeringen.se/pressmeddelanden/2024/06/karnkraftssamordnaren-lamnar-sina-forsta-forslag-till-regeringen/, accessed 7 August 2024.

635 - Regeringskansliet, "Uppdrag att vidta förberedande åtgärder för att kunna ställa ut statliga kreditgarantier för investeringar i ny kärnkraft", 17 November 2023 (in Swedish), see https://www.regeringen.se/regeringsuppdrag/2023/11/kreditgarantier-for-investeringar-i-ny-karnkraft/, accessed 28 July 2024.

636 - In August 2024, the Swedish Government released a report on "Financing and Risk Sharing for Investments in New Nuclear Power" that suggests the state should lend nuclear companies 75 percent of the investment cost of nuclear plants with the owners contributing 25 percent. Cost overruns should be financed in the same proportions. The report recommends that the government should guarantee, in the framework of a Contract for Difference, a strike price of SEK0.8/kWh (US$0.075/kWh) to investors over 40 years; see Ministry of Finance, "Promemoria – Finansiering och riskdelning vid investeringar i ny kärnkraft", Government of Sweden, August 2024 (in Swedish), see https://www.regeringen.se/contentassets/785ee941726840229ed69135ca8f890c/finansiering-och-riskdelning-vid-investeringar-i-ny-karnkraft.pdf, accessed 13 August 2024.

In January 2024, amendments to the Environmental Code took effect, removing the previous limit of ten operational nuclear reactors in Sweden. Additionally, the changes now allow for new plants to be built at new locations other than previous or current reactor sites. The changes were proposed by the government in October 2023 and adopted by Parliament the following month, with all three coalition parties and the right-wing extremist party of the Sweden Democrats voting for, and all other parties against.[637]

In their most recent report, the government-appointed Climate Policy Council criticizes the climate policies for their "one-sided emphasis on new nuclear reactors" that would reduce incentives for the expansion of other non-fossil energy production infrastructure, especially in the short term, and, assuming first reactors could come to the grid by 2035, it would be too late, as "half the time to reach zero emissions [would have] already passed."[638]

The final NECP, published in June 2024, assumes that 52 TWh of nuclear power will be generated by 2030—10 percent higher than today's production. Remarkably, however, while it states that nuclear "is a prerequisite for reaching climate objectives", i.e., fossil-free electricity production by 2040, the NECP includes no explicit target for nuclear power capacity beyond 2030 (albeit including scenarios on the potential expansion of renewables).[639] However, some of the NECP's projections are based on the Swedish Energy Agency's 2023 report on Scenarios of Sweden's Energy System.[640] This report analyzes three scenarios regarding the future electrification of Swedish energy demand. The scenarios assume an increase from 134 TWh of electricity demand in 2020 to 264, 349, and 228 TWh, respectively. An update on the "high demand scenario" was published in December 2023.[641]

In the original report, all scenarios assumed that existing reactors would operate for at least 60 years, and three of them would run for 80 years. Reactors are assumed to produce at a load factor varying from 85 to 90 percent.[642] Newbuild costs lie at an optimistic SEK50,000 (US$$_{2023}$4,712) per kW, less than half of current European newbuild projects (see Nuclear Economics and Finance in WNISR2023).

Nonetheless, nuclear power production from new reactors in 2050 is projected to be limited. In Scenario 1, with medium electrification, production falls to 31 TWh, of which 2.7 TWh are covered by new reactors, corresponding to roughly 340 MW[643] of new capacity. The original

637 - Sveriges Riksdag, "Betänkande 2023/24:NU5— Ny kärnkraft i Sverige", Swedish Parliament, approved 29 November 2023 (in Swedish), see https://www.riksdagen.se/sv/dokument-och-lagar/dokument/betankande/ny-karnkraft-i-sverige_hb01nu5/, accessed 28 July 2024.

638 - Swedish Climate Policy Council, "2024 Report of the Swedish Climate Policy Council", March 2024, see https://www.klimatpolitiskaradet.se/wp-content/uploads/2024/06/reportoftheswedishclimatepolicycouncil2024.pdf, accessed 29 July 2024.

639 - Ministry of Climate and Enterprise, "Sweden's updated National Energy and Climate Plan 2021-2030", dated June 2024, released 1 July 2024, Government Offices of Sweden, see https://commission.europa.eu/document/download/26d2c93e-641d-489f-a160-a7052fde58bb_en?filename=SE_FINAL%20UPDATED%20NECP%202021-2030%20%28English%29.pdf, accessed 11 July 2024.

640 - Energimyndigheten, "Scenarier över Sveriges energisystem 2023—Med fokus på elektrifieringen 2050", ER 2023:07, Swedish Energy Agency, April 2023 (in Swedish), see https://energimyndigheten.a-w2m.se/Home.mvc?ResourceId=213739, accessed 10 June 2024.

641 - Energimyndigheten, "Uppdaterade långsiktiga scenarier 2023— Bakgrund och viktiga förändringar i resultaten för elsystemet", Swedish Energy Agency, 12 December 2023 (in Swedish), see https://www.energimyndigheten.se/48ea22/globalassets/statistik/prognoser-och-scenarier/langsiktiga-scenarier/uppdaterade-langsiktiga-scenarier-2023.pdf, accessed 11 August 2024.

642 - For comparison, the average load factor of all Swedish reactors (including already closed ones) lies at 76 percent. Taken from IAEA, Power Reactor Information System (PRIS), 9 June 2024, https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=SE, accessed 10 June 2024.

643 - Assuming a 90 percent load factor.

Scenario 2, that assumes the highest electrification levels, showed an increase of nuclear power production to 66 TWh, of which 38 TWh are covered by new reactors, roughly 4.8 GW. The updated version of this scenario, with "an adapted electricity demand" (not specified, but definitely increased) and a "higher potential for nuclear power," but with slightly higher costs of SEK55,000 (US$$_{2023}$5,183) per kW, adds an *additional* 63 TWh of nuclear power production, covered by a total installed capacity of 16 GW (10 GW of which from new reactors).[644] In Scenario 3, which corresponds to the lowest electrification rate, nuclear power production falls from 47 TWh in 2020 to 28 TWh in 2050, and there is no newbuild. The original report, published before the government's announcement of substantial newbuild, showed that the plans were overambitious—and this is sustained by the updated report in which the planned capacities only become necessary when electricity demand exceeds 360 TWh. For comparison, the final NECP states that government plans assume a demand of only 300 TWh in 2045,[645] a demand level that could easily be covered under the original Scenario 2.

Swedish SMR Ambitions

Nonetheless, before the amendment of the phaseout legislation in late 2023, in June 2022, state-owned utility and nuclear operator Vattenfall had launched a feasibility study on the commercial, legal, and technological prerequisites to build at least two SMRs at Ringhals, to be followed by a public consultation process,[646] and notified the grid operator in December 2022 on the possibility of connecting 2.8 GW of new unspecified nuclear capacity at Ringhals by 2032.[647] The results of the study were published in February 2024 and also include preliminary assessments of high-capacity reactor projects to "create the most favorable preconditions for a successful project." Therein, Vattenfall draws from the experiences of other international nuclear newbuild projects to conclude that a reactor construction project should only begin once a final design has been completed (and is not modified thereafter). The utility further advocates for a whole fleet of new reactors to be built, potentially "3 to 5 SMRs" or 1.5 GW at Ringhals. It considers that the "existing Swedish legislation can be applied for SMR technology", though "the permit process needs to be simplified to become more predictable and efficient." Based on the "overall assessment" that "the commercialization of the technology will take slightly longer than previously communicated by suppliers" (six were evaluated), while acknowledging that "timing of commercialization is [the] main uncertainty with SMRs" yet noting that "shorter construction time is expected with SMRs," the study concludes that a first reactor could be connected "between 9-11 years from today." However, several necessary steps remain to be completed before Vattenfall would be able to make a final investment decision, including a risk sharing model with the state, a positive net-present value, a finalized reactor design, that would have to include construction plans with "robust supply chains", and the

644 - Energimyndhigheten, "Scenarier över Sveriges energisystem 2023—Med fokus på elektrifieringen 2050", Swedish Energy Agency, April 2023, op. cit.

645 - Ministry of Climate and Enterprise, Sweden's Updated National Energy and Climate Plan 2021-2030.

646 - Vattenfall, "Vattenfall begins feasibility study on construction of small modular reactors at Ringhals", Press Release, 28 June 2022, see https://group.vattenfall.com/press-and-media/pressreleases/2022/vattenfall-begins-pilot-study-on-construction-of-small-modular-reactors-at-ringhals, accessed 8 September 2023.

647 - Nora Buli, "Sweden's Vattenfall investigates new 2.8 GW nuclear capacity at Ringhals", *Reuters*, 25 January 2023, see https://www.reuters.com/business/energy/swedens-vattenfall-plans-new-28-gw-nuclear-reactors-ringhals-2023-01-25/, accessed 8 September 2023.

granting of all permits. An evaluation of high-capacity reactor feasibility was announced as a "next step".[648]

In October 2022, Finnish company Fortum, which operates the Loviisa plant in Finland, also launched a two-year feasibility study for the deployment of new nuclear—including SMRs—in both Finland and Sweden.[649] In August 2023, Swedish "nuclear-only" electricity provider Kärnfull Next launched a feasibility study together with Swedish nuclear service provider Studsvik regarding the deployment of SMRs at Studvik's Nyköping site. It had been planned to complete the pre-feasibility study by December 2023 and make "key decisions regarding financing, permitting and PPAs [power purchase agreements] with off-takers (...) in the second half of 2024."[650] In November 2023, Studsvik signed an MoU with Fortum to "explore conditions for new nuclear in Sweden", including to "assess the potential to construct small modular reactors (SMR) or conventional large reactors at the Studsvik site outside Nyköping." This investigation is supposed to be a part of Fortum's large-scale feasibility study mentioned above (see Finland in Annex 1), and will run in parallel to that of Kärnfull Next.[651] However, as of writing in mid-2024, there have been no indications that the latter study had been completed at the end of 2023 as planned. Instead, Kärnfull Next announced a strategic partnership with Finnish SMR developer Steady Energy to provide district heating,[652] and plans to assess another location for an industrial SMR site in Sweden near Valdemarsvik.[653]

In August 2023, Michael Lewis, CEO of Uniper, co-owner of all three currently operating nuclear power plants, reiterated that his company would "not invest any further in nuclear power" but rather in "new flexible capacities like batteries and gas plants that can be converted to being zero carbon." Uniper is planning to leave the coal sector and boost its non-fossil, low-carbon options from today's 20 percent to 80 percent by 2030 and become carbon neutral by 2040.[654] However, during a press conference held in November 2023 to present the Swedish Government's roadmap for new nuclear deployment, Energy Minister Ebba Busch said that Uniper was one of the private investors that had expressed interest in co-funding the

648 - Vattenfall, "Status of Vattenfall's initiative for new nuclear", 19 February 2024, see https://group.vattenfall.com/se/siteassets/documents/vattenfall-plan-for-new-nuclear-20240219.pdf, accessed 29 July 2024.

649 - Fortum, "Fortum launches a feasibility study to explore prerequisites for new nuclear", 17 October 2022, see https://www.fortum.com/media/2022/10/fortum-launches-feasibility-study-explore-prerequisites-new-nuclear, accessed 29 July 2024.

650 - Kärnfull Next, "Kärnfull Next Unveils Plans for SMR Campus in Nyköping, Sweden", Press Release, 24 August 2023, see https://www.knxt.se/studsvik, accessed 29 July 2024.

651 - *WNN*, "Studsvik, Fortum study prospects for new nuclear at Nyköping", 17 November 2023, see https://www.world-nuclear-news.org/Articles/Studsvik,-Fortum-study-prospects-for-new-nuclear-a, accessed 11 June 2024; and Fortum, "Fortum and Studsvik partner to explore possibilities for new nuclear in Sweden", 17 November 2023, Press Release, see https://www.fortum.com/media/2023/11/fortum-and-studsvik-partner-explore-possibilities-new-nuclear-sweden, accessed 29 July 2024.

652 - Kärnfull Next, "Steady Energy and Kärnfull Next Partner for Sustainable Swedish District Heating", Press Release, 18 June 2024, see https://www.knxt.se/news/steady, accessed 30 July 2024.

653 - Kärnfull Next, "Kärnfull Next Plans Major SMR Campus in Valdemarsvik", Press Release, Kärnfull Next, 26 June 2024, see https://www.knxt.se/valdemarsvik, accessed 30 July 2024.

654 - Charles Szumski, "Germany refuses to build nuclear Uniper plant in Sweden ", *Euractiv*, 11 November 2022, see https://www.euractiv.com/section/politics/news/germany-refuses-to-build-nuclear-uniper-plant-in-sweden/; and Nathan Witkop, "Uniper to avoid new investment in nuclear power – CEO", *Montel*, 1 August 2023, see https://www.montelnews.com/news/1513409/uniper-to-avoid-new-investment-in-nuclear-power--ceo; both accessed 9 September 2023.

construction of new reactors.[655] Regardless, the company's spokesperson reportedly stated "we do not have any plans currently to invest in new nuclear power."[656]

Swedish Prime Minister Ulf Kristersson visited Paris in January 2023 where he reiterated that the "new Swedish government is determined to build new nuclear power plants" and stated that he was "entirely open to France being one of the countries that will make sure that Sweden has more nuclear power."[657] In December 2023, a declaration of intent for the establishment of a long-term cooperation in the field of civil nuclear power was signed by Ebba Busch and her French counterpart.[658] In January 2024, a "strategic innovation partnership" was signed between France and Sweden to broaden cooperation in "three new areas: forestry, nuclear energy, and security".[659] The subject of international cooperation was also on the agenda in May 2023 when South Korean Prime Minister Han Duck-soo visited his Swedish counterpart, who promised that "Sweden is going to build new nuclear power plants," and explained, "South Korea is a role model when it comes to developing new nuclear energy, and we are now enhancing our cooperation."[660]

Swedish Lifetime Extension Strategy

With electricity prices sky-rocketing resulting from the energy crisis caused by Russia's invasion of Ukraine, Vattenfall was asked by the new government to investigate whether recently closed reactors Ringhals-1 and -2 could be restarted.[661] This option was swiftly declined by Torbjörn Wahlborg, Vattenfall's Head of Electricity Production, as it would be "risky, costly and perhaps not even possible", going as far as stating that it was "neither feasible nor desirable." Wahlborg explained that even if carried out, the restart would offer no relief on electricity prices in the 2020s, as the restart of Ringhals-1 alone would take at least six or seven years (if successful) and cost "many billions [SEK]" in any case.[662] Further, the restart of Ringhals-2 was not possible at all due to the damaged bottom plate of the reactor tank.

655 - Simon Johnson, "Sweden plans new nuclear reactors by 2035, will share costs", *Reuters*, 16 November 2023, see https://www.reuters.com/business/energy/sweden-plans-new-nuclear-reactors-by-2035-can-take-costs-2023-11-16/, accessed 10 June 2024.

656 - Simon Johnson, "Germany's Uniper says no plans to build new nuclear reactors in Sweden", *Reuters*, 17 November 2023, see https://www.reuters.com/business/energy/germanys-uniper-says-no-plans-build-new-nuclear-sweden-2023-11-17/, accessed 30 July 2024.

657 - *Euronews*, "Sweden turns to France as it looks to buy two new nuclear reactors", with *AFP*, 3 January 2023, see https://www.euronews.com/2023/01/03/sweden-turns-to-france-as-it-looks-to-buy-two-new-nuclear-reactors, accessed 9 September 2023.

658 - French Ministry for Energy Transition and Swedish Ministry of Climate and Enterprise, "Declaration of Intent for the Establishment of Long-Term Cooperation in the Nuclear Energy Sector Between the Ministry for Energy Transition of the French Republic and the Ministry of Climate and Enterprise of the Kingdom of Sweden", December 2023, see https://www.regeringen.se/contentassets/aa01f04272fc4e7da09b224987c33ad6/declaration-of-intent-for-the-establishment-of-long-term-cooperation-in-the-nuclear-energy-sector.pdf, accessed 28 July 2024.

659 - Prime Minister's Office, "Renewed strategic partnership between Sweden and France", Press Release, Government Offices of Sweden, 31 January 2024, see https://www.government.se/press-releases/2024/01/renewed-strategic-partnership-between-sweden-and-france/, accessed 10 June 2024.

660 - Prime Minister's Office, "New nuclear energy in focus when Prime Minister received South Korea's Prime Minister", Press Release, Government Offices of Sweden, 10 May 2023, see https://www.government.se/articles/2023/05/new-nuclear-energy-in-focus-when-prime-minister-receives-south-koreas-prime-minister/, accessed 8 September 2023.

661 - *WNN*, "New Swedish Government Seeks Expansion of Nuclear Energy", 17 October 2022, op. cit.

662 - SEK1 ≈ US$0.09 (as of June 2024)

Wahlborg stressed that Sweden should instead focus on operating facilities and pave the way for new nuclear capacities.[663]

Despite the postponement of the nuclear phaseout, several reactors have closed in the past decade for economic reasons. In 2015, operators decided to close the country's four oldest reactors.[664] Consequently, Unit 2 at Oskarshamn, which last produced electricity in 2013, was officially closed in January 2016, followed by Unit 1 in June 2017, then Ringhals-2 in December 2019, and Ringhals-1 in 2020. First grid connection for these units occurred in 1974, with the exception of Oskarshamn-1, which started up in 1971.[665] Decommissioning work is underway at both sites (see Decommissioning Status Report). The closure of these reactors is often attributed to a controversial tax on nuclear power plants that had existed since the year 2000 and had been increased over time by both left- and right-wing governments.[666]

Six reactors, half of the original fleet, are thus still in operation at Forsmark, Oskarshamn, and Ringhals. It is planned to operate each reactor for a full 60 years, resulting in the youngest reactors, Forsmark-3 and Oskarshamn-3, to be closed as late as 2045.[667] In June 2024, plans were announced for continued operation of up to 80 years of the reactors at Forsmark and Ringhals. Most investments for this would be necessary in the 2030s.[668]

In the past, due to historical nuclear phaseout plans and the current limitation of nuclear newbuild to existing sites and the replacement of old reactors, the Swedish strategy has focused on uprating existing reactors.[669] For example, at Forsmark, this has been ongoing since the 1980s and, according to IAEA-PRIS data, consecutive uprating has increased installed capacity of the three units by 15.6 percent, 24.6 percent, and 11.6 percent, respectively. Further plans included the uprating of Unit 1 by another 100 MW[670] and Forsmark-3 by a further 200 MW.[671] It appears that the former has been completed, while the latter was not.[672] In total, this strategy

663 - Torbjörn Wahlborg, "Debatt: Inte rimligt att återstarta reaktor vid Ringhals", *Dagens Industri*, 18 March 2023 (in Swedish), see https://www.di.se/debatt/debatt-inte-rimligt-att-aterstarta-reaktor-vid-ringhals/, accessed 9 September 2023.

664 - OKG, "Decision Made Regarding Premature Shutdown of Units Oskarshamn 1 and Oskarshamn 2", Press Release, Oskarshamns Kraftgrupp, 14 October 2015, see https://www.okg.se/en/press-room/decision-made-regarding-premature-shutdown-of-units-oskarshamn-1-and-oskarshamn-2; and Vattenfall, "Vattenfall changes direction for operational lifetimes of Ringhals 1 and 2", 28 April 2015, Press Release, see https://group.vattenfall.com/press-and-media/pressreleases/2015/vattenfall-changes-direction-for-operational-lifetimes-of-ringhals-1-and-2; both accessed 31 August 2022.

665 - SKB, "Plan 2019 - Costs from and including 2021 for the radioactive residual products from nuclear power - Basis for fees and guarantees for the period 2021-2023", Svensk Kärnbränslehantering/Swedish Nuclear Fuel and Waste Management Company, December 2019, see https://www.skb.com/publication/2494604/TR-19-26.pdf; and Vattenfall, "The Ringhals 1 reactor has crossed the finish line", Press Release, 2021, see https://group.vattenfall.com/press-and-media/newsroom/2021/the-ringhals-1-reactor-has-crossed-the-finish-line, both accessed 14 July 2022.

666 - Anne-Françoise Hivert, "The resurrection of Sweden's nuclear program", *Le Monde*, 14 February 2023, see https://www.lemonde.fr/en/economy/article/2023/02/14/the-resurrection-of-sweden-s-nuclear-program_6015670_19.html, accessed 12 September 2023.

667 - WNA, "Nuclear Power in Sweden", World Nuclear Association, Updated July 2023, see https://world-nuclear.org/information-library/country-profiles/countries-o-s/sweden.aspx, accessed 14 September 2023.

668 - Vattenfall, "Forsmark and Ringhals nuclear power plants aim for 80 years of operation of existing reactors", Press Release, 17 June 2024, op. cit.

669 - Ibidem.

670 - Roger Fry, "Vattenfall plans 100 MW upgrade to Forsmark 1 reactor", *Montel*, 13 June 2022, see https://www.montelnews.com/news/1327678/vattenfall-plans-100-mw-upgrade-to-forsmark-1-reactor; and *NEI Magazine*, "Vattenfall to increase power at Forsmark NPP unit 1", 16 June 2022, see https://www.neimagazine.com/news/newsvattenfall-to-increase-power-at-forsmark-npp-unit-1-9777570, accessed 9 September 2023.

671 - *NEI Magazine*, "Restart of Ringhals 4 faces further delay", 28 March 2023, op. cit.

672 - IAEA/PRIS, "Reactor Details - Forsmark-1", Updated 10 August 2024, see https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=541; and IAEA/PRIS, "Reactor Details - Forsmark-3", Updated 10 August 2024, see https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=532, both accessed 11 August 2024.

has, as of July 2024, led to around 999 MW of additional nuclear capacity in operational nuclear power plants.[673]

To operate reactors into the 2040s, owners need to win approval following ten-year periodic safety reviews. The first reactors to get permission were 39-year-old Forsmark-1 and 38-year-old Forsmark-2, which secured approval from the regulatory authority (SSM) on 18 June 2019 to operate for 10 more years until 2028.[674] SSM approved continued operation of the reactors, while also finding

> deficiencies regarding the containment and aging of concrete structures deemed as small in the current situation, but it may increase in the long term if the deficiencies are not remedied since serious degradations [...] may occur in the reactor containment and other building structures of importance for radiation safety.[675]

This could mean significant refurbishment work will be required in the coming years.

Major upgrading work at all of Sweden's reactors was completed in 2020. This relates to the SSM requirement that all reactors operating beyond 2020 have Independent Core Cooling Systems (ICCS) designed to withstand extreme external hazards. The new system obligation is a consequence of the stress tests carried out following the Fukushima disaster in 2011.[676] On 18 December 2020, SSM confirmed that the six reactors predominantly meet set conditions and requirements.[677] Further modernization of components at Ringhals-3 and -4 will be conducted by Framatome that in May 2023 was contracted by Vattenfall to update reactor control systems as well as refurbish reactor coolant pumps. This work is to commence in 2026 at Unit 3 and in 2027 at Unit 4.[678]

In 2023, 166 TWh of Swedish electricity (gross) were produced by mainly hydro (40 percent), nuclear (29 percent), and onshore wind (21 percent); the remainder coming from fossil fuel and bioenergy sources. Solar PV generation has been increasing over the past few years but remains small with 2.5 TWh in 2023, representing just 1.5 percent.[679] According to the new NECP, annual wind power production is expected to increase by 50 TWh by 2030, solar expansion remains limited, with only 8 TWh of expected additional annual production.

673 - IAEA, "Country Statistics—Sweden", Updated 13 August 2024, see https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=SE, accessed 14 August 2024.

674 - SSM, "Forsmark har förutsättningar att fortsätta driva F1 och F2 strålsäkert till 2028s", Press Release (in Swedish), Strålsäkerhetsmyndigheten/Swedish Radiation Safety Authority, 24 June 2019.

675 - SSM, "Återkommande helhetsbedömning—Forsmarks Kraftgrupp AB—Forsmark 1 och 2", Strålsäkerhetsmyndigheten/Swedish Radiation Safety Authority, 18 June 2019 (in Swedish), see https://www.stralsakerhetsmyndigheten.se/contentassets/6b998f90ef4c4dda8a5914ce3c3ca982/granskning-av-aterkommande-helhetsbedomning-av-forsmark-1-och-2.pdf, accessed 9 September 2023.

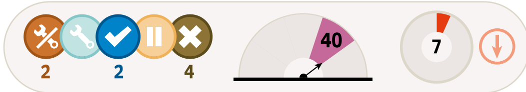
676 - Ministry of the Environment, "Sweden's Eighth National Report under the Convention on Nuclear Safety—Sweden's Implementation of the Obligations of the Convention", Swedish Government, Ds 2019:16, August 2019 see https://www.regeringen.se/contentassets/c8c431c94efb4c4abefb38ca36272b5a/swedens-eighth-national-report-under-the-convention-on-nuclear-safety-ds-201916.pdf, accessed 9 September 2023.

677 - SSM, "Forsmark, Ringhals och OKG uppfyller kraven på oberoende härdkylning", Strålsäkerhetsmyndigheten/Swedish Radiation Safety Authority, 18 December 2020 (in Swedish), see https://www.stralsakerhetsmyndigheten.se/press/nyheter/2020/forsmark-ringhals-och-okg-uppfyller-kraven-pa-oberoende-hardkylning/, accessed 15 July 2021.

678 - Framatome, "Framatome signs contract with Vattenfall to modernize reactor systems at Ringhals", Press Release, 10 May 2023, see https://www.framatome.com/medias/framatome-signs-contract-with-vattenfall-to-modernize-reactor-systems-at-ringhals/, accessed 9 September 2023.

679 - Ember, "Electricity Data Explorer—Sweden electricity generation by source", 2023, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 11 June 2024.

TAIWAN FOCUS



Taiwan has two operating reactors at Maanshan, owned by the Taiwan Power Company (Taipower), the state-owned utility monopoly. The latest reactor to close was the 985-MW BWR Kuosheng-2 (or Guosheng) on 14 March 2023, following the closure of Kuosheng-1 in July 2021. Maanshan-1 is scheduled for closure in July 2024[680] and Maanshan-2 in May 2025.[681]

This is the lowest nuclear share in the power mix since 1978.

As a logical consequence of the latest reactor closure, nuclear generation declined again in 2023. According to Taipower, nuclear power production decreased by 25.2 percent, generating 17.15 TWh which amounts to 7 percent of the country's electricity.[682] This is the lowest nuclear share in the power mix since 1978. Nuclear generation reached a maximum contribution of 41 percent in 1988.

After the January 2020 re-election of President Tsai Ing-wen of the Democratic Progressive Party (DPP), the government continued its strategy of phasing out nuclear and enacting an energy-transition policy.[683]

In a 2018-referendum, citizens had voted to remove the amendment to the Electricity Act which made the 2025-phaseout deadline legally binding. The amendment was withdrawn, but the government's commitment to the policy remained intact; thus, Kuosheng-2 was the fourth Taiwanese reactor to be closed under the national nuclear phaseout plan, marking another milestone in the island's energy transition.

National Politics

After DPP candidate William Lai won the presidential election in January 2024, Chinese Nationalist Party (KMT) legislators renewed calls for scrapping the nuclear reactor closure deadline, currently set to come after 40 years of service.[684] Although William Lai previously defended President Tsai's energy policy to phase out nuclear and will probably continue the policy, he rhetorically stated during his election campaign that "if emerging technologies can resolve nuclear waste and guarantee safety, nuclear power could be a viable option for the nation."[685]

On assuming the presidency on 20 May 2024, Lai made a pledge to carry on Tsai Ing-wen's energy policy (see the section below Energy and Climate Policy). Thus far, Lai's government

680 - Maanshan-1 closed on 27 July 2024 as scheduled. See Taipower,

681 - Nuclear Safety Commission, "Nuclear Power Plant Decommissioning Regulations", Nuclear Safety Commission, 16 April 2024, see https://www.nusc.gov.tw/english/Nuclear-Reactor-Safety/Nuclear-Power-Plant-Decommissioning-Regulations-271.html, accessed 16 April 2024.

682 - Taipower, "Nuclear Power Status and Performance - Power Generation Information", Taiwan Power Company, 2022, see https://www.taipower.com.tw/EN/page.aspx?mid=4494&cid=2922&cchk=1ea334fb-c4f5-42d4-bfd6-93fecb80e250, accessed 23 September 2023.

683 - Yang Chun-hui, Shih Hsiao-kuang and Lin Liang-sheng, "2020 Elections: Tsai wins by a landslide", *Taipei Times*, 12 January 2020, see https://www.taipeitimes.com/News/front/archives/2020/01/12/2003729107, accessed 7 July 2021.

684 - Lin Hsin-han and Jonathan Chin, "KMT seeks to scrap rules on nuclear power extensions", *Taipei Times*, 24 January 2024, see https://www.taipeitimes.com/News/taiwan/archives/2024/01/24/2003812551, accessed 30 May 2024.

685 - Chen Yun and Jake Chung, "Lai outlines energy plans", *Taipei Times*, 20 October 2023, see https://www.taipeitimes.com/News/taiwan/archives/2023/10/20/2003807964, accessed 30 May 2024.

has been characterized by an ambivalent attitude,[686] which can be understood as a tactical move rather than a policy change. Premier Jung-tai Cho, appointed by Lai, reaffirmed that the new government has no plans to extend the Maanshan Nuclear Power Plant's operational lifetime.[687] However, he has also indicated the government's openness to "new nuclear power" after 2030, if safety concerns associated with nuclear technology resolve.[688] This might be nothing more than lip service to those industrialists who have reiterated the significance of a stable supply of electricity through nuclear energy.[689] The newly established National Climate Change Response Committee, thus, includes both proponents and opponents of nuclear electricity. Two of the three conveners particularly characterize the opposing view: Pegatron Chairman and nuclear advocate Tung Tzu-hsien and Vice Premier Cheng Li-chun, who actively mobilized against the fourth nuclear power plant project in her youth, continued to criticize it as a lawmaker, and has recently emphasized the need to address the fundamental problem of nuclear waste.[690]

Lai and the new cabinet might also continue to face difficulties in stopping KMT legislators' attempts to delay the nuclear phaseout, as DPP no longer holds a majority in the Legislative Yuan, the country's parliament; the KMT is currently the biggest party by one seat over the DPP, while the upstart Taiwan People's Party (TPP) now holds key votes to support or block legislation.[691]

TPP's 2024 presidential candidate and current party leader Ko Wen-Je criticized President Tsai's nuclear policy and expressed support for using nuclear power as part of Taiwan's energy transition.[692] As of July 2024, the KMT proposed an amendment to the Nuclear Reactor Facilities Regulation Act, which would extend the operation limit of nuclear reactors; the amendment did not garner sufficient consensus during the standing committee's review and is rescheduled for further scrutiny.[693]

686 - Teng Pei-ju, "President Lai ambiguous on nuclear power despite premier's assurances", *Focus Taiwan/Central News Agency*, 19 June 2024, see https://focustaiwan.tw/politics/202406190009, accessed 22 August 2024.

687 - Teng Pei-ju, Liu Chien-ling, and Fan Cheng-hsiang, "Premier rules out extending life of Taiwan's last operational nuclear plant", *Focus Taiwan/Central News Agency*, 7 June 2024, see https://focustaiwan.tw/business/202406070015, accessed 21 July 2024.

688 - Li-hua Chung, "總統府氣候變遷委員會7/25登場 卓榮泰：對新核能採開放態度" ["National Climate Change Strategy Committee to start running from July 25 Jung-tai Cho: we remain an open attitude to new nuclear power"]", 鍾麗華*Liberty Times*, 17 July 2024, see https://news.ltn.com.tw/news/politics/breakingnews/4739361, accessed 21 July 2024.

689 - Crystal Hsu, "Trade groups call for stable power supply", *Taipei Times*, 21 March 2024, see https://www.taipeitimes.com/News/biz/archives/2024/03/21/2003815228; and *Focus Taiwan*, "Taiwan business group proposes nuclear energy revival", 8 May 2024, see https://focustaiwan.tw/business/202405080015; both accessed 21 July 2024.

690 - CNA "鄭麗君：須有核廢料解方才能負責任地使用核能" ["Cheng Li-chun: Only by having a solution for nuclear waste can we use nuclear energy responsibly"], *Central News Agency*, 2 July 2024, see https://netzero.cna.com.tw/news/202407020250, accessed 22 August 2024.

691 - *Focus Taiwan*, "No party gets legislative majority; small TPP to play key role", *Centra News Agency*, 13 January 2024, see https://focustaiwan.tw/politics/202401130019; and *Liberty Times*, "總統府氣候變遷委員會7/25登場 卓榮泰：對新核能採開放態度" ["Presidential Committee on Climate Change Debuts on 7/25: Dr. Chuo: Open to New Nuclear Power"], 17 July 2024, see https://news.ltn.com.tw/news/politics/breakingnews/4739361; both accessed 21 July 2024.

692 - Jono Thomson, "Ko Wen-je criticizes DPP, KMT plans for Taiwan's nuclear power", *Taiwan News*, 26 December 2023, see https://www.taiwannews.com.tw/news/5066627, accessed 6 June 2024.

693 - *PTS*, "藍委擬修《核管法》 提5版本盼核電延役" ["KMT legislators seek to amend Nuclear Reactor Facilities Regulation Act Five versions are proposed to extend life for Nuclear Power Plants"], *Taiwan Public Television Service*, 10 July 2024, see https://news.pts.org.tw/article/704203, accessed 21 July 2024.

The challenging political environment might explain the new DPP government's contradictory declarations of intentions to close nuclear power plants,[694] while not excluding the possibility of extending operations.[695]

Pro-nuclear lobbying had experienced a major setback in December 2021, when a proposal to resume the construction of two reactors at the Fourth Nuclear Power Plant in Lungmen was rejected in a referendum, indicating popular support for a nuclear-free policy.[696] Regardless of the vote's outcome though, the plant was unlikely to be completed or become operational owing to the dire state of the project (see The Lungmen Saga.)

In a major governmental reform in September 2023, a new independent body, the Nuclear Safety Commission (NSC), replaced the former nuclear regulator, the Atomic Energy Commission (AEC).[697] While scaled down from second-level to a third-level agency, the NSC will keep its staff size and shift focus from nuclear development to monitoring and regulating nuclear decommissioning,[698] as stipulated by the Nuclear Safety Commission Organization Act, the legal framework for NSC's establishment.[699] According to the Act, the new commission shall oversee and implement waste management, which will be a major challenge in the coming decades due to the scheduled closure of Taiwan's remaining nuclear fleet by 2025 and the ensuing decommissioning activities.

The authority was to be set up about a decade ago,[700] and the Executive Yuan (the government's executive branch) drafted an organizational Act in early 2013 as part of restructuring ministerial affiliations,[701] but it was delayed by KMT legislators.[702]

More recently, some KMT politicians have also promoted the idea of deploying small modular reactors (SMRs) "in every administrative region of Taiwan."[703] While the DPP has thus far evaded the subject, some environmental organizations such as Green Citizens' Action Alliance (GCAA) and Citizen of the Earth, Taiwan, have argued that SMRs would be a false solution to a real problem creating more waste than traditional plants. Moreover,

694 - *Taipei Times*, "Premier vows to combat fraud, make Taiwan nuclear free", with *Central News Agency*, 21 May 2024, see https://www.taipeitimes.com/News/taiwan/archives/2024/05/21/2003818180, accessed 30 May 2024.

695 - Crystal Hsu, "Rules on use of nuclear power could be revised if public agrees: minister", *Taipei Times*, 17 May 2024, see https://www.taipeitimes.com/News/biz/archives/2024/05/17/2003817967, accessed 30 May 2024.

696 - Ben Blanchard, "Taiwan referendums fail in major setback for opposition", *Reuters*, 18 December 2021, see https://www.reuters.com/markets/commodities/taiwan-opposition-hopes-boost-contentious-referendums-2021-12-18/, accessed 4 September 2022.

697 - Nuclear Safety Commission, "Nuclear Safety Commission Established as an Independent, Professional, and Impartial organization to Enhance Nuclear Safety Regulation in Taiwan", Press Release, 6 October 2023, see https://www.nusc.gov.tw/english/newsdetail/pressrelease/242.html, accessed 30 May 2024.

698 - Environmental Information Center, "朝野掀表決大戰 原能會降為三級獨立機關核安會" ["Vote-off between ruling and opposition parties: Atomic Energy Council to be reorganized into a third-level independant body Nuclear Safety Commission"], 29 May 2023.

699 - Law & Regulations Database of the Republic of China (Taiwan), "Nuclear Safety Commission Organization Act", 2023, see https://law.moj.gov.tw/ENG/LawClass/LawAll.aspx?pcode=J0000101, accessed 30 May 2024.

700 - WNA, "Nuclear Power in Taiwan", World Nuclar Assocaition, Updated 3 May 2024, see https://world-nuclear.org/information-library/country-profiles/others/nuclear-power-in-taiwan, accessed 30 May 2024.

701 - Executive Yuan, "Nuclear Safety Commission organizational act passed by the Executive Yuan", Press Release, 21 February 2013, see https://english.ey.gov.tw/Page/61BF20C3E89B856/90b39fbf-96d0-428f-9c60-0f9a0f7c81cf, accessed 30 May 2024.

702 - Environmental Information Center, "國民黨反對降級三級機關 原能會改名核安會組改草案送協商" ["KMT opposes Atomic Energy Council's reduction to third-level body, Nuclear Safety Commission Organization Bill proceeds to party caucuses negotiation"], 24 April 2023, see https://e-info.org.tw/node/236602, accessed 30 May 2024.

703 - Jason Pan, "KMT backs Terry Gou's Taiwan-wide nuclear plan", *Taipei Times*, 6 May 2023, see https://www.taipeitimes.com/News/taiwan/archives/2023/05/06/2003799264, accessed 30 May 2024.

environmentalists emphasize that new nuclear power would be too slow and too expensive to be a feasible solution to Taiwan's urgent need for an energy transition in the face of the climate crisis.[704]

Reactor Closures

As reported in previous WNISR-editions, Taipower announced the closure of Chinshan-1 on 5 December 2018. The reactor had not generated power since the end of 2014. Chinshan-2 had been off-grid since June 2017, but was not officially closed until 15 July 2019, when its 40-year operating license expired.

On 1 July 2021, Taipower stated that due to lack of spent-fuel storage-capacity, Kuosheng-1 was closed six months ahead of schedule.[705] The closure of the reactor, located on the northern coast, only 22 km away from Taipei, was originally slated for 27 December 2021, the day its operating license expired. A new batch of nuclear fuel had been loaded into the reactor during the refueling and maintenance outage in 2020, but in February 2021, Taipower reduced the reactor power-level to 80 percent to save fuel and extend operations until the higher-consumption month of June.[706]

Kuosheng-2 ceased operating in March 2023. The 985-MW BWR/6 unit was supplied by General Electric (GE) and connected to the grid on 29 June 1982.

The remaining two PWRs at Maanshan are scheduled for closure on 26 July 2024 and 17 May 2025, respectively. In line with the nuclear phaseout and current regulation, the application to disconnect the units from the grid was submitted in July 2021.[707]

Despite the fact that the spent-fuel pools of the Chinshan and Kuosheng power plants have reached full capacity, for various reasons, the government has made little effort to arrange dry cask storage for the high-level radioactive waste. Little attention has been paid to intermediate storage and final disposal of spent fuel. In 2023, GCAA and other environmental groups lobbied in vain to legislate on the issue.[708]

Reactor closures, in general, have not ushered in the actual technical decommissioning phase, which would come only after the spent-fuel assemblies in the reactors have been unloaded and placed in fully operational dry cask facilities.

704 - *Liberty Times*, "綠盟：全球再生能源超越核電、SMR比傳統更多核廢料 ["Green Alliance: Global renewable energy surpasses nuclear power, and SMR produces more nuclear waste than traditional ones"]", 29 March 2023, see https://news.ltn.com.tw/news/life/breakingnews/4254756, accessed 30 May 2024.

705 - Taipower, "核二1號機燃料池滿今提前停機 台電：歲修機組陸續歸隊與民營電廠機組加入，持續確保供電無虞" ["NPP No. 2's Fuel Pool is Full and Shut Down Early Today TEPCO: Year-end Repair Teams Returning and Private Power Plant Teams Joining to Ensure Continuous Supply of Electricity"], 1 July 2021, see https://www.taipower.com.tw/tc/news_info.aspx?id=4741&chk=75ddf691-44f7-406a-922c-ebf676c2fbd8&mid=17, accessed 27 September 2023.

706 - *WNN*, "Early shutdown for Taiwanese reactor", 1 July 2021, see https://www.world-nuclear-news.org/Articles/Early-shutdown-for-Taiwanese-reactor, accessed 7 July 2021.

707 - *NEI Magazine*, "Taipower applies to close down Maanshan NPP", 29 July 2021, see https://www.neimagazine.com/news/taipower-applies-to-close-down-maanshan-npp-8946136/, accessed 18 June 2024.

708 - François Bougon, "À Taïwan, la sortie du nucléaire laisse des traces", *Mediapart*, 8 May 2023 (in French), see https://www.mediapart.fr/journal/international/080523/taiwan-la-sortie-du-nucleaire-laisse-des-traces, accessed 30 May 2024.

The Lungmen Saga

In an attempt to reverse the nuclear phaseout policy, a national referendum was held on 18 December 2021. The voters were asked whether they back the resumption of the construction of two long-mothballed ABWRs at the Lungmen site on the northern coast. Official results indicated that voters rejected the proposal by 52.84 percent against to 47.16 percent in favor, by a small 5.68 percent margin.[709] Residents of Gongliao, the neighboring town, delivered an overwhelming 'no' vote at 75.7 percent.[710]

Construction of the plant and the two reactors started in 1999. In stark contrast to the three other twin-unit plants built under turnkey contracts during the 1970–80s, construction at Lungmen was characterized by a complex chain of more than 500 contractors and subcontractors, who tended to cut corners and replace long-term with temporary workers.[711]

According to the now defunct AEC, as of the end of March 2014, Lungmen-1 was 97.7 percent complete,[712] while Lungmen-2 was 91 percent complete. The plant was by then estimated to have cost NT$300 billion (US$$_{2014}$9.9 billion).[713] After multiple delays, budget blowouts, numerous exposés of dubious construction practices,[714] and large-scale public and political opposition, including through local referendums, on 28 April 2014, then-Premier Jiang Yi-huah announced that Lungmen-1 would be mothballed after the completion of safety checks, while work on Unit 2 was also to be stopped. In December 2014, it was announced that the project was put on hold for three years,[715] and it has not resumed since.

There is little prospect that the units would ever operate even with a favorable political decision. Numerous obstacles stand in the way of resuming construction. First, resumption would require approval from both Taiwan's legislature and the NSC.[716] In addition, the initial construction permit expired at the end of 2020. The acquisition of a new permit would require a new environmental impact assessment and an additional geological survey. Research conducted in 2009 by the Central Geological Survey (CGS), a government agency of the Ministry of Economic Affairs, found a fault line extending up to 90 kilometers off the coast of

709 - Brian Hioe, "DPP Sweeps Taiwan's Latest Referendum Vote", *The Diplomat*, see https://thediplomat.com/2021/12/dpp-sweeps-taiwans-latest-referendum-vote/, accessed 1 September 2022; and Central Election Commission, "110年全國性公民投票結果 ["Results of the 110th National Referendum"]", published 23 December 2021, see https://web.cec.gov.tw/upload/file/2021-12-28/e214404c-ab34-419d-8bdb-005225b1a95e/559fac11f734827f5c7a9888fbd6f247.pdf, accessed 18 June 2024.

710 - Central Election Commission, "表5-新北市–全國性公民投票得票數一覽表(投開票所)" ["Table 5-New Taipei City-Complete Charts of the Results of National Referendum (sorted by polling stations)"]", December 2021, see https://web.cec.gov.tw/referendum/cms/p_result/36189, accessed 21 July 2024.

711 - Control Yuan, "核四工程收賄 監察院彈劾台電官員周吉村" ["The Control Yuan Impeached Taipower Official Zhou Jicun for Taking Bribes from Contractors of the 4th Nuclear Power Plant"], 12 July 2011, see https://www.cy.gov.tw/News_Content.aspx?n=124&sms=8912&s=5666, accessed 30 May 2024.

712 - Planning Department, "Status and Challenges of Nuclear Power in Taiwan", Atomic Energy Commission, April 2014.

713 - *WNN*, "Political discord places Lungmen on hold", 28 April 2014, see http://www.world-nuclear-news.org/NN-Political-discord-places-Lungmen-on-hold-2804144.html, accessed 7 July 2021; and Dennis Engbarth, "Technology: Investigation Belies GEH Claims About ABWRs", *Nuclear Intelligence Weekly*, 19 November 2021.

714 - Control Yuan, "臺電公司違規辦理核四廠設計變更 輕忽核安 監察院糾正 ["Taipower Corporation Illegally Changed the Design of the 4th Nuclear Power Plant and Neglected Nuclear Safety"]", Press Release, 8 June 2011, see https://www.cy.gov.tw/News_Content.aspx?n=124&sms=8912&s=5608, accessed 18 June 2024.

715 - Clara Tan, "Lungmen Put On Hold for Three Years", *Nuclear Intelligence Weekly*, 19 December 2014; and Ministry of Foreign Affairs, "Taiwan seals Lungmen No.1 nuclear reactor", *Taiwan Today*, 1 July 2015, see https://taiwantoday.tw/news.php?unit=6&post=12347, accessed 8 September 2022.

716 - Dennis Engbarth, "Taiwan: Tsai Pushes to Defeat Lungmen-4 Revival", *Nuclear Intelligence Weekly*, 9 April 2021.

the Lungmen site.[717] According to a survey conducted by Taipower four years later, the fault line was only 34.5 km-long, but the area of investigation was limited to 50 km from the coastline, thus suggesting a substantial underestimation of the potential risk.[718]

Even if the seismic fault was proven inactive, many technical challenges would need to be addressed. Taipower explained in February 2019 that it would not be possible to simply replace major electronic components installed nearly two decades ago, including instrumentation and control. Moreover, the resumption plan entailed that full-scale difficult negotiations with the main supplier, General Electric (GE), were to be expected.[719] In 2021, the AEC chairman cited a "10 years or more" timeline until grid connection of both units.[720]

Moreover, in November 2021, the government revealed confidential documents from 2015 that showed the impact of unresolved safety issues if the project were to relaunch. The documents came to light as a result of the Control Yuan's (the country's highest ombudsperson institution) 2019-investigation into two settlement payments made by Taipower to GE Hitachi. The first was a US$158 million compensation for equipment supplied at Lungmen awarded to GE by the International Chamber of Commerce (ICC). This was awarded in a December 2018 ruling (notified in March 2019), following a 3-year investigation initiated at GE's request over Taipower's cessation of payments. A second ruling by ICC resulted in a settlement agreement between the two companies, with Taipower paying a third of the US$66 million that GE had originally demanded (Taipower said it agreed to a settlement in order to minimize the compensation payment and avoid further legal fees).[721]

Compliance with safety specifications has long been subject to contradicting or inconsistent assertions. For instance, citing the task force report he had commissioned, the former Minister of Economic Affairs Chang Chia-chu declared in 2014 that Unit 1 was cleared for hot-testing and fuel-loading. An AEC investigation later concluded that Minister Chang's July 2014 claims had "no legal standing," yet they "created the mistaken understanding among a part of society that the report meant that the nuclear power plant was safe."[722] See Taiwan in WNISR2023 for further details on the investigation.

WNISR took the Lungmen units off the construction listing in 2014 and has retained that stance as of 1 July 2024. The IAEA had classified the Lungmen reactors as "under construction"

717 - *Central News Agency*, "未評估海域斷層對核四影響 監院糾正台電經濟部 ["The Control Yuan Corrects Taipower and the Ministry of Economic Affairs for failing to Assess the impact of Faults on the 4th Nuclear Power Plant"]", as published on Taiwan Geoscience Portal, 6 November 2019, see https://twgeoref.gsmma.gov.tw/GipOpenWeb/wSite/ct?xItem=222598&ctNode=1407&mp=6 , accessed 30 May 2024.

718 - Citizen of the Earth, Taiwan, "核四斷層事證確鑿 地質學者: 核四耐震遠遠不足" ["Fault line near Fourth Nuclear Power Plant Confirmed, Geologists: Fourth Nuclear Plant Is Far From Being Earthquake Resistant"], 25 November 2021, see https://www.cet-taiwan.org/node/4061, accessed 30 May 2024.

719 - *NEI* Magazine, "Taipower rules out operation of Lungmen", 6 February 2019, see https://www.neimagazine.com/news/newstaipower-rules-out-operation-of-lungmen-6970272, accessed 7 July 2021; and Dennis Engbarth, "Taiwan: Extending Reactor Operations 'Infeasible'", *Nuclear Intelligence Weekly, 1 February 2019*.

720 - Dennis Engbarth, "Taiwan: Tsai Pushes to Defeat Lungmen-4 Revival", *Nuclear Intelligence Weekly*, 9 April 2021.

721 - Dennis Engbarth, "Taiwan: GEH Awarded $158 Million in Lungmen Dispute", *Nuclear Intelligence Weekly*, 8 March 2019; and *Nuclear Intelligence Weekly*, "Briefs—Taiwan", 23 August 2019; also Dennis Engbarth, "Taiwan: Government Probe Unearths Safety Issues With Lungmen", *Energy Intelligence*, 19 November 2021, see https://www.energyintel.com/0000017d-33fa-d08a-abfd-fffe71af0000, 4 September 2022.

722 - Ibidem.

at least until the end of 2019[723] and removed them from the list before releasing its annual statistics for 2021.[724]

Energy and Climate Policy

Public opposition to nuclear power in Taiwan reached a new high in the immediately after the Fukushima disaster was triggered.[725] Sending shock waves through Taiwan, the event increased public acceptance for a nuclear phaseout and an energy transition. Having returned to power in 2016, the DPP announced the "New Energy Policy Vision" aimed at establishing "a low carbon, sustainable, stable, high-quality and economically efficient energy system" through an energy transition and energy industry reform.[726] On 12 January 2017, the Electricity Act Amendment completed its third reading in the legislature, ushering Taiwan's energy transition, including the nuclear phaseout.[727]

During the second term of Tsai's presidency (2020–24), Taiwan aspired to become a leading country of renewable energy in the Asia-Pacific region.[728] The island's renewable energy potential is significant, and in 2021, the Global Wind Energy Council estimated Taiwan's offshore wind technical potential to be as high as 494 GW.[729] Taiwan aims to develop 5.7 GW of offshore wind capacity by 2025. In 2020, the government set a goal to add an additional 10 GW of offshore wind capacity between 2026 and 2035.[730] In May 2021, the target was increased to 15 GW with annual deployment of 1.5 GW over the decade. The target has been confirmed in 2023.[731]

However, until a significant boost in 2022, the development of renewable energy had been slow. In 2022, the installed renewable energy capacity reached 14.1 GW, representing 23 percent of installed capacity, and renewable power generation increased by 37 percent to reach 23.8 TWh, contributing 8.3 percent of the total electricity production. The year 2022 marked the first time that the share of renewable energy—including geothermal, biomass, waste, and hydro—in total electricity production slightly surpassed nuclear power (8.3 percent versus 8.2 percent),

723 - IAEA-PRIS, "Taiwan, China", as of 10 June 2019, see https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=TW, accessed 11 June 2019.

724 - IAEA, "Nuclear Power Reactors in the World—2020 Edition", Reference Data Series No. 2, International Atomic Energy Agency, July 2020, p. 29, see https://www-pub.iaea.org/MTCD/Publications/PDF/RDS-2-40_web.pdf; and IAEA, "Nuclear Power Reactors in the World—2021 Edition", Reference Data Serires No. 2, July 2021, see https://www-pub.iaea.org/MTCD/Publications/PDF/RDS-2-41_web.pdf; both accessed 18 June 2024.

725 - Ming-sho Ho, "The Fukushima effect: explaining the resurgence of the anti-nuclear movement in Taiwan", Environmental Politics, 2014.

726 - MOEA, "Taiwan's New Energy Policy", 6 April 2017, Ministry of Economic Affairs, Government of Taiwan.

727 - Bureau of Energy, "The Three-Stage Reading Process for Electricity Act Amendment Completed Moving Towards the 2025 Target of Nuclear-Free Homeland", Ministry of Economic Affairs, Government of Taiwan.

728 - Energy Taiwan, "Energy Taiwan Establishing the Trifecta of PV Solar, Wind Power and Smart Energy Storage", 16 October 2020; and *Energy Trend*, "2020 Energy Taiwan Commenced as Taiwan Become Hot Spot for Global Green Energy Investment", 15 October 2020, see https://www.energytrend.com/news/20201015-19621.html, both accessed 7 July 2021.

729 - GWEC, "Offshore Wind Technical Potential in Taiwan", Global Wind Energy Council, June 2021, see https://gwec.net/wp-content/uploads/2021/06/Taiwan_Offshore-Wind-Technical-Potential_GWEC-OREAC.pdf, accessed 5 September 2022.

730 - U.S. Department of Commerce, "Taiwan Renewable Energy Market", 5 March 2021, see https://www.trade.gov/market-intelligence/taiwan-renewable-energy-market, accessed 7 July 2021.

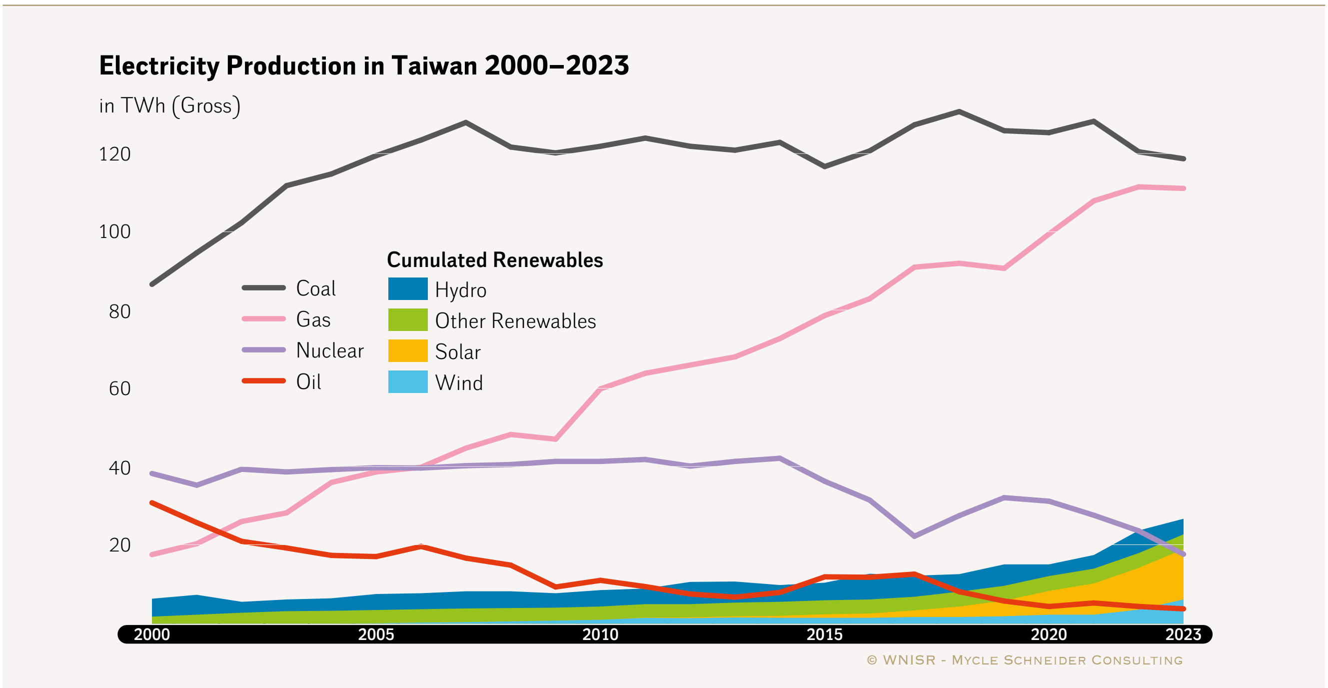
731 - Energy Administration, "Taiwan's Offshore Wind Market Matures, Continually Attracting International Developers", Ministry of Economic Affairs, Government of Taiwan, 10 April 2023, see https://www.moeaboe.gov.tw/ECW/english/news/News.aspx?kind=6&menu_id=958&news_id=30361, accessed 24 September 2023.

with a 163-percent increase in offshore wind power generation compared to the previous year and a 57-percent increase in total wind production.[732]

The trend continued in 2023, when the share of renewable energy in total electricity production reached 9.5 percent (compared to nuclear power's 6.3-percent contribution), with wind power (onshore and offshore combined) and solar PV power generation achieving growth rates of 74.4 percent and 20.9 percent, respectively. The installed capacity of renewable energies reached 18 GW (a 27-percent increase compared to 2022), of which 12.4 GW were solar PV (+27.2 percent) and 2.7 GW wind (+69.4 percent).[733]

However, over the past two decades, Liquefied Natural Gas (LNG)-generated electricity shot up from less than 20 TWh in 2000 to 111.6 TWh in 2023, making up 39.5 percent of total electricity generation, coming close to the 42.2 percent share of coal-fired electricity generation,[734] see Figure 41.

Figure 41 • Electricity Production in Taiwan, 2000–2023



Sources: MOEA, Energy Handbook, Various Years

Current targets for 2025 place solar capacity at 20 GW and combined renewable energy capacity at 20 percent of the power mix.[735] These goals remain ambitious, but the deployment acceleration has also been noted by investors. Taiwan again moved up two places in the

732 - Bureau of Energy, "2022年能源統計手冊—Energy Statistics Handbook 2022", Ministry of Economic Affairs, Government of Taiwan, July 2023, see https://www.moeaea.gov.tw/ECW/english/content/ContentDesc.aspx?menu_id=1539, accessed 30 May 2024.

733 - Bureau of Energy, "2023年能源統計手冊—Energy Statistics Handbook 2023", Ministry of Economic Affairs, Government of Taiwan, July 2024, see https://www.esist.org.tw/publication/handbook/handbook_2023/2023EnergyStaHandBook.pdf, accessed 21 July 2024.

734 - Ibidem.

735 - MOEA, "Energy Transition Promotion Scheme—Promote Green Energy, Increase Nature Gas, Reduce Coal-fired, Achieve Nuclear-free", Ministry of Economic Affairs, Undated, see https://www.moea.gov.tw/MNS/english/Policy/Policy.aspx?menu_id=32904&policy_id=19, accessed 30 May 2024.

Ernst & Young's Renewable Energy Country Attractiveness Index 2023 to rank 24th in 2023[736] and maintained that position in 2024[737].

Despite not being able to participate in the Paris Agreement and COP negotiations, in April 2021, the Taiwanese Government unilaterally pledged to achieve Net-Zero by 2050, announcing that it would draft regulations to that end, accelerate the implementation of existing targets and achieve the energy transition towards renewables.[738] In 2022, Taiwan passed the Climate Change Response Act, which replaced the former Greenhouse Gas Reduction and Management Act of 2015, making legally binding the goal of Net-Zero by 2050.[739] Regulatory measures regarding carbon pricing schemes and carbon footprint verification have, thus far, not been put into place. The actual implications of the Climate Change Response Act for carbon reduction therefore remain to be seen.

As of 2023, the island remained heavily dependent on imported fossil fuels (see Figure 41). Coal-based electricity production has only slightly decreased to remain over 100 TWh, and gas imports have exploded to reach a level similar to coal; instead of an energy *transition* from fossil fuels to renewables, these data rather suggest and *accumulation* of various energy sources. Per capita energy consumption has hardly gone down over the past decade, and per capita electricity consumption has increased by 14 percent over the decade 2013–2022 and decreased only slightly, by 1.2 percent, in 2023. Peakload experienced the strongest growth rate at 19.5 percent over that decade to exceed 40 GW for the first time in 2022,[740] hitting a new record in February 2024 at 41.2 GW.[741]

The government's strategy has aimed to "promote green energy, increase natural gas, reduce coal-fired power, and achieve nuclear-free."[742] This implies that Taiwan would continue to see a substantial increase in natural gas consumption which would then provide 50 percent of gross electricity production by 2025.

In March 2022, Taiwan's National Development Council unveiled its latest Pathway to Net-Zero Emissions in 2050. The strategy was based on a NT$900 billion (US$$_{2022}$32.4 billion) budget to 2030, of which NT$210.7 billion (~US$$_{2022}$7.6 billion) were allocated to "renewables

736 - EY, "Renewable Energy Country Attractiveness Index (RECAI)—62nd Edition", Ernst & Young, November 2023, see https://www.ey.com/content/dam/ey-unified-site/ey-com/en-gl/insights/energy-resources/documents/ey-recai-62-v9-final.pdf, accessed 31 May 2024.

737 - EY, "Renewable Energy Country Attractiveness Index (RECAI)—63rd Edition", Ernst & Young, June 2024, see https://www.ey.com/content/dam/ey-unified-site/ey-com/en-gl/insights/energy-resources/documents/ey-gl-recai-63-report-06-2024.pdf, accessed 27 June 2024.

738 - Ben Blanchard, "Taiwan begins to plan for zero emissions by 2050", *Reuters*, 22 April 2022, see https://www.reuters.com/business/environment/taiwan-begins-plan-zero-emissions-by-2050-2021-04-22/, accessed 22 August 2024; and Office of the President, "President Tsai addresses COP26 Taiwan Day event", Government of Taiwan, 7 November 2021, see https://english.president.gov.tw/NEWS/6186; also Chang Tzi-chin, "Taiwan: Cooperating With the World to Achieve a Net-Zero Future", Environmental Protection Administration, Government of Taiwan, as published in *The Diplomat*, 28 October 2021, see https://thediplomat.com/2021/10/taiwan-cooperating-with-the-world-to-achieve-a-net-zero-future/; both accessed 6 September 2022.

739 - *Taipei Times*, "Updated climate change guidelines unveiled", with *CNA*, 19 November 2023, see https://www.taipeitimes.com/News/taiwan/archives/2023/11/19/2003809389, accessed 30 May 2024.

740 - Eric Chang, "Taiwan electricity use surpasses 40 GW for first time", *Taiwan News*, 21 July 2022, see https://www.taiwannews.com.tw/en/news/4602212, accessed 16 November 2023.

741 - *Focus Taiwan*, "Taiwan's daily power usage hits record high", *Central News Agency*, 2 July 2024, see https://focustaiwan.tw/business/202407020025, accessed 6 August 2024.

742 - MOEA, "Energy Transition Promotion Scheme: Promote Green Energy, Increase Nature Gas, Reduce Coal-Fired, Achieve Nuclear-Free", Ministry of Economic Affairs, Undated, see https://www.moea.gov.tw/MNS/english/Policy/Policy.aspx?menu_id=32904&policy_id=19, accessed 30 May 2024.

and hydrogen", and another NT$207.8 billion (~US$_{2022}$7.5 billion) were to be invested in "grid and energy storage". The plan included 40 GW of combined wind and solar capacity by 2030, and by 2050, an installed capacity of 40–80 GW in solar and 40–55 GW of offshore wind alone, for a combined share of more than 60 percent.[743]

Deputy Minister of Economic Affairs Tseng Wen-sheng reportedly stated on 20 September 2023 that as Taiwan "excels at manufacturing," the future energy trend, "which no longer relies on [natural resources] but manufactured devices especially solar panels and wind turbines to get hold of power" would pose a challenge but was in itself an economic opportunity for the country.[744]

A second stage of the electricity market reform (2019–2025) includes grid unbundling and the restructuring of Taipower into a holding company with two separate entities: a power generation corporation and a transmission and distribution corporation within six to nine years.[745]

Under the presidency of William Lai, the new DPP government is expected to follow the preceding administration's footsteps for the energy transition, but tensions in national and international politics might render implementation more challenging.

TÜRKIYE FOCUS

There are four nuclear reactors currently under construction in Türkiye, at Akkuyu in Mersin province. President Recep Tayyip Erdoğan announced in early June 2024 that the construction of the first VVER-1200 unit—started in 2018—has reached 90-percent completion.[746] The three other units have been under construction since April 2020, March 2021, and July 2022 respectively.[747] As previously reported, the project has experienced delays at various stages (see earlier editions of the WNISR). Originally, Unit 1 was scheduled to start up in 2023.

In October 2023, Alparslan Bayraktar, Minister of Energy and Natural Resources, set the commissioning date of Unit 1 to 29 October 2024.[748] Six months later, Alexey Likhachev, Director General of Rosatom, announced that commissioning would be delayed into 2025

743 -NDC, "Taiwan's Pathway to Net-Zero Emissions in 2050", Presentation, National Development Council, Government of Taiwan, 30 March 2022, accessed 28 September 2023; and Max Tingyao Lin, "Taiwan's net-zero roadmap promises $170 billion in spending, renewable expansion; more could be required", IHS Markit, S&P Global, 8 April 2022.

744 - *Focus Taiwan*, "KMT energy mix proposal needs more explanation: MOEA deputy head", *Central News Agency*, 20 September 2023, see https://focustaiwan.tw/business/202309200020, accessed 25 September 2023.

745 - Chung-Han Yang and Chengkai Wang, "The Energy Regulation and Markets Review: Taiwan", *The Law Reviews*, 16 June 2021.

746 - *Daily Sabah, "90% of Akkuyu nuke plant's 1st reactor in southern Türkiye completed", 4 June 2024, see* https://www.dailysabah.com/business/energy/90-of-akkuyu-nuke-plants-1st-reactor-in-southern-turkiye-completed, accessed 16 June 2024.

747 - WNISR, "Akkuyu-4 in Turkey: Second Construction Start in a Week for the Russian Nuclear Industry—Anyways 4", 24 July 2022 see https://www.worldnuclearreport.org/Akkuyu-4-in-Turkey-Second-Construction-Start-in-a-Week-for-the-Russian-Nuclear.html, accessed 3 July 2024.

748 - Fuat Kabakcı, Gökçe Topbaş, Sibel Morrow and Başak Erkalan, "Enerji Bakanı Bayraktar, Akkuyu NGS'nin ilk reaktörünün 29 Ekim 2024'te devreye alınacağını bildirdi", *Anadolu Agency*, 5 October 2023 (in Turkish), see https://www.aa.com.tr/tr/ekonomi/enerji-bakani-bayraktar-akkuyu-ngsnin-ilk-reaktorunun-29-ekim-2024te-devreye-alinacagini-bildirdi/3008326, accessed 5 April 2024.

without specifying a precise date.[749] In May 2024, Denis Sezemin, Director for Construction and Production Management of Akkuyu Nuclear JSC, stated that commissioning of the first unit would occur in April 2025.[750] Only one month later, the Russian State Duma Committee on Energy, while visiting the Turkish Parliament, indicated that it anticipated the startup of the first unit in October or November 2025. According to media reports, in a meeting with members of the Committee on Industry, Trade, Energy, Natural Resources, the Russian delegation stated that, "We have given the necessary information to your Ministry of Energy. We are trying to avoid delays, but the most important thing is the continuation of sanctions against Russia and the withdrawal of our contracts for equipment for cooling systems."[751] It was also stated that some equipment was produced by Chinese companies in a short time as a replacement.[752] Denis Sezemin gave more details in an interview, informing that some switchgear equipment that could not be delivered from Germany has been waiting for export permits on German soil since July 2023, and that the company decided to change suppliers when joint initiatives with Türkiye to ensure the delivery of this gas-insulated 400 kilovolt voltage equipment did not yield results.[753] Sezemin added that his team ordered this equipment from China in January 2024 and is striving to commission the first unit in 2025 in accordance with the terms of the intergovernmental agreement.[754] Two days later President Recep Tayyip Erdoğan also pointed at Germany and said that, "We currently have a problem with Germany as the turbines that are supposed to arrive for the Akkuyu Nuclear Power Plant are waiting at German customs. This has seriously disturbed us."[755]

During his June 2024 visit to Türkiye, Pavel Zavalny, Chairman of the Russian State Duma Energy Committee, emphasized the risk of Akkuyu startup delays associated with supply issues caused by sanctions. He stated that, in the absence of a solution, the commissioning deadline for the first unit, scheduled for 2025, may not be met.[756] Zavalny identified two primary issues contributing to the delay. The first was the non-delivery of the electricity distribution system, which was re-ordered from a Chinese company. The second issue was the non-arrival of a special watercraft required for the installation of the cooling system. Zavalny stated that "Rosatom had paid for both elements, that the orders had not been fulfilled, and that the amounts paid had not yet been returned." Zavalny responded to the question of whether Russia would request a price revision by saying, "If there is such a need, the parties will discuss. Some of the electricity will be sold in the free market. (...) It may be possible to extend the repayment

749 - Akkuyu Nuclear, "Full-Scale Start-up and Commissioning Works Started at Akkuyu NPP Unit 1", Rosatom, 10 April 2024, see https://akkuyu.com/en/news/full-scale-start-up-and-commissioning-works-started-at-akkuyu-npp-unit-1, accessed 2 July 2024.

750 - Mustafa Ercan, "Türkiye'nin ilk nükleer güç santrali! Çalışmalar sürüyor gözler 2025'te", *Demirören News Agency* as published by *Milliyet*, 18 May 2024, (in Turkish), see https://www.milliyet.com.tr/ekonomi/turkiyenin-ilk-nukleer-guc-santrali-calismalar-suruyor-gozler-2025te-7128920, accessed 19 June 2024.

751 - Ibidem.

752 - Ibidem.

753 - Özlem Doğaner "Akkuyu'yu nasıl engellemeye çalıştı? Almanya bildiğiniz gibi!", *Sabah*, 10 July 2024 (in Turkish), see https://www.sabah.com.tr/galeri/ekonomi/almanya-bildiginiz-gibi accessed 2 August 2024, accessed 3 August 2024.

754 - Ibidem.

755 - Serdar Açıl and Ferdi Türkten, "Cumhurbaşkanı Erdoğan: Akkuyu NGS için türbinlerin Alman gümrüğünde bekliyor olması bizi ciddi manada rahatsız etmiştir", *Anadolu Agency*, 12 July 2024 (in Turkish), see https://www.aa.com.tr/tr/gundem/cumhurbaskani-erdogan-akkuyu-ngs-icin-turbinlerin-alman-gumrugunde-bekliyor-olmasi-bizi-ciddi-manada-rahatsiz-etmistir/3273837, accessed 2 August 2024.

756 - Mehmet Kaya, "Rusya'dan Akkuyu NGS mesajı: Sorunlar var, çözüm olmazsa verdiğimiz sürelere uyamayız", *Ekonomim*, 14 June 2024 (in Turkish), see https://www.ekonomim.com/sirketler/rusyadan-akkuyu-ngs-mesaji-sorunlar-var-cozum-olmazsa-verdigimiz-surelere-uyamayiz-haberi-749132, accessed 28 June 2024.

period in the contract to 20 years [from 15 years]. If necessary, the parties will discuss this further."[757]

The cost of the Akkuyu nuclear plant was estimated at US$20 billion when the project was first announced in 2010.[758] The cost has risen to US$24–25 billion according to the Director General of Rosatom Alexey Likhachev who spoke at the meeting of the Russian Council of Science and Education in June 2024.[759] This indicates a further increase in costs in less than a year. In September 2023, during a public meeting in Nizhny Novgorod Oblast, Russian President Vladimir Putin asked Likhachev for an update on the Akkuyu NPP cost. Likhachev replied that the cost in Türkiye would be US$23–24 billion rather than the US$17 billion suggested by President Putin in his question.[760]

The Turkish Government has announced plans to construct eight additional reactors in two other locations, with the goals of reaching 7.2 GW of installed nuclear capacity by 2035 and over 20 GW by 2050.[761] The Minister of Energy and Natural Resources (MOE), Alparslan Bayraktar, indicated that the initiative would encompass not only conventional large-scale nuclear power plants but also Small Modular Reactors (SMRs).[762] There has been a notable increase in interest in SMRs in Türkiye in recent years. In 2020, Rolls-Royce and Türkiye's EUAS International ICC signed a Memorandum of Understanding (MoU) to conduct a study evaluating various aspects of SMRs' applicability and a potential joint production.[763] In September 2023, MOE Alparslan Bayraktar met with Rolls-Royce Group to discuss the possibility of collaboration on SMRs.[764] The U.S. is also interested in the Turkish market for SMR technology, as evidenced by occasional statements made by Justin Friedman, a senior advisor for the U.S. Department of State, during his visits to Türkiye in recent years.[765] In May 2024, Bayraktar invited American companies to invest in Türkiye in the field of SMRs.[766] During his visit to China the same month,

757 - Ibidem.

758 - WNA, "Nuclear Power in Turkey", World Nuclear Association, Updated 30 April 2024, see https://world-nuclear.org/information-library/country-profiles/countries-t-z/turkey, accessed 12 April 2024.

759 - Kerim Ülker, "Akkuyu'nun maliyeti 5 milyar dolar arttı", *Dünya*, 21 June 2024 (in Turkish), see https://www.dunya.com/kose-yazisi/akkuyunun-maliyeti-5-milyar-dolar-artti/733054, accessed 28 June 2024; and *Interfax*, "Building Akkuyu NPP in Turkey costs $24-25 bln at current prices – Likhachev", 13 June 2024, see https://interfax.com/newsroom/top-stories/103324/, accessed 2 July 2024.

760 - Ibidem.

761 - Firdevs Yüksel, "Enerji ve Tabii Kaynaklar Bakanı Bayraktar: Sinop projesinde Rosatom ile işbirliğimizi geliştirmek istiyoruz", *Anadolu Agency*, 25 March 2024 (in Turkish), see https://www.aa.com.tr/tr/ekonomi/enerji-ve-tabii-kaynaklar-bakani-bayraktar-sinop-projesinde-rosatom-ile-isbirligimizi-gelistirmek-istiyoruz/3174313; and Zeynep Beyza Kilic, "Türkiye plans over 20 gigawatts of nuclear capacity by end of 2050", *Anadolu Agency*, 25 September 2023, see https://www.aa.com.tr/en/energy/nuclear/turkiye-plans-over-20-gigawatts-of-nuclear-capacity-by-end-of-2050/38960; both accessed 5 April 2024.

762 - Zeynep Beyza Kilic, "Türkiye plans over 20 gigawatts of nuclear capacity by end of 2050", *Anadolu Agency*, 25 September 2023, op. cit.

763 - Rolls Royce, "Rolls-Royce and Turkey's EUAS International ICC agree study for compact nuclear power stations", Press Release, 19 March 2020, see https://www.rolls-royce.com/media/press-releases/2020/19-03-2020-rr-and-turkey-euas-international-icc-agree-study-for-compact-nuclear-power-stations.aspx, accessed 1 June 2024.

764 - Ministry of Energy and Natural Resources, "'Yeni dönem enerji stratejimiz içinde nükleer enerji önemli bir yer tutuyor'", 27 September 2023 (in Turkish) see https://enerji.gov.tr/haber-detay?id=21181 accessed 1 June 2024.

765 - Gülşen Çağatay, "ABD'li uzman, SMR teknolojisinde Türkiye piyasasını cazip bulduklarını bildirdi", *Anadolu Agency, 28 December 2023 (in Turkish), see* https://www.aa.com.tr/tr/bilim-teknoloji/abdli-uzman-smr-teknolojisinde-turkiye-piyasasini-cazip-bulduklarini-bildirdi/3094360; and Zeynep Beyza Karabay, "Turkish companies excited for possible US partnership in small nuke reactors", *Anadolu Agency*, 23 December 2022, see https://www.aa.com.tr/en/energy/nuclear/turkish-companies-excited-for-possible-us-partnership-in-small-nuke-reactors/37175; both accessed 1 June 2024

766 - Dilara Zengin Okay and Sevgi Ceren Gökkoyun, "Bakan Bayraktar, Amerikan şirketlerini SMR alanında Türkiye'de yatırım yapmaya davet etti", *Anadolu Agency*, 10 May 2024 (in Turkish), see https://www.aa.com.tr/tr/ekonomi/bakan-bayraktar-amerikan-sirketlerini-smr-alaninda-turkiyede-yatirim-yapmaya-davet-etti/3215436, accessed 1 June 2024.

to sign an MoU on cooperation in the field of energy between the two countries, Bayraktar mentioned SMRs and renewables amongst the range of discussed energy technologies.[767]

A Brief History of Nuclear Energy in Türkiye

Türkiye's nuclear ambition dates back to the 1950s. In 1956, Türkiye established its Atomic Energy Commission with the objective of encouraging, coordinating, and supervising scientific, economic, technical, and administrative studies related to atomic energy.[768] In 1962, a 1-MW 'pool' type experimental nuclear research reactor, named TR-1, was commissioned at the Çekmece Nuclear Research and Training Centre (ÇNAEM) and operated until 1977.[769] TR-2 achieved its first criticality on 19 December 1981 at the same location.[770] The third and only operational research reactor, Triga Mark-2, was commissioned in March 1979 and is located at the Ayazağa Campus of Istanbul Technical University.[771]

Between 1965 and 2000, Türkiye attempted to launch a commercial nuclear power plant project on four occasions, but none of these attempts reached the construction phase.[772] Between these attempts, Akkuyu was granted its first site license in 1976.[773]

In 2004, Türkiye's Ministry of Energy and Natural Resources announced the construction of three nuclear power plants, each with four units and an installed capacity of 5 GW. The initial plan was for the first reactor to commence construction in 2007 and become operational in 2012. However, this did not proceed as planned.[774] In the final nuclear tender of Türkiye's history, which opened on 24 September 2008, thirteen companies or partnerships received specifications, six of them submitted their bid envelopes, of which five contained 'thank you' notes signaling the bidders' withdrawal. Only the Turkish-Russian consortium led by Atomstroyexport, with Inter RAO and Park Teknik, submitted a bid based on the Russian VVER design. The proposal met all nine of the Turkish Atomic Energy Agency's (TAEK) criteria.[775] On 19 January 2009, the kilowatt-hour price offered by Atomstroyexport-Inter RAO-Park Teknik

767 - *Hurriyet Daily News*, "Türkiye, China sign cooperation deal on energy transition", 22 May 2024, see https://www.hurriyetdailynews.com/turkiye-china-sign-cooperation-deal-on-energy-transition-193817, accessed 2 June 2024; and Ministry of Energy and Natural Resources, "Çin ile 'Enerji Dönüşümü' anlaşması", Government of Türkiye, 21 May 2024 (in Turkish) see https://enerji.gov.tr/haber-detay?id=21303, accessed 3 August 2024.

768 - TMMOB Elektrik Mühendisleri Odası, "Nükleer Enerji Raporu 2013", Chamber of Electrical Engineers, Türk Mühendis ve Mimar Odaları Birliği/ Union of Chambers of Turkish Engineers and Architects, 2013 (in Turkish) p. 61 see https://www.emo.org.tr/ekler/d28ac2cf3783f23_ek.pdf, accessed 10 April 2024: and *Resmî Gazete, "Atom Enerjisi Komisyonu kurulması hakkında Kanun— No. 6821", Issue 9398 (in Turkish), 1956, see* https://www5.tbmm.gov.tr/tutanaklar/KANUNLAR_KARARLAR/kanuntbmmc038/kanuntbmmc038/kanuntbmmc03806821.pdf, accessed 2 July 2024.

769 - Chamber of Electrical Engineers, "Nükleer Enerji Raporu 2013", 2013, op. cit., p. 62.

770 - Ahmet Bayülken, "Türkiye'de Nükleer Enerji", Energy Institute, Instanbul Technical University, Undated (in Turkish) see https://inis.iaea.org/collection/NCLCollectionStore/_Public/41/103/41103131.pdf, accessed 10 June 2024.

771 - Energy Institute, "TRIGA Mark-II Reaktörü", Istanbul Technical University, Undated (in Turkish) see http://www.triga.itu.edu.tr/, accessed 10 April 2024.

772 - Ahmet Bayülken, "Türkiye'de Nükleer Enerji", Energy Institute, Instanbul Technical University, Undated, op. cit.

773 - IAEA, "Country Nuclear Power Profiles—Turkey", Updated 2017, see https://www-pub.iaea.org/MTCD/Publications/PDF/cnpp2017/countryprofiles/Turkey/Turkey.htm, accessed 12 April 2024.

774 - Chamber of Electrical Engineers, "Nükleer Enerji Raporu 2013", 2013, op. cit., p. 66.

775 - Serdar İskender, Dünya, "Dördüncü nükleer enerji ihalesi de fiyaskoyla tamamlandı", 5 February 2009 (in Turkish), see https://www.dunya.com/gundem/dorduncu-nukleer-enerji-ihalesi-de-fiyaskoyla-tamamlandi-haberi-67798, accessed 1 August 2024.

Group in the framework of a build-own-operate scheme was revealed to be US$21.16 cents.[776] Later, it became known that the consortium subsequently made a new, lower price offer, claiming that there had been a change in input costs, as the initial offered price was considered high by the public. Since the tender for the nuclear power plant was organized as a competition, according to the law, a bidder could not submit a second bid with a lower price. The tender commission did not accept this envelope, but ministry officials did.[777] The subsequent attempt to reduce the given price led to objections and a stay of execution decision was taken from the relevant court against the lawsuit filed by The Union of Chambers of Turkish Engineers and Architects. This decision also played an important role in the subsequent cancellation of the tender,[778] which took place on 20 November 2009.[779]

Following the failure of previous initiatives including the most recent proposal, the Turkish Government pursued an alternative course of action by entering an intergovernmental agreement with Russia. On 12 May 2010, during former Russian President Dmitry Medvedev's visit to Ankara, it was announced that Türkiye's first nuclear power plant will be constructed by the Russian industry.[780] On the same day, Türkiye and Russia signed the Agreement on Cooperation on the Construction and Operation of a Nuclear Power Plant at the Akkuyu site.[781] The agreement was published in the Official Gazette on 6 October 2010.[782] At the time, projected startup dates of the four reactors were set "between 2016 and 2019."[783]

The Russian Deal

The intergovernmental agreement contains important provisions regarding the cost of the project for Türkiye and the ownership and management of the plant. The construction of the Akkuyu NPP is entirely financed by Russia.[784] This was an advantageous deal for cash-

776 - *Cumhuriyet*, "Nükleer santral ihalesi iptal edildi", 20 November 2009 (in Turkish), see https://www.cumhuriyet.com.tr/haber/nukleer-santral-ihalesi-iptal-edildi-100652, accessed 11 April 2024.

777 - Serdar İskender, "Dördüncü nükleer enerji ihalesi de fiyaskoyla tamamlandı", *Dünya*, 5 February 2009 (in Turkish), see https://www.dunya.com/gundem/dorduncu-nukleer-enerji-ihalesi-de-fiyaskoyla-tamamlandi-haberi-67798, accessed 1 August 2024.

778 - *Elektrik Mühendisliği*, "Nükleer Santral İhalesi İptal Edildi", Chamber of Electrical Engineers, December 2009 (in Turkish), see https://www.emo.org.tr/ekler/39690257da35df7_ek.pdf?dergi=593, accessed 1 August 2024.

779 - *Dünya*, "Nükleer santrale 'dördüncü' iptal", 20 November 2009 (in Turkish), see https://www.dunya.com/gundem/nukleer-santrale-039dorduncu039-iptal-haberi-97333, accessed 11 April 2024; and Mete Yüksel, "Nükleer Enerji ve Türkiye", TASAM, Türk Asya Stratejik Araştırmalar Merkezi/Turkish Asian Center for Strategic Studies, 21 May 2010 (in Turkish), see https://tasam.org/tr-TR/Icerik/1261/nukleer_enerji_ve_turkiye, accessed 10 June 2024; also Aaron Stein, "Türkiye'nin Nükleer Enerjiye Dair Hedefleri: Büyük Planlar, Ufak Adımlar", EDAM, Ekonomi ve Dış Politika Araştırmalar Merkezi/Centre for Economics and Foreign Policy Studies, November 2012 (in Turkish), p. 5, see https://edam.org.tr/wp-content/uploads/2012/09/T%C3%BCrkiye%E2%80%99nin-N%C3%BCkleer-Enerjiye-Dair-Hedefleri-B%C3%BCy%C3%BCk-Planlar-Ufak-Ad%C4%B1mlar.pdf, accessed 11 June 2024.

780 - *BBC News Türkçe*, "Türkiye'nin ilk nükleer santralini Rusya inşa ediyor", 12 May 2010 (in Turkish), see https://www.bbc.com/turkce/haberler/2010/05/100512_akkuyu_russia, accessed 11 June 2024.

781 - Ministry of Energy and Natural Resources, "Akkuyu Nükleer Güç Santrali Projesi", Government of Türkiye, Updated 9 September 2022, (in Turkish), see https://enerji.gov.tr/neupgm-akkuyu-nukleer-guc-santrali-projesi, accessed 28 June 2024.

782 - *Resmî Gazete*, "Karar Sayısı : 2010/918—Milletlerarasi Andlaşma— Türkiye Cumhuriyeti Hükümeti İle Rusya Federasyonu Hükümeti Arasinda Türkiye Cumhuriyetinde Akkuyu Sahasi'nda Bir Nükleer Güç Santralinin Tesisine Ve İşletimine Dair İşbirliğine İlişkin Anlaşma", Issue 27721, 6 October 2010 (in Turkish), see https://www.resmigazete.gov.tr/eskiler/2010/10/20101006-6.htm, accessed 28 June 2024.

783 - *POWER Magazine*, "New Nuclear Projects for Turkey, Jordan, and Mexico—Mexico Considers Building 10 Nuclear Power Plants by 2028", 19 May 2010, see https://www.powermag.com/new-nuclear-projects-for-turkey-jordan-and-mexico/, accessed 1 June 2022.

784 - Akkuyu Nuclear JSC, "The Presidents of Russia and Turkey Jointly Celebrate the Launch of Akkuyu NPP Construction", 3 April 2018, see https://akkuyu.com/en/news/the-presidents-of-russia-and-turkey-jointly-celebrate-the-launch-of-akkuyu-npp-construction, accessed 3 August 2024.

strapped Türkiye but led to problems with the start of the sanctions against Russia.[785] Article 5 of the intergovernmental agreement specifies that the project company, owner of the plant, will be established by the Russian party. Furthermore, the cumulative shares of the Russian authorized organizations in the project company must always remain at 51 percent or above.[786]

The power purchase guarantee is set out in Article 10. It states that 70 percent of the power generated from the first two units and 30 percent from the other two units will be purchased by the Turkish Electricity Trade and Contract Corporation (TETAŞ) for 15 years at a weighted average price of US$12.35 cents per kWh, excluding VAT.[787] Any remaining electricity generated will be sold on the open market. The Chamber of Electrical Engineers calculated the sum to be paid to Akkuyu Nuclear JSC in 15 years under the purchase guarantee as US$35.2 billion based on the assumption that the plant generates 38 TWh of electricity per year.[788]

The opposition has strongly criticized the build-own-operate agreement, particularly due to its purchase-guarantee requirement and Russian ownership.[789] Ahmet Akın, former Deputy Vice President of the main opposition party CHP (Cumhuriyet Halk Partisi/Republican People's Party), expressed concern that the guaranteed purchase price was three times higher than the current market price (as of May 2021).[790] Former Energy Minister Fatih Dönmez offered a different perspective, noting that nuclear will initially be costly under current market conditions, but that it should be seen as an 80-year investment. "The average price over its lifetime will be very, very low. One should think of it as an investment which is expensive for 15 years but reasonable for 65 years," Dönmez said.[791]

Alpay Antmen, a CHP Member of Parliament, expressed concern about the lack of technology transfer, the 60 years of Russian ownership, and the potential environmental impact of the plant, as well as its limited contribution to the Turkish economy.[792] Meral Akşener, former leader of the center-right İYİ Parti (Good Party), called on the Ministry of Energy in August 2022 via social media to intervene in a dispute between local contractors and the Russian project company, requesting the nationalization of the power plant if necessary.[793] The dispute began

785 - Brendan Cole, "Putin's Nuclear Project Inside NATO Country Dealt a Blow", *Newsweek*, 8 July 2024, see https://www.newsweek.com/russia-nuclear-turkey-sanctions-nato-energy-1922117, accessed 4 August 2024.

786 - *Resmî Gazete*, "Karar Sayısı : 2010/918—Milletlerarasi Andlaşma— Türkiye Cumhuriyeti Hükümeti İle Rusya Federasyonu Hükümeti Arasinda Türkiye Cumhuriyetinde Akkuyu Sahasi'nda Bir Nükleer Güç Santralinin Tesisine Ve İşletimine Dair İşbirliğine İlişkin Anlaşma", Issue 27721, 6 October 2010, op. cit., Articles 5.3 and 5.4; and Government of the Republic of Turkey and Government of the Russian Federation, "Agreement Between the Government of the Republic of Turkey and the Russian Federation on Cooperation in Relation to the Construction and Operation of a Nuclear Power Plant at the Akkuyu Site in the Republic of Türkiye", 6 October 2010, Articles 5.3 and 5.4, see https://akkuyu.com/upload/iga-en.pdf, accessed 29 June 2024.

787 - Ibidem, Article 10.5.

788 - Chamber of Electrical Engineers, "Alım Garantili 'Serbest' Piyasanin Faturasi Ağir!", Undated, (in Turkish), see https://www.emo.org.tr/genel/bizden_detay.php?kod=122032 accessed 12 June 2024.

789 - Gülsen Solaker, "Beş maddede Akkuyu tartışmalarının perde arkası", *Deutsche Welle*, 2 August 2022 (in Turkish), see https://www.dw.com/tr/be%C5%9F-maddede-akkuyu-tart%C4%B1%C5%9Fmalar%C4%B1n%C4%B1n-perde-arkas%C4%B1/a-62683349, accessed 5 May 2024.

790 - Erdem Sevgi, "CHP'li Ahmet Akın, Akkuyu Nükleer Santralı'na verilen alım garantisine dikkat çekti", *Cumhuriyet*, 17 May 2021 (in Turkish), see https://www.cumhuriyet.com.tr/haber/chpli-ahmet-akin-akkuyu-nukleer-santralina-verilen-alim-garantisine-dikkat-cekti-1836757, accessed 15 June 2024.

791 - *Patronlar Dünyası*, "Bakan Dönmez itiraf etti: Nükleer enerjiyi 15 yıl pahalı 65 yıl ucuz diye düşünmek lazım", 26 January 2022, (in Turkish), see https://www.patronlardunyasi.com/bakan-donmez-itiraf-etti-nukleer-enerjiyi-15-yil-pahali-65-yil-ucuz-diye-dusunmek-lazim, accessed 1 August 2024.

792 - Gülsen Solaker, "Beş maddede Akkuyu tartışmalarının perde arkası", *Deutsche Welle*, 2 August 2022, op. cit.

793 - Meral Akşener, on X (former Twitter), 1 August 2022 (in Turkish) see https://x.com/meral_aksener/status/1554061752874278913, accessed 5 May 2024.

when the Russian side terminated the engineering, procurement, and construction contract with the Turkish company IC İçtaş on 26 July 2022.[794] Rosatom stated that IC İçtaş committed contract violations that affected the quality and delivery time of the project.[795] IC İçtaş, on the other hand, denied these allegations and claimed that Rosatom's aim was to minimize the presence of Turkish companies in the project.[796] The dispute was later resolved with the intervention of Putin and Erdoğan, and IC İçtaş resumed work at Akkuyu.[797]

Article 10.9 of the agreement also contains a provision on waste management, which sets out Akkuyu Nuclear JSC's payment obligations:

> The Project Company shall pay a separate amount 0.15 US dollar cent per kWh to the account for spent fuel, radioactive waste management and 0.15 US dollar cent per kWh to the account for decommissioning for electricity purchased by TETAŞ within the framework of the PPA.[798]

Article 12.2 states that potential reprocessing of Russian-origin nuclear fuel in the Russian Federation would be subject to a separate agreement.

One of the most crucial elements of the agreement is Article 6 which stipulates that the construction of Unit 1 must be completed within seven years of the issuance of "all documents, permits, licenses, consents and approvals necessary to start the construction." Subsequent units must be placed in commercial operation at one-year intervals. The construction license for the first unit was granted on 2 April 2018,[799] meaning Unit 1 would have to commence operation in April 2025 at the latest to comply with the terms.

Further Newbuild Options

Historically, three sites have been proposed for a nuclear power plant in Türkiye, Akkuyu (Mersin province), Sinop, and İğneada (Kırklareli province), mainly because they are claimed to be far from active fault lines. However, the Chamber of Geological Engineers of Türkiye argues that the Akkuyu site is very close to the Ecemiş-Deliler Fault (3–5 kilometers), as well as the Biruni Fault, which is the previous fault's continuation in the Mediterranean Sea.[800] Many environmental groups, such as the East Mediterranean Platform of Environment Associations (DACE), called for a halt to the construction of the Akkuyu NPP after major earthquakes struck the south-eastern part of the country in February 2023 killing more than

794 - *BBC Türkçe*, "Akkuyu Nükleer Santrali: Rusya'nın hangi kararı ihtilafa yol açtı, bundan sonra ne olacak?", 5 August 2022 (in Turkish), see https://www.bbc.com/turkce/haberler-dunya-62421141, accessed 3 August 2024.

795 - Ibidem.

796 - *BirGün*, "İçtaş İnşaat'tan Akkuyu açıklaması: Amaç Türk şirketlerinin projedeki varlığını azaltmak", 29 July 2022 (in Turkish), see https://www.birgun.net/haber/ictas-insaat-tan-akkuyu-aciklamasi-amac-turk-sirketlerinin-projedeki-varligini-azaltmak-397134, accessed 3 August 2024.

797 - Senem Görür and Okan Yücel "Putin-Erdoğan görüşmesinden "Akkuyu" çıktı: Sözleşmesi feshedilen Türk şirketi projeye geri döndü", *Medyascope*, 17 September 2022 (in Turkish), see https://medyascope.tv/2022/09/17/putin-erdogan-gorusmesinden-akkuyu-cikti-sozlesmesi-feshedilen-turk-sirket-projeye-geri-dondu/, accessed 4 August 2024.

798 - Government of the Republic of Turkey and Government of the Russian Federal, "Agreement Between the Government of the Republic of Turkey and the Russian Federation on Cooperation in Relation to the Construction and Operation of a Nuclear Power Plant at the Akkuyu Site in the Republic of Türkiye", 6 October 2010, op. cit., Article 10.5, 6 October 2010, op. cit.

799 - Ministry of Energy and Natural Resources, "Akkuyu Nükleer Güç Santrali Projesi", Government of Türkiye, Updated 9 September 2022, op. cit.

800 - Chamber of Geological Engineers, "TMMOB Jeoloji Mühendisleri Odasının Nükleer Düzenleme Kanunu Tasarı Teklifine Ilişkin Görüş ve Değerlendirmeleri", 1 March 2022, see https://www.tmmob.org.tr/icerik/tmmob-jeoloji-muhendisleri-odasinin-nukleer-duzenleme-kanunu-tasari-teklifine-iliskin-gorus, accessed 3 July 2024.

50,000 people.[801] Two weeks after the earthquake, Akkuyu Nuclear JSC responded to these concerns with a media release, claiming that "the Akkuyu NPP project is designed for a safe shutdown [in case of an] earthquake of magnitude up to 9."[802]

The northernmost tip of Türkiye, Sinop has long been identified as one of the possible sites to build a nuclear power plant. Preliminary studies for Sinop began in the early 1980s but were halted following investigations into earthquake risks.[803] Although the last and most serious attempt to build a nuclear power plant by a Japanese-led consortium ended in failure,[804] the recent site approval by the Nuclear Regulatory Authority (3 April 2024) can be interpreted as preparation for a new process.[805] In March 2024, Energy Minister Alparslan Bayraktar spoke of possible cooperation with Rosatom for Sinop, but also mentioned interest of South Korea and China.[806] As of June 2024, Pavel Zavalny, Chairman of the State Duma's Energy Committee, was "90 percent certain" that Rosatom would be selected for the Sinop project.[807] He also revealed Rosatom plans to build two units with a capacity of 1250 MW each at the site.[808]

The Thrace region, and particularly a small town called İğneada in the province of Kırklareli close to the Bulgarian border, is the third site proposed for the construction of a nuclear power plant in Türkiye since the 1970s.[809] Recently, government officials have been using "Thrace region" to identify the location of the third site instead of "İğneada", which could indicate that a new site in the region is being considered. Energy Minister Alparslan Bayraktar revealed during his visit to China that Türkiye is negotiating with China for the planned nuclear power plant in the Thrace region to be equipped with four reactors and is working to finalize the intergovernmental agreement in a few months.[810]

801 - *BBC News Türkçe*, "Doğu Akdeniz Çevre Platformu: Deprem riski nedeniyle Akkuyu Nükleer Santrali'nin yapımı durdurulmalı", 16 March 2023 (in Turkish), see https://www.bbc.com/turkce/live/haberler-turkiye-64973493; and Filiz Kinik Oz, "50,783 people confirmed dead in Türkiye earthquakes", *Anadolu Agency*, 22 April 2023, see https://www.aa.com.tr/en/turkiye/50-783-people-confirmed-dead-in-turkiye-earthquakes/2878735; both accessed 14 June 2024.

802 - Akkuyu Nuclear, "Information Message", Rosatom, 20 February 2023, see https://akkuyu.com/en/news/information-message-2, accessed 18 June 2024.

803 - Chamber of Electrical Engineers, "Nükleer Enerji Raporu", 2013, op. cit., p. 64.

804 - *Daily Sabah*, "Japanese partner reported to abandon Sinop nuclear plant project", 5 December 2018, see https://www.dailysabah.com/energy/2018/12/05/japanese-partner-reported-to-abandon-sinop-nuclear-plant-project; accessed 16 June 2024.

805 - NDK, "Site Approval was granted for the Sinop Nuclear Power Plant Site", Nükleer Düzenleme Kurumu/Nuclear Regulatory Authority, 2 May 2024, see https://www.ndk.org.tr/en-US/news/site-approval-was-granted-for-the-sinop-nuclear-power-plant-site, accessed 16 June 2024.

806 - Firdevs Yüksel, "Enerji ve Tabii Kaynaklar Bakanı Bayraktar: Sinop projesinde Rosatom ile işbirliğimizi geliştirmek istiyoruz", *Anadolu Agency*, 25 March 2024 (in Turkish), see https://www.aa.com.tr/tr/ekonomi/enerji-ve-tabii-kaynaklar-bakani-bayraktar-sinop-projesinde-rosatom-ile-isbirligimizi-gelistirmek-istiyoruz/3174313, accessed 17 June 2024.

807 - *TASS*, "Turkey 90% likely to cede second NPP project in Sinop to Russia", *Russian News Agency*, 14 June 2024, see https://tass.com/economy/1803695, accessed 17 June 2024.

808 - Ibidem.

809 - Nedim Bülent Damar, "Türkiye'de Nükleer Santrallar Ve Emo'Nun Nükleer Santrallara Karşi Mücadelesi", Nuclear Power Plant Monitoring Commission, The Union of Chambers of Turkish Engineers and Architects, *Elektrik Mühendisliği*, November 2023 (in Turkish) see https://www.emo.org.tr/ekler/7ed71d2cba4c7a2_ek.pdf?dergi=1325, accessed 17 June 2024.

810 - *TRT Haber*, "Çin ile nükleer santral için yapılan görüşmelerde sona yaklaşıldı", 24 May 2024 (in Turkish), see https://www.trthaber.com/haber/ekonomi/cin-ile-nukleer-santral-icin-yapilan-gorusmelerde-sona-yaklasildi-859668.html, accessed 17 June 2024.

Incidents During Akkuyu Construction Raise Criticism

According to the Akkuyu Nuclear JSC, there are 25,000 workers involved in the construction of Akkuyu NPP where four units are being built simultaneously.[811] This number went up to 30,000 in Rosatom's other statements, and it is stressed that the four units must be constructed by the end of 2028 according to the intergovernmental agreement.[812]

The first unit was granted a commissioning permit on 21 November 2023.[813] Commissioning work was announced to commence in the beginning of April 2024.[814] Construction of the other units is also underway. Installation of the roof on the turbine building of the second unit was completed in May 2024.[815]

Throughout the project's history, the construction work has been heavily criticized by environmental groups and opposition parties. The discovery of cracks in the concrete of the reactor building's foundation of the first unit became a major controversial issue.[816] According to news reports, the (former) Turkish Atomic Energy Agency intervened twice and had problematic sections of the foundation redone.[817] Rosatom denied the claims saying that the reactor's base had been completed in accordance with International Atomic Energy Agency safety standards.[818] Over the years, media reports covered several incidents that occurred due to construction activities at the site, including damage to nearby houses caused by planned dynamite explosions and several fire outbreaks.[819]

From time to time, the media also reported on poor working conditions with dire consequences such as widespread food poisoning or flooding of a canteen.[820] There were also claims of mobbing and non-payment of salaries, and once some of the workers publicly complained that they had to go to the hospital by their own means when they had a work accident.[821]

811 - Akkuyu Nuclear, "About the Project", Rosatom, Undated, see https://akkuyu.com/en/about/info, accessed 16 June 2024.

812 - Rosatom, "Newsletter #276—Turkey's Nuclear Future", April 2024, see https://rosatomnewsletter.com/2024/04/25/turkeys-nuclear-future/, accessed 18 June 2024.

813 - Nuclear Regulatory Authority, "Licensing of Akkuyu Nuclear Power Plant—Akkuyu Nuclear Power Plant-Milestones", Undated, see https://www.ndk.gov.tr/en-US/licensing-of-akkuyu-nuclear-power-plant, accessed 19 June 2024.

814 - Akkuyu Nuclear, "Full-Scale Start-up and Commissioning Works Started at Akkuyu NPP Unit 1", 10 April 2024, op. cit.

815 - Akkuyu Nuclear, "Turbine Building Roof Installation Was Completed at Akkuyu NPP Unit Two (Türkiye)", 13 May 2024, see https://akkuyu.com/en/news/turbine-building-roof-installation-was-completed-at-akkuyu-npp-unit-two-t-rkiye, accessed 5 July 2024.

816 - Olcay Aydilek, "Nükleer santral temelinde çatlak", *Habertürk*, 6 May 2019 (in Turkish), see https://www.haberturk.com/son-dakika-nukleer-santral-temelinde-catlak-2452726-ekonomi, accessed 10 May 2024.

817 - Ibidem.

818 - Ilgin Karlidag and Ksenia Idrisova, "Analysis: Fears of nuclear disaster as Russia builds Turkey's first plant", *BBC Monitoring*, 28 August 2019, see https://monitoring.bbc.co.uk/product/c20110yk, accessed 27 June 2024.

819 - *Habertürk*, "Son dakika haberler… Mersin Akkuyu'daki patlama anı ortaya çıktı", 20 January 2021 (in Turkish), see https://www.haberturk.com/son-dakika-akkuyudaki-patlama-ani-ortaya-cikti-haberler-2944048; and *Sözcü*, "Akkuyu Nükleer Santrali'nde trafo patladı, yangın çıktı", 31 October 2021 (in Turkish), see https://www.sozcu.com.tr/akkuyu-nukleer-santralinde-trafo-patladi-yangin-cikti-wp6740340; both accessed 10 May 2024.

820 - *ANKA*, "Akkuyu Nükleer Güç Santrali Inşaatinda, Yemekhaneyi Su Bastı", 8 November 2011 (in Turkish), see https://ankahaber.net/haber/detay/akkuyu_nukleer_guc_santrali_insaatinda_yemekhaneyi_su_basti_61413, accessed 12 May 2024; and *bianet*, "Hundreds of workers suffer from food poisoning at Turkey's Akkuyu nuclear plant", 22 September 2023, see https://bianet.org/haber/hundreds-of-workers-suffer-from-food-poisoning-at-turkey-s-akkuyu-nuclear-plant-284333, accessed 5 July 2024.

821 - Abidin Yağmur, "Akkuyu işçileri kölelik düzenini anlattı: 'Maaş alamıyoruz, mobbinge uğruyoruz, hırsızlığa zorlanıyoruz'", *Artı Gerçek*, 8 March 2024 (in Turkish), see https://artigercek.com/emek/akkuyu-iscileri-kolelik-duzenini-anlatti-maas-alamiyoruz-mobbinge-ugruyoruz-286989h; and *Artı TV*, "Akkuyu işçileri kölelik düzenini anlattı 'Maaş alamıyoruz, mobbinge uğruyoruz, hırsızlığa…'", as published on Youtube (in Turkish), 8 March 2024, see https://youtu.be/NVNpce805jc?si=VmVfEp-XUmpliauG; both accessed 4 August 2024.

In early 2024, a deadly meningitis outbreak became public, and the Mersin Medical Chamber attested that it was aware of two fatalities, though one could not be confirmed as a meningitis case. At the time, the alleged number of casualties was five.[822] Rosatom confirmed the deaths of two workers.[823] In early February 2024, Dr. Nasır Nesanır, President of the Mersin Medical Chamber, said that the number of identified cases had reached four. Two of them died, with meningitis being the established cause of death for one of them according to medical records. The cause of death for the second person could not be established with certainty.[824] Nesanır stressed that the contraction of the disease is often linked to poor housing, hard working conditions, and malnutrition.

Another event related to the workers of Akkuyu Nuclear Power Plant was the discovery in February 2024 of a suspected ISIS member amongst the workers. According to the local police, the arrested suspect was a Russian citizen who used a fake identity.[825]

One of the major setbacks was the above mentioned dispute between Akkuyu Nuclear and one of its subcontractors, IC İçtaş İnşaat, which took two months to resolve involving Russian President Vladimir Putin and Turkish President Recep Tayyip Erdoğan.[826]

The Cases of Gennady Sakharov and Cüneyd Zapsu

There were several changes at the Akkuyu Nuclear JSC Board of Directors over the years, but two of these are particularly noteworthy. Gennady Sakharov, the Director of Capital Investments, State Construction Supervision and State Expertise of Rosatom was arrested on 28 March 2024 on bribery charges.[827] His "request to resign from the Board of Directors of Akkuyu Nuclear JSC", as it is labeled in the Trade Registry Gazette, was to be discussed at Akkuyu Nuclear JSC's General Assembly Meeting on 29 March 2024.[828] Sakharov may face up to 15 years in jail.[829]

Beside Sakharov, another board member of Akkuyu Nuclear JSC is also facing trial. Henri Proglio, former CEO of French state-controlled utility EDF from 2009 to 2014, is on trial at

822 - *BigGün*, "Akkuyu'da menenjit ölümleri | Tabip Odası'ndan çağrı: Kaynağı araştırılmalı", 16 January 2024 (in Turkish), see https://www.birgun.net/haber/akkuyu-da-menenjit-olumleri-tabip-odasi-ndan-cagri-kaynagi-arastirilmali-498810, accessed 12 May 2024.

823 - Ibidem; and *Enerji Günlüğü*, "Akkuyu NGS'de menenjit alarmı", 17 January 2024 (in Turkish), see https://www.enerjigunlugu.net/akkuyu-ngsde-menenjit-alarmi-57338h.htm, accessed 12 May 2024.

824 - *BirGün*, "Meningitis cases continue at Akkuyu: 4th after 20 days", 8 February 2024 (in Turkish), see https://www.birgun.net/haber/akkuyu-da-menenjit-vakalari-suruyor-20-gun-sonra-4-uncu-504964, accessed 12 May 2024.

825 - *Duvar*, "ISIS suspect found working in Akkuyu Nuclear Power Plant construction in Turkey", 13 February 2024, see https://www.duvarenglish.com/isis-suspect-found-working-in-akkuyu-nuclear-power-plant-construction-in-turkey-news-63833, accessed 12 May 2024.

826 - *NEI Magazine*, "Details provided on resolution of Akkuyu construction dispute", 27 September 2022, see https://www.neimagazine.com/news/details-provided-on-resolution-of-akkuyu-construction-dispute-10038241/, accessed 23 June 2024.

827 - *DHNews*, "Arrest of a high ranking official", 31 March 2024, see https://dailyhub.news/en/espreso.tv/news/2001189/; and *TADVISER*, Sakharov Gennady Stanislavovich", see https://tadviser.com/index.php/Person:Gennady_Stanislavovich_Sakharov; both accessed 15 June 2024.

828 - *Türkiye Ticaret Sicil Gazetesi*, "Ankara Ticaret Sicili Müdürlüğü'nden—Ticaret Unvanı Akkuyu Nükleer Anonm Şirketi—Ticaret Sicil No: 289100", Trade Registry Gazette, No:11041, 12 March 2024.

829 - *DHNews*, "Arrest of a high ranking official", 31 March 2024, op. cit.

the Paris Criminal Court accused of favoritism in the award of 44 consultancy contracts worth €36 million (US$39 million) omitting the required competitive bidding process.[830]

On 24 July 2024, Akkuyu Nuclear JSC announced managerial changes and the CEO Anastasia Zoteeva was replaced by Anton Dedusenko.[831] Media saw this change as a termination not a handover.[832]

Another significant managerial change, officialized in December 2022, that attracted media attention was the resignation of Cüneyd Zapsu, who had previously served as an advisor to President Erdoğan.[833] Zapsu was the only Turkish citizen to ever make it to the board, and since his departure there has been no Turkish representation on the Board of Directors of Akkuyu Nuclear JSC.[834] Zapsu had initiated legal proceedings against the company prior to his resignation, citing a national security issue with Russia—a radar system to be installed at the nuclear power plant—as the reason for the dispute.[835] Cüneyd Zapsu also asserted that a disagreement with the subcontractor company resulted in an additional US$2 billion loss for the NPP company.[836]

Nuclear Waste

Türkiye does not currently have a permanent or temporary waste repository. The intergovernmental agreement stipulates that Akkuyu Nuclear JSC is responsible for the decommissioning of the power plant and waste management, but this responsibility is limited to its contribution to the relevant fund.[837] According to the environmental impact assessment report, used nuclear fuel will be sent to Russia.[838] However, Akkuyu Nuclear JSC on its old website had the following information: "If Turkey wants to buy the waste, it [the spent fuel] could stay in Turkey."

The Akkuyu JSC's former Vice President, Rauf Kasumov, discussed the issue of low- and medium-level waste in a TV interview with *BloombergHT* in 2014, and he stated that these waste

830 - *Energy News*, "Proglio trial: EDF's former CEO goes on trial for favoritism", 23 May 2024, see https://energynews.pro/en/proglio-trial-edfs-former-ceo-goes-on-trial-for-favoritism/, accessed 4 August 2024; and Jérôme Lefilliâtre, "Au procès d'Henri Proglio, deux ans de prison avec sursis requis contre l'ex-PDG d'EDF", *Le Monde*, 18 June 2024 (in French), see https://www.lemonde.fr/societe/article/2024/06/18/au-proces-d-henri-proglio-deux-ans-de-prison-avec-sursis-requis-contre-l-ex-pdg-d-edf_6241102_3224.html, accessed 21 August 2024.

831 - Trade Registry, issue 1128, page 260, 24 July 2024.

832 - *Bloomberg HT*, "Akkuyu Nükleer'in genel müdürü görevden alındı", 26 July 2024 (in Turkish), see https://www.bloomberght.com/akkuyu-nukleer-in-genel-muduru-gorevden-alindi-2357291, accessed 4 August 2024.

833 - Murat Yetkin, "Akkuyu: Erdoğan rapor istedi, Zapsu'nun istifası cebinde", *Yetkin Report*, 10 August 2022 (in Turkish), see https://yetkinreport.com/2022/08/10/akkuyu-erdogan-rapor-istedi-zapsunun-istifasi-cebinde/ accessed 14 May 2024.

834 - Okan Yücel, "Cüneyd Zapsu ayrıldı: Akkuyu'nun yönetim kurulunda Türk kalmadı", *Medyascope*, 20 December 2022 (in Turkish), see https://medyascope.tv/2022/12/20/cuneyd-zapsu-ayrildi-akkuyunun-yonetim-kurulunda-turk-kalmadi/, accessed 14 May 2024.

835 - Ibidem.

836 - Ibidem.

837 - Government of Turkey and Government of Russia, "Agreement Between the Government of the Republic of Turkey and the Russian Federation on Cooperation in Relation to the Construction and Operation of a Nuclear Power Plant at the Akkuyu Site in the Republic of Turkey", Article 12.4 (in English and Russian) 12 May 2010, see https://www.resmigazete.gov.tr/eskiler/2010/10/20101006-6-1.pdf, accessed 12 June 2024.

838 - Akkuyu EIA, (in Turkish) Section V.2.1-2.5 - Page 118.

categories would remain in Akkuyu.[839] In 2022, correspondence between the Gendarmerie and the Directorate of Environment and Urbanization revealed that a "Radioactive Waste Disposal and Storage Site" spanning 4 million square meter was planned to be built in the grassland of the Polatlı district of Ankara.[840] There is limited information available about the nuclear waste management plans in Türkiye, and the messages are confusing.

Opinion Polls

Despite the ongoing construction of a nuclear power plant in Mersin province, surveys indicate a strong anti-nuclear sentiment in Türkiye. In one of the latest Konda surveys, carried out in November 2022, 77 percent included nuclear energy amongst two power plant technologies they would be "most opposed to".[841] This rate was 75 percent in September 2021.[842] In 2021, Konda conducted another study and found that a total of five percent of respondents indicated a preference for the use of nuclear power plants to generate electricity.[843]

Energy Outlook

Türkiye's installed electricity generating capacity had reached 110 GW by the end of May 2024.[844] Thermal power plants account for the largest share in the power mix, with a total capacity of 49 GW, while hydroelectric power plants represent the second largest source, with 32-GW capacity. With recent additions, wind and solar power capacity passed 27 GW (12 and 15 GW respectively), as of 1 June 2024. In 2023, with over 3 GW, solar energy was by far the largest contributor to the annual capacity additions.[845] The peak demand for Türkiye remains low compared to the installed capacity; at its highest, demand reached 55 GW on 26 July 2023.[846]

Two recent plans offer insights into the government's vision for Türkiye's energy future. The "Türkiye National Energy Plan", released at the end of 2022, outlines a strategy to increase the installed capacity of wind energy to 29.6 GW and solar energy to 52.9 GW by 2035.[847] The Türkiye National Energy Plan indicates that hydroelectric power plants are expected to have an installed capacity of 35.1 GW, while geothermal and biomass power plants would have a

839 - Bloomberg HT, "BloombergHT Tv'de Finans Merkezi programı canlı yayınından", as published on Youtube by Akkuyu Nükleer A.Ş., 17 March 2014, see https://www.youtube.com/watch?v=5wjh7mjIkk8, accessed 5 July 2024.

840 - *Baskent Haber*, "İYİ Partili Oral Belgelerle Konuştu: Polatlı Nükleer Atık Çöplüğü mü Olacak?", 17 November 2022 (in Turkish), see https://baskenthaber.org/iyi-partili-oral-belgelerle-konustu-polatli-nukleer-atik-coplugu-mu-olacak/; and *Cumhuriyet*, "Ankara, Akkuyu'nun 'nükleer çöplüğü' mü olacak? İYİ Parti'den tepki geldi", 3 December 2022 (in Turkish), see https://www.cumhuriyet.com.tr/siyaset/ankara-akkuyunun-nukleer-coplugu-mu-olacak-iyi-partiden-tepki-geldi-2008638; both accessed 20 June 2024.

841 - KONDA, "Türkiye'de İklim Değişikliği Algısı ve Enerji Tercihleri 2022", April 2023 (in Turkish), p. 36, see https://www.iklimhaber.org/wp-content/uploads/2023/05/Iklim-Haber-Konda-Arastirma-2022.pdf, accessed 21 June 2024.

842 - Ibidem.

843 - KONDA, "İklim Değişikliği Algısı Raporu— Aralık 2021", December 2021 (in Turkish), p. 124, see https://konda.com.tr/uploads/konda-iklimdegisikligialgisiraporu-aralik2021-final-0f4b56136ada676fb5d43b7ce0550c9430762ac3bcbffa11476e469bbda930a8.pdf, accessed 21 June 2024.

844 - TEİAŞ, "Türk Tevzi Bilgi Sistemi Günlük İşletme Neticeleri", Türkiye Elektrik İletim A. Ş./Turkish Electricity Transmission Corporation, 1 June 2024, p. 12.

845 - TEİAŞ, "Türk Tevzi Bilgi Sistemi Günlük İşletme Neticeleri", Türkiye Elektrik İletim A. Ş./Turkish Electricity Transmission Corporation, 1 January 2023; and TEIAŞ, "Türk Tevzi Bilgi Sistemi Günlük İşletme Neticeleri", 1 January 2024.

846 - Ibidem.

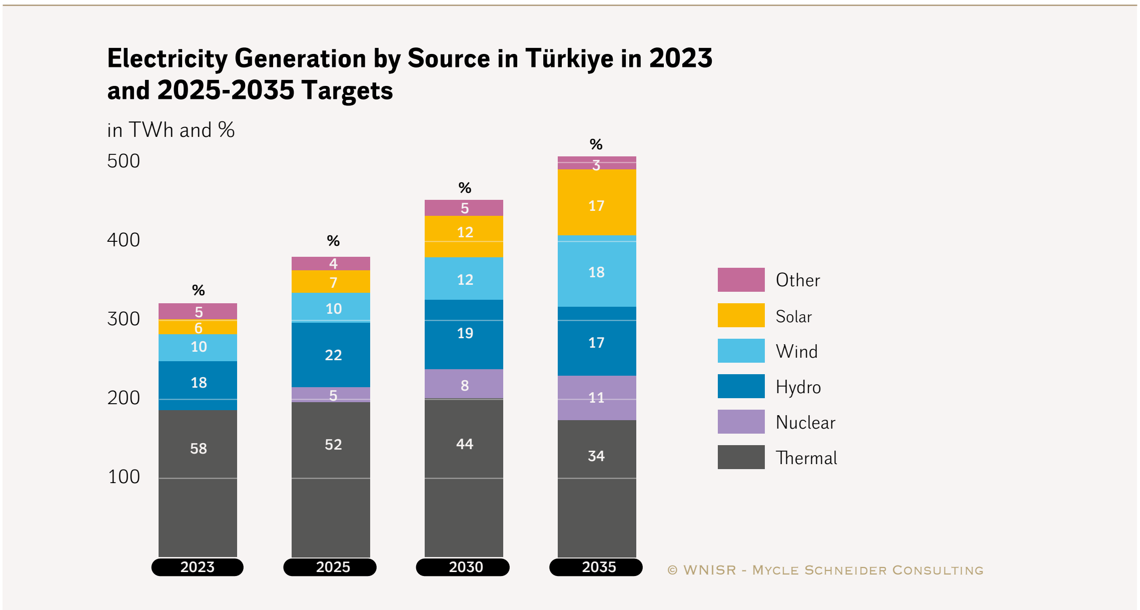
847 - Ministry of Energy and Natural Resources, "Türkiye National Energy Plan 2022", Government of Türkiye, 2022, see https://enerji.gov.tr/Media/Dizin/EIGM/tr/Raporlar/TUEP/T%C3%BCrkiye_National_Energy_Plan.pdf, accessed 15 May 2024.

combined 5.1 GW installed capacity. If that happens, Türkiye will have 122.7 GW of renewable energy capacity by 2035.

The Plan foresees adding 2.4 GW in gas power plant capacity by 2030, and possibly a further 10 GW by 2035 "in addition to the abovementioned investments to contribute to the management of the imbalance of intermittent renewable energy plants in the system, and to the sustainability of energy supply security." By 2030, 1.7 GW of coal power capacity is to be added. By 2035, a further 1.5 GW of coal and 7.2 GW of nuclear capacity (including Akkuyu) would be available, according to the Plan.

As a result, by 2035, as shown on Figure 42, thermal sources would still cover 34.2 percent of the power production with 17.7 percent provided by wind, 17.3 percent by hydro, 16.5 percent by solar, 11.1 percent by nuclear, and 3.2 percent by biomass and geothermal.

Figure 42 · 2025–2035 Targets for Electricity Generation in Türkiye



Sources: Türkiye National Energy Plan 2022 and TEIAŞ, 2024[848]

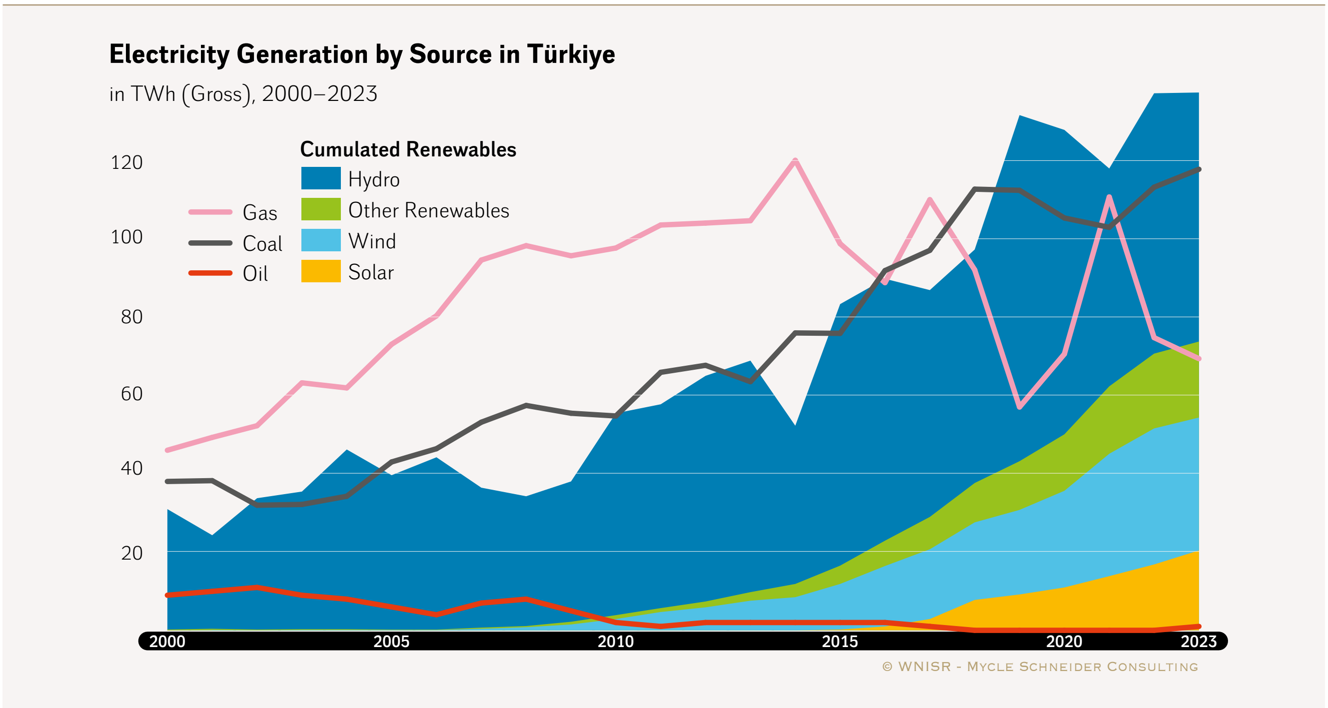
The Twelfth Development Plan approved on 31 October 2023 also includes some indications on the country's energy planning. The plan anticipates that the total installed capacity will reach 136 GW by 2028, including 18 GW of wind power, 30 GW of solar power, and 5 GW in battery storage. Renewable energy is planned to cover 50 percent of the electricity generation by 2028 and all four units of the Akkuyu nuclear plant are expected to be operational. Efforts are to be pursued to further increase the installed nuclear power capacity, including through new technologies "such as small modular reactors, fusion technologies, and advanced generation reactors."[849]

848 - Ministry of Energy and Natural Resources, "Türkiye National Energy Plan 2022", Government of Türkiye, 2022, op.cit.

849 - Presidency of Strategy and Budget, "Twelfth Development Plan (2024-2028)", Presidency of the Republic of Türkiye, approved 31 October 2023, see https://www.sbb.gov.tr/wp-content/uploads/2024/06/Twelfth-Development-Plan_2024-2028.pdf, accessed 15 May 2024.

Due to the struggling economy, electricity demand stagnated and the high price of gas led to cheaper imported coal taking over. In 2023, for the first time in Türkiye's history, thermal power plants running on imported coal became the leading source of electricity generation with a share of 22.3 percent.[850] The share of fossil fuels in the electric mix was 57.8 percent and that of renewables including hydro was 41.9 percent. Non-hydro renewables contributed 22.4 percent of the total electrical energy generated in the country in 2023 with wind contributing 10.5 percent, solar 5.8 percent, geothermal 3.4 percent, and biomass 2.7 percent.[851] (See Figure 43)

Figure 43 · Electricity Production by Source in Türkiye



Source: Energy Institute, 2024

In the past five years, electricity consumption has increased by an average of 4.5 percent per year but drew a fluctuating graph. In one of the five years it increased by more than 8 percent, while in another two (including in 2023) it slightly declined.[852] The reference scenario of Turkish Electricity Transmission Company's (TEİAŞ) 10-Year Demand Forecast Report, released in March 2023, estimated that the electricity demand would be 335 TWh for the running year, over 358 TWh in 2025, and 450 TWh in 2032.[853]

850 - Ekosfer, "Elektrik üretiminde ithal kömür zirveye oturdu", 9 May 2024 (in Turkish), see https://ekosfer.org/elektrik-uretiminde-ithal-komur-zirveye-oturdu/, accessed 20 June 2024.

851 - TEIAŞ, "Türk Tevzi Bilgi Sistemi Günlük İşletme Neticeleri", 1 January 2024.

852 - Union of Chambers of Turkish Engineers and Architects (TMMOB) Chamber of Mechanical Engineers (MMO), "Türkiye Enerji Görünümü 2024", 4 June 2024 (inTurkish), p. 24, see https://www.mmo.org.tr/sites/default/files/gonderi_dosya_ekleri/TEG%20 2024%20TEMEL%20SUNUM%203.6.2024.pdf, accessed 26 June 2024.

853 - TEİAŞ, "10 Yıllık Talep Tahminleri Raporu", Türkiye Elektrik İletim A. Ş./Turkish Electricity Transmission Corporation, March 2023 (in Turkish), p. 54, see https://webim.teias.gov.tr/file/f09f9857-4844-42b0-a0fa-74cdacfe4013?download, accessed 6 July 2024.

In reality, Türkiye's electricity consumption was 330 TWh in 2023,[854] i.e. above the low case scenario but below the reference scenario and far below the high case scenario of 352 TWh.[855]

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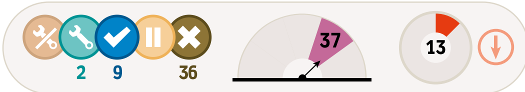
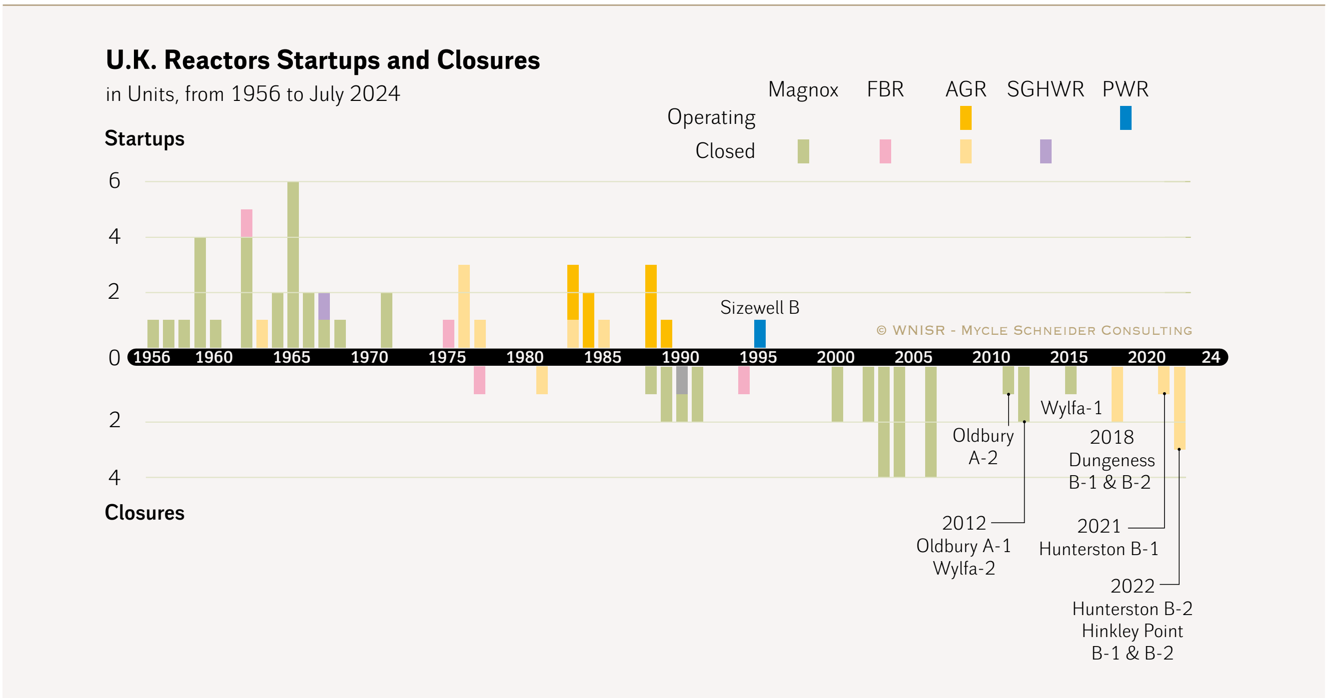


As of mid-2024, the United Kingdom (U.K.) operated nine reactors, the same as in the previous edition of the WNISR. The average fleet age is 37.1 years (see Figure 45). The last reactors to close were the two units at Hinkley Point B on 6 July 2022 (B-2) and 1 August 2022 (B-1), respectively. This followed the closure of the two reactors at Hunterston in 2021 and 2022, and two units at Dungeness officially closed in 2021 (last power generation in 2018, see Figure 44).

In total, 36 nuclear reactors have been closed in the U.K., the second largest number of any country behind the United States (see United Kingdom in Decommissioning Status Report). This includes all 26 Magnox reactors, two fast breeders, one small Steam-Generating Heavy Water Reactor (SGHWR), and seven Advanced Gas Reactors (AGRs). There is now 5.8 GW of nuclear capacity in operation, with 7.8 GW awaiting decommissioning.

Figure 44 · U.K. Reactor Startups and Closures



Sources: WNISR with IAEA-PRIS and EDF Energy, 2022–2024

Type of Reactors: **AGR**: Advanced Gas Reactors; **FBR**: Fast Breeder Reactor; **PWR**: Pressurized Water Reactor; **SGHWR**: Steam-Generating Heavy Water Reactor

854 - Ministry of Energy and Natural Resources, "Elektrik", Government of Türkiye, 24 June 2024 (in Turkish), see https://enerji.gov.tr/bilgi-merkezi-enerji-elektrik, accessed 28 June 2024.

855 - TEİAŞ, "10 Yıllık Talep Tahminleri Raporu", March 2023, op. cit., p. 54.

In 2023, electricity generated from nuclear power decreased over the previous year, going from 43.6 TWh (14.2 percent of electricity) to 37.3 TWh (12.5 percent), down from a maximum share of 28 percent in 1997.

Eight of the nine operating reactors are AGRs in pairs at Torness, Heysham (four reactors), Hartlepool, and one PWR at Sizewell. All operating AGRs were completed in the 1980s, while Sizewell B started operating in 1995.

Managing reactors as they age is a constant problem of any technology design, and the AGRs are no exception. As has been commented on in previous editions of the WNISR, issues with the core's graphite moderator bricks have raised concerns. Previously, Hinkley Point B and Hunterston B were due to operate until 2023, while Dungeness B was due to operate until 2028, however, by early 2022, the situation had changed dramatically. With ongoing graphite issues and other age related problems, EDF officially closed Dungeness B-1 and -2 in June 2021, Hunterston B in January 2022, and Hinkley Point B in July/August 2022.[856] In January 2024, EDF announced that it was planning to extend the operating lifetimes for eight reactors, two each at Torness, Heysham A and B, and Hartlepool and that a decision would be taken by the end of 2024.[857]

Hartlepool and Heysham A were due to close in 2024, but EDF delayed closure by two years in March 2023[858] "with a plus or minus one year window on either side of this date" according to Centrica.[859] The Office for Nuclear Regulation (ONR) has said that while a plant life extension does not require formal approval, EDF must produce updated safety cases for the plants, which the regulator will assess.[860] (See Table 9)

856 - EDF, "EDF decides to move Dungeness B into defuelling phase", Press Release, 7 June 2021, see https://www.edfenergy.com/media-centre/news-releases/edf-decides-move-dungeness-b-defuelling-phase; and EDF, "Zero-carbon electricity generation ends at Hunterston B" Press Release, 7 January 2022, see https://www.edfenergy.com/media-centre/news-releases/zero-carbon-electricity-generation-ends-hunterston-b; also EDF, "Hinkley Point B power station", Undated, see https://www.edfenergy.com/energy/power-stations/hinkley-point-b; all accessed 4 July 2024.

857 - Julia Kollewe, "EDF Energy plans to extend life of four UK nuclear power plants", *The Guardian*, 9 January 2024, see https://www.theguardian.com/business/2024/jan/09/edf-energy-uk-nuclear-power-plants, accessed 27 July 2024; and EDF Energy, "Investment boost to maintain UK nuclear output at current levels until at least 2026", Press Release, 9 January 2024, see https://www.edfenergy.com/media-centre/investment-boost-maintain-uk-nuclear-output-current-levels-until-least-2026, accessed 21 August 2024.

858 - EDF Energy, "EDF confirms plans to keep turbines turning at Heysham 1 and Hartlepool power stations", Press Release, 9 March 2023, see https://www.edfenergy.com/media-centre/news-releases/edf-confirms-plans-keep-turbines-turning-heysham-1-and-hartlepool-power, accessed 4 July 2024.

859 - Centrica, "Centrica PLC Annual Report and Accounts 2023", February 2024, see https://www.centrica.com/media/fobalevh/strategic-report-ar-2023.pdf, accessed 4 July 2024.

860 - ONR, "EDF announces operating life extensions for Heysham 1 and Hartlepool", Office for Nuclear Regulation, 9 March 2023, see https://news.onr.org.uk/2023/03/edf-announces-operating-life-extensions-for-heysham-1-and-hartlepool/, accessed 4 July 2024.

Table 9 · Status of U.K. EDF AGR Nuclear Reactor Fleet (as of 1 July 2024)

Reactor	Net Capacity (MW)	Grid Connection	Closure/ Expected Closure
Dungeness B-1 **Dungeness B-2**	545 545	03/04/1983 29/12/1985	Closed June 2021 (Last power in 2018)
Hartlepool A-1 **Hartlepool A-2**	590 595	01/08/1983 31/10/1984	March 2026
Heysham A-1 **Heysham A-2**	485 575	09/07/1983 11/10/1984	March 2026
Heysham B-1 **Heysham B-2**	620 620	12/07/1988 11/11/1988	March 2028
Hinkley Point B-1 **Hinkley Point B-2**	485 480	30/10/1976 05/02/1976	Closed July/August 2022
Hunterston B-1 **Hunterston B-2**	490 495	06/02/1976 31/03/1977	Closed November 2021 Closed January 2022
Torness-1 **Torness-2**	595 605	25/05/1988 03/02/1989	March 2028

Source: EDF Energy, 2024

« The Nuclear Decommissioning Authority (NDA), overseen by DESNZ [the Department for Energy Security and Net Zero], does not fully understand the UK's civil nuclear sites, making it difficult to judge the cost and timescale of decommissioning them »

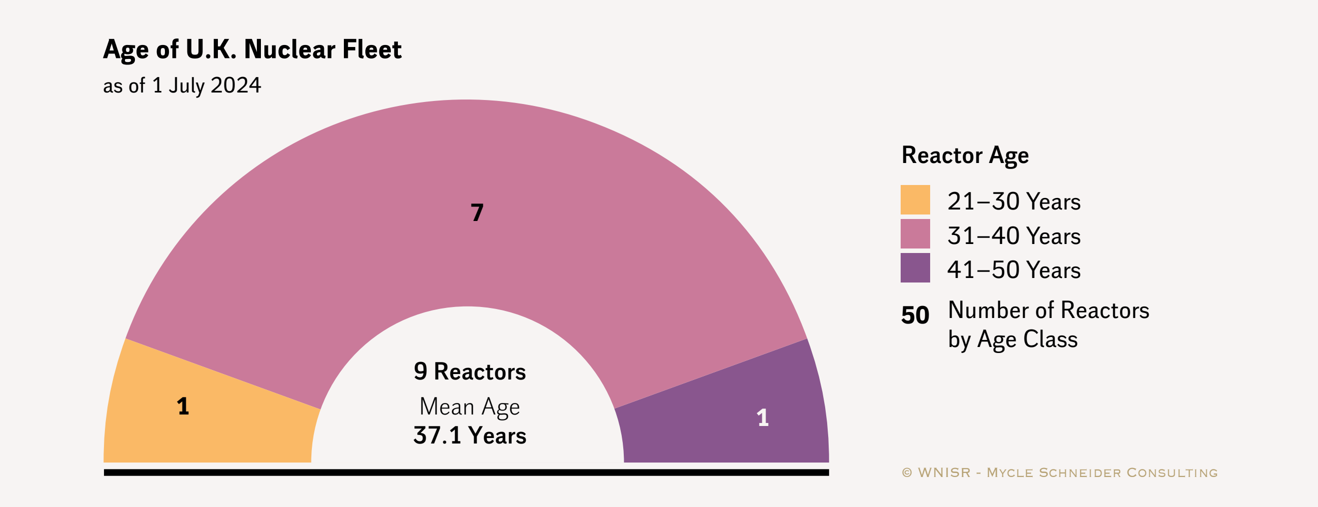
Public Accounts Committee – U.K. Parliament

The decommissioning cost estimates for nuclear, military, and civil facilities continue to rise. According to the Public Accounts Committee of the Parliament, "The Nuclear Decommissioning Authority (NDA), overseen by DESNZ [The Department for Energy Security and Net Zero], does not fully understand the UK's civil nuclear sites, making it difficult to judge the cost and timescale of decommissioning them," and they further say that "currently, the NDA estimates that decommissioning the UK's civil nuclear sites will cost £132 billion [US$$_{2020}$169 billion] and take until 2333," some 300 years from now.[861] The annual cost of decommissioning civil nuclear facilities owned by the NDA for 2022–2023 is £4.69 billion (~US$$_{2024}$5.9 billion)[862] (for more details on decommissioning in the U.K. see United Kingdom in Decommissioning Status Report). When defueling the AGRs is complete, ownership and responsibility for carrying out and paying for decommissioning will pass from EDF to NDA.

861 - Public Accounts Committee, "Eighth Annual Report of the Chair of the Committee of Public Accounts", HC628, House of Commons, March 2024, see https://committees.parliament.uk/publications/44073/documents/219015/default/, accessed 4 July 2024.

862 - Department for Energy Security and Net Zero, "Department Overview 2022-23", U.K. Government, February 2024, see https://www.nao.org.uk/wp-content/uploads/2024/02/department-for-energy-security-and-net-zero-2022-23-overview.pdf, accessed 4 July 2024.

Figure 45 · Age Distribution of U.K. Nuclear Fleet



Sources: WNISR, with IAEA-PRIS, 2024

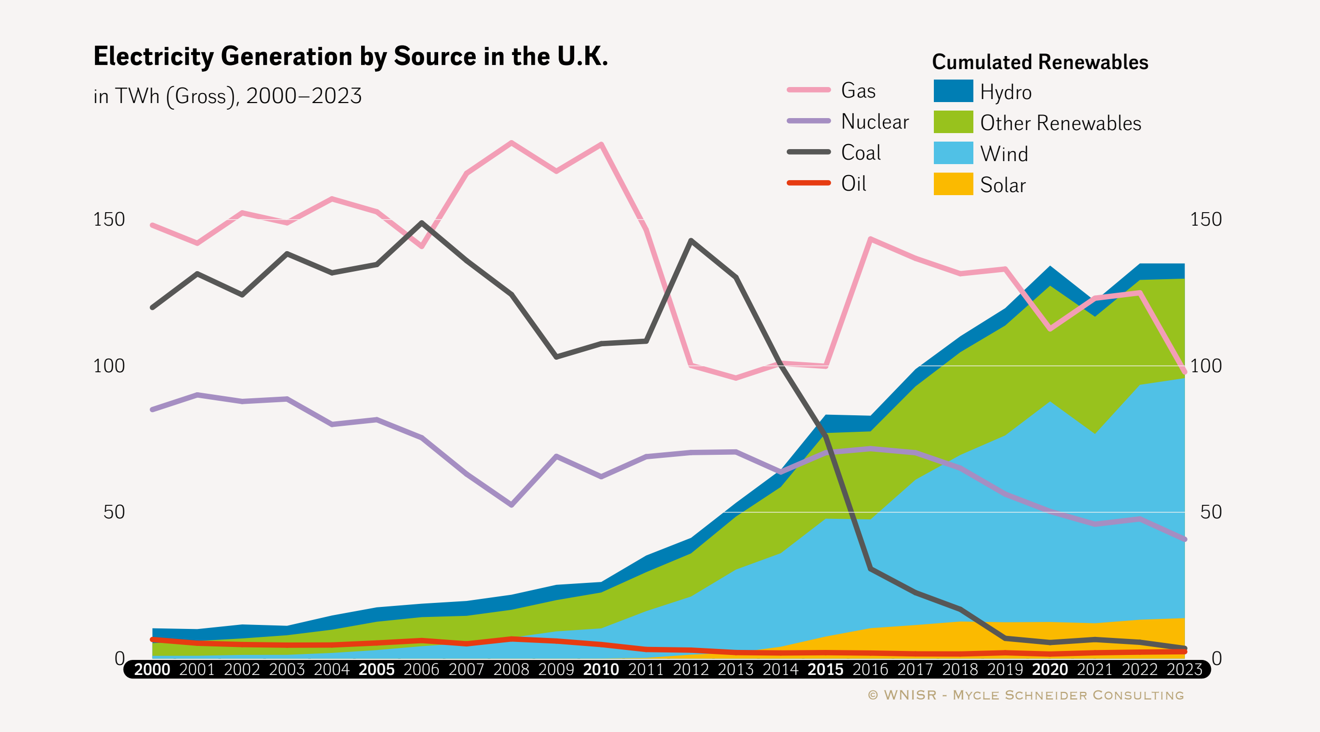
Pathways to Net Zero

Total electricity generation fell by 11 percent in 2023—to the lowest level in 30 years—partly due to continuing reductions in demand and high volumes of imported electricity. Despite leaving the E.U., the U.K. continues trading electricity with the continental and Irish electricity and gas markets. Over the past few years, electricity interconnector capacity has increased to enable a significant exchange volume, bringing market stability across Europe. The generation of electricity from fossil fuels decreased by 22 percent in 2023 to 103.8 TWh, its lowest level since the 1950s. Production from nuclear power also decreased by 15 percent, to 37 TWh, providing just 12.5 percent.

The generation of electricity from fossil fuels decreased by 22 percent in 2023 to 103.8 TWh, its lowest level since the 1950s

The electricity mix in the U.K. has changed rapidly over the past decades, as seen in Figure 46. The most significant trend was the rapid reduction in the use of coal; economic and environmental considerations drove this decline, and it has gone from providing about one-third of the electricity generated in the U.K. in 2000 to less than 2 percent in 2023, while renewables have grown so that they provided 47 percent from 2.8 percent at the turn of the century.

Figure 46 · Electricity Generation by Source in the U.K. – The Coal Plunge



Source: DUKES, U.K. Government, 2024[863]

The U.K. has set one of the world's most ambitious greenhouse gas emissions targets, committing to a 68 percent reduction from 1990 levels by 2030 and 78 percent by 2035[864] compared to a 52 percent reduction to 384 Mt CO2e achieved in 2023.[865]

The Conservative Administrations (2010–2024)

Since 2010, when David Cameron was elected, there have been four consecutive Conservative administrations headed by Theresa May, Boris Johnson, Liz Truss, and then Rishi Sunak. All of these governments have supported nuclear power. In 2010, the Conservative Party pledged to encourage new low-carbon energy production, including "clearing the way for new nuclear power stations – provided they receive no public subsidy."[866] Then, in 2015, the Conservatives pledged, "We need a Conservative Government to see through this long-term plan and secure clean but affordable energy supplies for generations to come. This means a significant expansion in new nuclear and gas (...)."[867] In 2019, they said, "We will **support gas for**

863 - Department for Energy Security & Net Zero, "National Statistics—Digest of UK Energy Statistics – Fuel used in electricity generation and electricity supplied", U.K. Government, Updated 27 June 2024, see https://www.gov.uk/government/statistics/electricity-section-5-energy-trends, accessed 11 July 2024.

864 - BEIS and Prime Minister's Office, "UK enshrines new target in law to slash emissions by 78% by 2035", Press Release, Department for Business, Energy and Industrial Strategy, U.K. Government, 2021, see https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035, accessed 4 July 2024.

865 - Office for National Statistics, "Measuring UK greenhouse gas emissions", Updated 26 June 2024, see https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/measuringukgreenhousegasemissions, accessed 4 July 2024.

866 - Conservative Party, "Invitation to Join the Government of Britain—The Conservative Manifesto 2010", 2010, see https://general-election-2010.co.uk/2010-general-election-manifestos/Conservative-Party-Manifesto-2010.pdf, accessed 4 July 2024.

867 - Conservative Party, "Strong Leadership, A Clear Economic Plan a Brighter, More Secure Future—The Conservative Party Manifesto 2015", 2015, see https://www.theresavilliers.co.uk/files/conservativemanifesto2015.pdf, accessed 4 July 2024.

hydrogen production and **nuclear energy**, including fusion, as important parts of the energy system, alongside **increasing our commitment to renewables**" [emphasis in bold replicated from the original document].[868]

In November 2020, the U.K. Government published The Ten Point Plan for a Green Industrial Revolution, which included a specific point on "Delivering New and Advanced Nuclear Power".[869] The plan put forward milestones for the sector, including the completion of Hinkley Point C (HPC) in the mid-2020s and the deployment of the first SMRs in the early 2030s. In December 2020, the government published a long-awaited Energy White Paper, which stated that the aim was to

> **bring at least one large-scale nuclear project to the point of Final Investment Decision** by the end of this Parliament [2024], subject to clear value for money and all relevant approvals.[870] [emphasis in bold from the original document]

In an accompanying press statement, the government said it would begin negotiations with EDF on Sizewell C.[871] However, the approval requires a "value-for-money" hurdle to be passed, which could be challenging given the current economics of nuclear vs. renewables. This timetable was unmet, and no decision was made before the July 2024 election. The government also further outlined a plan for the development projects, including to "develop an overall siting strategy for the long term" targeted at eight designated nuclear sites (listed in this order): Hinkley, Sizewell, Heysham, Hartlepool, Bradwell, Wylfa, Oldbury, and Moorside.[872]

The government announced upon release of its British Energy Security Strategy published in April 2022 that "a new government body, Great British Nuclear [GBN], will be set up immediately to bring forward new projects, backed by substantial funding" and that it would "launch the £120 million [~US$$_{2022}$148 million] Future Nuclear Enabling Fund this month."[873] However, it was not until the following year, in July 2023, that GBN was finally launched, and the statement announced "a massive revival of nuclear energy" and a "rapid expansion of new nuclear power plants in the U.K. at an unprecedented scale and pace."[874] There were two main elements of the launch:

868 - Conservative Party, "Get Brexit Done—Unleash Britain's Potential", 2019, see https://assets-global.website-files.com/5da42e2cae7ebd3f8bde353c/5dda924905da587992a064ba_Conservative%202019%20Manifesto.pdf, accessed 4 July 2024.

869 - U.K. Government, "The Ten Point Plan for a Green Industrial Revolution", November 2020, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf, accessed 4 July 2024.

870 - U.K. Government, "Energy white paper—Powering our net zero future", CP 337, December 2020, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943807/201214_BEIS_EWP_Command_Paper_LR.pdf, accessed 4 July 2024.

871 - BEIS, "Government sets out plans for clean energy system and green jobs boom to build back greener", Press Release, Department for Business, Energy and Industrial Strategy, 14 December 2020, see https://www.gov.uk/government/news/government-sets-out-plans-for-clean-energy-system-and-green-jobs-boom-to-build-back-greener, accessed 4 July 2024.

872 - BEIS, "Fund to secure our energy supply and boost cutting-edge nuclear projects opens for business", Press Release, 13 May 2022, see https://www.gov.uk/government/news/fund-to-secure-our-energy-supply-and-boost-cutting-edge-nuclear-projects-opens-for-business, accessed 17 July 2024.

873 - BEIS and Prime Minister's Office, "Major acceleration of homegrown power in Britain's plan for greater energy independence", Press Release, U.K. Government, 2022, see https://www.gov.uk/government/news/major-acceleration-of-homegrown-power-in-britains-plan-for-greater-energy-independence#:~:text=The%20government's%20British%20Energy%20Security,by%202030%20being%20low%20carbon, accessed 4 July 2024.

874 - Department for Energy Security and Net Zero, Great British Nuclear, and Nuclear Decommissioning Authority, "British nuclear revival to move towards energy independence", Press Release, U.K. Government, 18 July 2023, see https://www.gov.uk/government/news/british-nuclear-revival-to-move-towards-energy-independence, accessed 4 July 2024.

- the announcement of a competition to get support for the construction of SMRs; and
- the award of £157 million (~US$\$_{2023}$195 million) of grant funding. This includes:
    - £77 million (~US$\$_{2023}$96 million) for businesses to accelerate advanced nuclear designs,
    - £58 million (~US$\$_{2023}$72 million) for further development of a new generation of SMRs that operate at higher temperatures—with three winning projects announced—and
    - £22 million (~US$\$_{2023}$27 million) from the Nuclear Fuel Fund, allocated to fuel fabrication facilities for the development of a new type of nuclear fuel—High-Assay Low-Enriched Uranium (HALEU).[875]

The level of funding so far allocated, while politically relevant, will contribute only a small proportion of the costs needed to bring the designs to commercial deployment. In July 2023, the Parliament's Science, Innovation and Technical Committee published a report reviewing the government's nuclear plans. The Committee mainly supported nuclear power and the former government's objective of having 24 GW of new nuclear in addition to HPC by 2050 but strongly questioned its (lack of) strategy to meet the goal. In particular, the Committee asked the government to clarify the role of Great British Nuclear beyond initially supporting SMRs and how it would engage with any projects beyond Sizewell C.[876] The government responded to the Committee's report and stated it was developing a "new nuclear National Policy Statement," which would "cover the deployment of new nuclear power stations beyond 2025."[877]

Over the fourteen years of the continually supportive set of administrations for nuclear power, the industry has declined.

Over the fourteen years of the continually supportive set of administrations for nuclear power, the industry has declined. Twelve reactors have closed; the only reactors under construction, at Hinkley Point C, have suffered extreme cost overruns and delays (see Hinkley Point C, below); and nuclear's contribution to power production continues to decrease.

Labour Government

In May 2024, Rishi Sunak, the then Prime Minister, surprised many by calling for an early election on 4 July 2024 despite being significantly behind in the opinion polls—the administration could have remained in post until the end of the year. The party's level of support did not increase, and the Labour Party, under Sir Keir Starmer, won the election with a considerable majority. This should enable the Party to be more ambitious about its agenda as it will not have to rely on other parties' votes and risk disagreements with internal factions without derailing policy implementation.

875 - Ibidem.

876 - Science, Innovation and Technology Committee, "Delivering nuclear power", U.K. Parliament, 31 July 2023, see https://publications.parliament.uk/pa/cm5803/cmselect/cmsctech/626/summary.html, accessed 4 July 2024.

877 - U.K. Government, "Delivering nuclear power: Government Response to the Committee's Eighth Report", 25 October 2023, see https://committees.parliament.uk/publications/41818/documents/207526/default/, accessed 4 July 2024.

At the heart of the incoming government's energy and climate policy is said to be a new "Energy Independence Act".[878] It will support establishing a publicly owned energy company—Great British Energy, which will be capitalized with £8.3 billion (US$10.5 billion) from the government over the next five years and is to be designed to support capital-intensive low-carbon technologies. The objective for renewables is to "double onshore wind, triple solar power, and quadruple offshore wind by 2030." In 2023, offshore wind generated 17.3 percent of power, onshore wind 11.4 percent, and solar 4.9 percent. Therefore, meeting these targets would mean that generation from solar and wind alone would exceed current levels of electricity consumption in the U.K., which is an extremely ambitious target. However, there is an opportunity for the government to facilitate the acceleration of renewable energy, with proposed changes in the planning laws. This is particularly pertinent as it has been shown that over 60 percent of renewable and battery projects in 2018–2023 have been stopped during the planning phase, which is partially a result of speculative applications but also an indication that the planning system does not have sufficient resources to process all the applications.[879]

On nuclear power the Labour Party has pledged to "ensure" the extension of the lifetime of existing reactors and get Hinkley Point C completed, neither of which is under its control, while also supporting the completion of Sizewell C and SMRs.[880] Under the new government it is likely that Great British Nuclear, will become part of Great British Energy.

Nuclear Newbuild

The U.K. has one power station with two reactors under construction at Hinkley Point C, and one project with two units awaiting a Final Investment Decision (FID) at Sizewell C. Both projects are based on the Franco-German European Pressurized Water Reactor (EPR) design. The development of two new reactors at Bradwell, using the Chinese Hualong One design, has been halted. While the regulator completed the Generic Design Assessment (GDA) of the Hualong One, the project did not get beyond the study phase.

Hinkley Point C

The regulator concluded its five-year GDA of the U.K. EPR in December 2012, and EDF Energy was given planning permission to build two reactors at Hinkley Point in April 2013. (For more detailed information see previous editions of WNISR). In October 2015, EDF and the U.K. Government announced updates to the October 2013 provisional agreement of commercial terms of the deal for the £16 billion (US$$_{2013}$25 billion) overnight construction cost of Hinkley Point C (HPC).[881] The Chinese company China General Nuclear Power

878 - Labour Party, "Change—Labour Party Manifesto 2024", 2024, see https://labour.org.uk/wp-content/uploads/2024/06/Labour-Party-manifesto-2024.pdf, accessed 4 July 2024.

879 - Rachel Millard, "Bulk of UK onshore renewable energy projects fail to get beyond planning stage", *The Financial Times*, 24 June 2024, see https://www.ft.com/content/1fd56de4-5930-4fd6-a683-a98d8ac09cab, accessed 26 June 2024.

880 - Labour Party, "Change—Labour Party Manifesto 2024", 2024, op. cit.

881 - Department of Energy & Climate Change, "Hinkley Point C to power six million UK homes" , Press Release, U.K. Government, 21 October 2015, see https://www.gov.uk/government/news/hinkley-point-c-to-power-six-million-uk-homes; and Department of Energy and Climate Change and Prime Minister's Office, "Initial agreement reached on new nuclear power station at Hinkley", Press Release, U.K. Government, 21 October 2013, see https://www.gov.uk/government/news/initial-agreement-reached-on-new-nuclear-power-station-at-hinkley; both accessed 4 July 2024.

Group (CGN), a state-controlled company, agreed to meet 33.5 percent of the investment in the FID. The estimated cost of construction has since risen at the following times:

- In 2017, it stood at £$_{2015}$19.6 billion (~US\$$_{2015}$30 billion).[882]
- In September 2019, EDF announced new completion cost (still in 2015 values) of between £21.5 billion (US\$$_{2015}$32.8 billion) and £22.5 billion (US\$$_{2015}$34.4 billion).[883]
- In March 2022, EDF confirmed that Unit 1 is expected to generate power in June 2026, compared to end-2025 as announced in 2016. The project completion costs were then estimated in the range of £$_{2015}$22–23 billion (US\$$_{2015}$33.6–35.1 billion).[884]
- Less than three months later, in May 2022, EDF announced that cost estimates had further risen to between £$_{2015}$25–26 billion (US\$$_{2015}$38.2–39.7 billion) and that its start-up would be delayed by an additional year to June 2027.[885]
- In February 2023, EDF announced that the costs had risen to £32 billion (US\$$_{2021}$44 billion) (note the previous £26 billion figures were in 2015 values, while £32 billion is in 2021 values, and so some of the rise in costs is inflationary).[886]
- In January 2024, further cost increases and delays were announced, with a new expectation that in 2015 prices the likely costs would be between £31–35 billion, with completion of unit one expected to be between 2029–2031.[887] Or in current values in the order of £41.3–46.6 billion (US\$52.5–59.2 billion), which has led to the French Government putting pressure, unsuccessfully, on the U.K. Government to help foot the bill for the cost overruns.[888]

The critical point of the deal was a Contract for Difference (CfD), effectively a guaranteed real electricity price for 35 years, which, depending on the number of units ultimately built, i.e. whether construction at Sizewell C proceeded, would be £89.50–92.50/MWh (US\$$_{2012}$141–146MWh), with annual increases until and from startup linked to the Consumer Price Index.[889] In early 2020, EDF broke down the £92.50/MWh (US\$$_{2012}$146/MWh) strike price:

- overnight construction costs, excluding financing: only £11 (US\$$_{2012}$17.4);
- operating and maintenance costs: £19.5 (US\$$_{2012}$30.8);
- financing costs for "typical regulated asset without construction risk": £26 (US\$$_{2012}$41);

882 - EDF, "Clarifications on Hinkley Point C project", Press Release, 3 July 2017, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/clarifications-on-hinkley-point-c-project, accessed 4 July 2024.

883 - EDF, "Update on Hinkley Point C project", Press Release, 25 September 2019, see https://www.edfenergy.com/media-centre/news-releases/update-on-hinkley-point-c-project, accessed 4 July 2024.

884 - EDF Energy, "Annual Report and Financial Statements—31 December 2021", 2022, see https://www.edfenergy.com/sites/default/files/edf_energy_holdings_limited_fy21_signed_financial_statements_full.pdf, accessed 4 July 2024.

885 - EDF, "Hinkley Point C Update", Press Release, 19 May 2022, see https://www.edf.fr/sites/groupe/files/epresspack/3081/ccb6205433272bb0cbfac560cea3b537.pdf, accessed 4 July 2024.

886 - EDF, "2023: Q1 Sales and highlights—Appendices", February 2023, see https://www.edf.fr/sites/groupe/files/2023-04/2023-04-28-edf-book-q1-2023.pdf, accessed 4 July 2024.

887 - EDF, "Hinkley Point C Update", Press Release, 23 January 2024, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/hinkley-point-c-update-1, accessed 15 July 2024.

888 - Sarah White, "EDF's Hinkley Point woes pile pressure on global nuclear push", *The Financial Times*, 29 January 2024, see https://www.ft.com/content/d401e42b-d953-4ef0-b3ea-ed80e974249a, accessed 30 January 2024.

889 - EDF, "Agreement reached on commercial terms for the planned Hinkley Point C nuclear power station", Press Release, 21 October 2013.

- first-of-a-kind construction risk: £36 (US$$_{2012}$57) to cover.[890]

EDF did not provide details of these calculations, so it is not possible to assess their accuracy.

Within the original 2016-CfD agreement, EDF is to receive a 35-year firm price per MWh, but if commercial operation starts after November 2029, the CfD is reduced in length, one year for every year of delay until 2033. This is the "longstop date", after which the contract could be canceled if the project is not completed. On 29 November 2022, the longstop date was extended from 1 November 2033 to 1 November 2036.[891]

The expected composition of the consortium owning the plant changed from October 2013 to October 2015 with the effective bankruptcy and dismantling of AREVA, making their planned contribution of 10 percent impossible; the Chinese stake, through CGN, fell to 33.5 percent from 40 percent; and the other investors (up to 15 percent) had not materialized, leaving EDF with 66.5 percent rather than 45 percent it had hoped for in 2013.

The rising construction cost and its increased share have impacted the amount EDF has to pay. As of 2020, the cost of EDF's expected project share had increased by about 150 percent since 2013.[892] Responsibility for any delays and cost overruns falls solely on EDF under the CfD model, and when the company realized the scale of risk this entailed, it pushed for change. In response, in June 2022, the British Government set out its case for Sizewell C to be built under the Regulated Asset Base (RAB) rather than the CfD model.[893]

The costs of construction are continuing to cause problems for all parties, as the total financing needs exceed the contractual commitments of the shareholders. In the latter half of 2023, the shareholders were asked for voluntary contributions to meet the additional costs, but CGN refused and so EDF is having to cover all additional costs. In 2024, EDF announced in its annual financial report that it had written off €12.9 billion (US$$_{2023}$14 billion) in costs associated with HPC assets and EDF Energy (the U.K. arm of the company).[894]

The HPC delays and cost overruns were part of the credit-rating agency Standard & Poor's (S&P) rationale to downgrade EDF's rating in February 2022,[895] and its placement on credit-watch negative in May 2022.[896] In the same rating action, S&P downgraded EDF's U.K. subsidiary EDF Energy to BB, deep in speculative territory ("junk") and put it on credit-watch

890 - Phil Chaffee, "United Kingdom: Industry Pushes for Government Action", *Nuclear Intelligence Weekly*, 6 March 2020.

891 - Department for Energy Security & Net Zero, "Hinkley Point C: contractual documents", U.K. Government, Updated 29 November 2022, see https://www.gov.uk/government/publications/hinkley-point-c-documents, accessed 4 July 2024.

892 - Steve Thomas and Alison Downes, "Financing the Hinkley Point C Project", Public Services International Research Unit, University of Greenwich, January 2020.

893 - *WNN*, "UK government confirms Sizewell C eligible for RAB financing", 14 June 2022, see https://world-nuclear-news.org/Articles/UK-government-confirms-Sizewell-C-eligible-for-RAB, accessed 27 July 2024; and BEIS and Kwasi Kwarteng, "Kwarteng advances plans for funding new nuclear projects, including Sizewell C", Department for Business, Energy & Industrial Strategy, U.K. Government, 14 June 2022, see https://www.gov.uk/government/news/kwarteng-advances-plans-for-funding-new-nuclear-projects-including-sizewell-c, accessed 12 July 2022.

894 - EDF, "Universal Registration Document 2023 - including the Annual Financial Report", filed 4 April 2024, see https://www.edf.fr/sites/groupe/files/2024-04/edf-urd-annual-financial-report-2023-en-updated-2024-04-11.pdf, accessed 15 July 2024.

895 - S&P Global Ratings, "Research Update: Electricite de France Downgraded To 'BBB' From 'BBB+' On Strong Debt Increase In 2022-2023; Outlook Negative", Standard & Poor's, 21 February 2022, see https://www.edf.fr/sites/groupe/files/2022-02/sp-edf-ratings-direct-2022-02-21.pdf, accessed 4 July 2024.

896 - S&P Global Ratings, "Research Update: Electricite de France Placed On CreditWatch Negative On Further Nuclear Issues And Increase In Debt", Standard & Poor's, 24 May 2022, see https://www.edf.fr/sites/groupe/files/2022-05/sp-press-release-2022-05-24_0.pdf, accessed 4 July 2024.

negative for potential further downgrade. In July 2023, EDF was fully renationalized (see France Focus).

In June 2023, Moody's published a credit opinion on EDF Group reporting the downgrading of the Baseline Credit Assessment (BCA) from baa3 to ba1 due to slow progress in its recovery, high and volatile wholesale electricity prices, and the group's significant debt burden. Around Hinkley Point they said:

> The increasing cost estimates illustrate the execution risks that EDF and CGN face in constructing the power station. In addition, EDF's balance sheet will have to suffer the financial implications of a very long construction phase, given that the cost will have to be debt funded because the group has entered into a fixed-price contract-for-differences agreement with the U.K. government and has no ability to recover the higher costs from customers; and the investment will not generate any cash flow until the power plant is operational.[897]

In June 2024, S&P gave EDF a more positive outlook, with nuclear generation increasing in France and an expectation that income should be able to cover "finance interests and taxes, and most of EDF's capex" and the costs linked to the renationalization. However, on the issue of current construction, including both Hinkley and Sizewell, S&P was less confident about EDF, saying that the company's stand-alone credit profile will be affected by the risks of newbuild, particularly the construction of Hinkley and the latest three-year delay in completion of the units, as well as the uncertainty over the funding of Sizewell,[898] see Sizewell C, below.

Sizewell C

Initially, it was proposed that EDF and CGN would develop a follow-on to HPC, the Sizewell C project, which would be a copy of HPC, with two EPR 1.6 GW units. Chinese investment was to be limited to 20 percent, leaving EDF with 80 percent of the company that would take the project to FID; neither party was obliged to take any share in the company that actually built, owned, and operated it. In 2022, EDF stated that it had planned to pre-finance the development of its share of the initial budget of up to £458 million (US$$_{2022}$564 million), with no agreement to invest beyond that stage.[899] On 24 June 2020, the U.K. Planning Inspectorate accepted the application for development consent received the previous month,[900] and in July 2022, the government gave its development consent to build Sizewell C.[901]

897 - Moody's, "Electricite de France—Update following rating affirmation", 6 June 2023, see https://www.edf.fr/sites/groupe/files/2023-06/edf-credit-opinion-moodys-update-2023-06-06.pdf, accessed 4 July 2024.

898 - Emmanuel Dubois-Pelerin, "EDF Outlook Revised To Positive On Recovering Domestic Nuclear Activity; Ratings Affirmed At 'BBB/A-2'", S&P Global, 5 June 2024, see https://disclosure.spglobal.com/ratings/en/regulatory/article/-/view/type/HTML/id/3192062, accessed 18 June 2024.

899 - EDF, "Universal Registration Document 2021—Including the Annual Financial Report", filed 17 March 2022, see https://www.edf.fr/sites/groupe/files/2022-03/edf-2021-universal-registration-document.pdf, accessed 4 July 2024.

900 - The Planning Inspectorate, "Application by NNB Nuclear Generation (SZC) Limited for an Order Granting Development Consent for The Sizewell C Project—Notification of decision to accept an application for Examination for an Order Granting Development Consent", Email to Richard Bull, EDF Energy, National Infrastructure Planning, Ministry of Housing, Communities and Local Government, U.K. Government, 24 June 2020, see https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010012/EN010012-002268-A05%20Notification%20of%20decision%20to%20accept%20application_.pdf, accessed 19 July 2023.

901 - Planning Inspectorate, "The Sizewell C Project development consent decision announced", Press Release, U.K. Government, 20 July 2022, see https://www.gov.uk/government/news/the-sizewell-c-project-development-consent-decision-announced, accessed 4 July 2024.

EDF was optimistic that it could reduce construction cost and in 2020 estimated it would be £18 billion (US$\$_{2020}$23 billion).[902] However, it is also hoping to reduce the financing costs of Sizewell C by shifting from the CfD mechanism to the RAB model. EDF has suggested that with a better financing model and no "first-of-a-kind costs", it could "peel away" the strike price by £36/MWh (US$\$_{2012}$56.9/MWh).[903] However, in its planning documents, EDF confirmed construction cost estimates of "circa £20 billion" (US$\$_{2020}$25.6 billion).[904]

In March 2021, EDF's financial report for 2020 said an FID was likely to be made in mid-2022 but used cautious language on the whole about the project, stating "to date, it is not clear whether the group will reach this target."[905] It went on to say:

> EDF's ability to make a[n] FID on Sizewell C and to participate in the financing of this project beyond the development phase could depend on the operational control of the Hinkley Point C project, on the existence of an appropriate regulatory and financing framework, and on the sufficient availability of investors and funders interested in the project. To date, none of these conditions are met.
>
> Failure to obtain the appropriate financing framework and appropriate regulatory approval could lead the Group not to make an investment decision or to make a decision in less than optimal conditions.

In January 2022, the government reiterated its intention to see an FID on "at least one" large-scale nuclear project in the current Parliament—which has not been met. The government has also pledged £100 million (US$\$_{2022}$123.3 million) for EDF to "help bring it [the project] to maturity, attract investors and advance the next phase in negotiations." In return, the government will take rights over the land of Sizewell C and EDF's shares in the project company, "should the project not ultimately be successful."[906]

In June 2022, the U.K. Government announced that it had taken out the £100 million option which would be converted into equity to take a 20 percent share in Sizewell C, should the project reach an FID.[907] However, as noted above, this share of costs in the company that will take the project to FID has no bearing on the stake it takes in the successor company. In July 2022 the U.K. Government announced that Sizewell C had been granted development consent.

Then in November 2022, the U.K. Government made its Investment Decision and confirmed it was investing a further £679 million (US$\$_{2022}$837 million), of which it refused to say how

902 - *NEI Magazine*, "Plans for Sizewell C submitted to UK Planning Inspectorate", *Nuclear Engineering International*, 28 May 2020, see https://www.neimagazine.com/news/newsplans-for-sizewell-c-submitted-to-uk-planning-inspectorate-7943163, accessed 4 July 2024.

903 - Phil Chaffee, "United Kingdom: Industry Pushes for Government Action", *Nuclear Intelligence Weekly*, 6 March 2020.

904 - SZC, "The Sizewell C Project—4.2 Funding Statement", Revision 1.0, EDF Energy and CGN, submitted to Infrastructure Planning Inspectorate, May 2020, see https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010012/EN010012-001678-SZC_Bk4_4.2_Funding_Statement.pdf, accessed 4 July 2024.

905 - EDF, "2020 Annual Results – Appendices", February 2021, see https://www.edf.fr/sites/default/files/contrib/groupe-edf/espaces-dedies/espace-finance-en/financial-information/publications/financial-results/2020-annual-results/pdf/annual-results-2020-appendices-20210304.pdf, accessed 4 July 2024.

906 - BEIS, "Government readies Sizewell C nuclear project for future investment", Press Release, Department for Business, Energy and Industrial Strategy, U.K. Government, 27 January 2022, see https://www.gov.uk/government/news/government-readies-sizewell-c-nuclear-project-for-future-investment, accessed 4 July 2024.

907 - Alex Lawson, "UK buys option to take 20% stake in Sizewell C nuclear power plant", *The Guardian*, 14 June 2022, see https://www.theguardian.com/environment/2022/jun/14/uk-buys-option-to-take-20-stake-in-sizewell-c-nuclear-power-plant, accessed 4 July 2024.

much has been used to buy out CGN, although the press suggested that it was £100 million (US$$_{2022}$123.3 million).[908] The departure of the Chinese investors from the project means that the U.K. Government and EDF will now each take a 50 percent equity stake in the Sizewell C project. The government invested a further £511 million (US$$_{2023}$635 million) announced in the summer of 2023, taking the total, at this stage, to £1.2 billion (US$$_{2023}$1.5 billion).[909]

It is expected that private investment will come into the project, as EDF has stated it intends to take no more than a 19.99 percent stake at FID conditioning its participation on "the ability of EDF not to control the project."[910] At minimum, this will require £12 billion (US$$_{2023}$15 billion) from further investors given the completion cost-estimate of £20 billion (US2_{2020}$25.7 billion).[911] However, it is more likely that a future investment will provide a mixture of equity and debt financing, reducing the initial amount invested. A more prudent investor might assume, given the experience from HPC and current rates of inflation, to double that cost estimate.

Raising investment commitments is likely to be difficult, and two of Britain's most significant pension funds, the B.T. Pension Scheme and NatWest, explicitly ruled out backing the project.[912] Barclays Bank was appointed in May 2022 to advise the government on the investment process. An equity raise was launched in September 2023,[913] with interested investors required to go through a pre-qualification process. Press reports suggest that, as of April 2024, talks are underway with at least six potential investors: Emirates Nuclear Energy Corportation (ENEC), Centrica, pension investor Universities Superannuation Scheme (USS), and fund managers Amber Infrastructure, Equitix, and Schroders Greencoat.[914]

On 15 January 2024, the Sizewell C Development Consent Order was triggered, opening the path for construction start, despite no FID. Later in January, the government made available £1.3 billion (US$1.6 billion)—making a total government investment to date of £2.5 billion (US$3.2 billion)—to enable infrastructure development work, such as roads and railways, to be undertaken prior to any FID.[915] It is important to note that at present the government

908 - EDF, "EDF welcomes the UK government's decision to invest in the development of Sizewell C", Press Release, 29 November 2022, see https://www.edf.fr/sites/groupe/files/epresspack/4235/PR_EDF-welcomes-the-UK-governments-decision-to-invest-in-the-development-of-Sizewell-C.pdf; and BEIS and Great British Nuclear "UK government takes major steps forward to secure Britain's energy independence", Press Release, U.K. Government, 29 November 2022; also Faye Brown, "China bought out of Sizewell C as UK confirms £700m stake in nuclear project", Sky News, 29 November 2022, see https://news.sky.com/story/sizewell-c-nuclear-power-plant-go-ahead-reconfirmed-with-700m-public-investment-shapps-announces-12757786, accessed 14 September 2023.

909 - Department for Energy Security and Net Zero, "Sizewell C starts private investment process", Press Release, U.K. Government, 18 September 2023, see https://www.gov.uk/government/news/sizewell-c-starts-private-investment-process, 16 July 2024.

910 - EDF, "2023 Annual Results", February 2024, see https://www.edf.fr/sites/groupe/files/2024-04/annual-results-edf-2023-presentation-2024-04-02.pdf, accessed 16 July 2024.

911 - Jim Pickard, "UK government to pay Chinese group £100mn to exit Sizewell C", *The Financial Times*, 29 November 2022.

912 - Matt Oliver and Szu Ping Chan, "Pension funds shun Sizewell C in major blow to Britain's nuclear ambitions", *The Telegraph*, 22 April 2023, see https://www.telegraph.co.uk/business/2023/04/22/uk-nuclear-ambitions-pension-funds-shun-sizewell-c/, accessed 23 July 2024.

913 - Department for Energy Security and Net Zero, "Sizewell C starts private investment process", Press Release, 18 September 2023, op. cit.

914 - Tanu Pandey and Stefano Berra, "Six bidders advance in Sizewell C round two", *ION Analytics*, 6 April 2024, see https://ionanalytics.com/insights/infralogic/six-bidders-advance-in-sizewell-c-round-two/, accessed 8 July 2024.

915 - Sizewell C, "Green light for construction phase as Sizewell C triggers Development Consent Order", 15 January 2024, see https://www.sizewellc.com/news-views/green-light-for-construction-phase-as-sizewell-c-triggers-development-consent-order/; and Department for Energy Security and Net Zero, "Further steps to prepare Sizewell C for construction", Press Release, U.K. Government, 22 January 2024, see https://www.gov.uk/government/news/further-steps-to-prepare-sizewell-c-for-construction; both accessed 16 July 2024; also Rachel Morison, "UK Puts Up an Extra £1.3 Billion to Build Sizewell C Reactor", *Bloomberg*, as published by *Yahoo Finance*.

has committed to put in £2.5 billion and EDF appears to have invested £1.3 billion (that is its contractual obligation met), so if no more money is put in, that would leave the government at about 66 percent ownership of the investment vehicle established to take Sizewell C to the FID.

Then in March 2024, a government standalone company, Sizewell C Ltd, signed a deal with EDF to purchase the freehold of the land for the new power plant, followed in April 2024 by Framatome signing contracts "worth multi-billion euros" with Sizewell C Ltd for the delivery of the nuclear steam supply systems, the safety instrumentation and control systems, long-term supply of nuclear fuel, and maintenance services.[916] The land ownership question was one of the unresolved issues that had held up ONR's issuing of a site license, which was finally granted in May 2024.[917]

The development of Sizewell C, under various Conservative administrations, with ongoing and continually increasing government financial support is a far cry from their pledge of no subsidies for nuclear power. It also highlights the challenge for governments of supporting nuclear power, whose development and construction costs continue to rise, and all too often require more and more handouts to avoid the collapse of the projects.

The deadline of a FID in the previous Parliament, has come and gone. While there is no indication that the new administration will change track on Sizewell, investment on this scale from a third party will undoubtedly seek assurances from the new government before proceeding. Therefore, with so many other stated energy developments to support, such as the rapid increase in renewable deployment, the establishment of a state-owned energy company, and the acceleration of household energy efficiency, it is far from clear how much additional state funding there will be for Sizewell.

Bradwell

EDF was allowing CGN to use the Bradwell site it initially bought as a backup if either the Hinkley Point or Sizewell projects proved unsuccessful and took a 33.5 percent stake in the company set up to take the project to FID. However, as has been documented in previous editions of the WNISR, the project was blocked, initially largely at the request of the U.S. Government, for security reasons. However, the Parliament's Intelligence and Security Committee has also highlighted the misguided nature of the arrangement when it concluded in July 2023 that:

> It is astonishing that the investment security process for Hinkley Point C did not therefore take Bradwell B into account. It is unacceptable for the Government still to be considering Chinese involvement in the UK's Critical National Infrastructure (CNI) at a granular level, taking each case individually and without regard for the wider security risk. (...) Effective Ministerial oversight in this area is still lacking, more than eight years on from the

916 - Framatome, "Framatome has signed contracts worth multi-billion euros for Sizewell C in the UK", Press Release, 15 April 2024, see https://www.framatome.com/medias/framatome-has-signed-contracts-worth-multi-billion-euros-for-sizewell-c-in-the-uk/, accessed 16 April 2024.

917 - ONR, "Progress update: Sizewell C site licence", Press Release, Office for Nuclear Regulation, 11 July 2024, see https://www.onr.org.uk/news/all-news/2022/07/progress-update-sizewell-c-site-licence/; and ONR, "ONR grants nuclear site licence for Sizewell C", Press Release, 7 May 2024, see https://www.onr.org.uk/news/all-news/2024/05/onr-grants-nuclear-site-licence-for-sizewell-c/; both accessed 16 July 2024.

Committee's Report on the national security implications of foreign involvement in the UK's CNI.[918]

There is currently no likelihood of construction by Chinese companies of any nuclear reactors in the U.K.

Other Sites

Other sites have been proposed and developed to various degrees over the years. This includes Moorside in Cumbria being developed at some point by Toshiba-Westinghouse as well as Hitachi-GE owned Wylfa Newydd on Anglesey and Oldbury on Severn in South Gloucestershire.

In March 2024 the government announced that it had, through Great British Nuclear, purchased the nuclear sites in Wylfa and Oldbury and that the Wylfa site was the preferred option for a third large-scale nuclear project after Hinkley and Sizewell.[919]

Sort of Small Modular Reactors (SMRs)

The government has continued to promote SMRs as a means of meeting future energy security and decarbonization objectives. This has gone further than just talk, and the government has made not insignificant funding available to develop the sector, but not enough to assist deployment on any scale.

In November 2020, to support the development of a potential next generation of reactors, the government proposed to provide up to £385 million (~US$500 million) in an Advanced Nuclear Fund, with up to £215 million (US$$_{2020}$276 million) going to Rolls-Royce's SMR program.[920] This, in November 2023, led to Rolls-Royce announcing that it had received £210 million (US$$_{2021}$289 million) in government funding and £195 million (US$$_{2021}$268 million) in private funds[921] and the following month an additional £85 million (US$$_{2021}$117 million) from the Qatar Investment Authority.[922]

Rolls-Royce is developing a 470-MW reactor—thus technically it does not fall under the SMR definition with nominal capacities between 30 MW and 300 MW. In 2021, Rolls-Royce hoped its technology would complete the Generic Design Assessment (GDA) process with U.K. regulators around September 2024 to deliver the first power in the early 2030s,[923]

918 - Intelligence and Security Committee of Parliament, "China", HC 1605, U.K. Parliament, July 2023, see https://isc.independent.gov.uk/wp-content/uploads/2023/07/ISC-China.pdf, accessed 4 July 2024.

919 - Department for Energy Security and Net Zero and Office of the Secreatry of State for Wales, "New nuclear power plant earmarked for North Wales", Press Release, U.K. Government, 22 May 2024, see https://www.gov.uk/government/news/new-nuclear-power-plant-earmarked-for-north-wales, accessed 23 May 2024.

920 - U.K. Government, "The Ten Point Plan for a Green Industrial Revolution", November 2020, see https://assets.publishing.service.gov.uk/media/5fb5513de90e0720978b1a6f/10_POINT_PLAN_BOOKLET.pdf; and BEIS, "Advanced Nuclear Technologies", Policy Paper, Department for Business, Energy and Industrial Strategy, U.K. Government, Updated 15 August 2023, see https://www.gov.uk/government/publications/advanced-nuclear-technologies/advanced-nuclear-technologies; both accessed July 2024.

921 - Rolls-Royce SMR, "Funding secured to enable smr delivery to meet net zero", Press Release, 8 November 2023, see https://www.rolls-royce-smr.com/press/funding-secured-to-enable-small-modular-reactor-delivery-to-meet-net-zero, accessed 5 July 2024.

922 - Rolls-Royce SMR, "Rolls-Royce and QIA announce nuclear investment", Press Release, 20 December 2021, see https://www.rolls-royce-smr.com/press/rolls-royce-and-qia-announce-nuclear-investment, accessed 5 July 2024.

923 - *WNN*, "Rolls-Royce on track for 2030 delivery of UK SMR", 11 February 2021, see https://world-nuclear-news.org/Articles/Rolls-Royce-on-track-for-2030-delivery-of-UK-SMR, accessed 5 July 2024.

but as of 2023, the company aimed to conclude Step 2 in July 2024, and the final phase in August 2026.[924] In December 2023, the ONR began its GDA for a different reactor design, from Holtec International,[925] and then in January 2024 for GE's BWRX-300 design.[926]

Rolls-Royce is rather confident about the cost of the units and suggests that the nth-of-a-kind reactor (after ten have been built) will be in the order of £1.8 billion (US$2.3 billion) (Capex) for 440-MW units and at a cost of £$_{2019}$40–75/MWh (US$$_{2019}$51–96/MWh) over 60 years.[927] In evidence submitted in 2017, Rolls-Royce told the House of Lords, that 7 GW—equivalent to 15 Rolls-Royce SMRs—would "be of sufficient scale to provide a commercial return on investment from a U.K.-developed SMR, but it would not be sufficient to create a long-term, sustainable business for U.K. plc." The House of Lords concluded: "Therefore, any SMR manufacturer would have to look to export markets to make a return on their investment."[928] In May 2024, the Polish Government announced that it had taken a decision in principle on ordering the Rolls-Royce SMRs, although no timetable was made clear at this time.[929] Then, in June, Vattenfall announced that it was on a shortlist of two for an SMR order in Sweden.[930]

Firming up orders domestically or internationally in the short term will be crucial, as it is reported that Rolls-Royce's SMR program will run out of funds towards the end of the year without a further cash injection.[931]

The capital cost estimate is a heroic assumption equating to £4,000/kW (US$5,083/kW) compared to what EDF estimates for the cost of Sizewell C of £5,600/kW (US$7,116/kW) and the current cost estimate for HPC of £8,100/kW (US$10,293/kW). It is fair to say that if there were any confidence that the SMRs would be delivered at the quoted cost within a foreseeable timeframe, construction projects of Sizewell C and any similar-sized reactors would be abandoned.

924 - Environment Agency and Natural Resources Wales, "GDA Step 1 statement: summary on the Rolls-Royce SMR", U.K. Government, 3 April 2023, see https://www.gov.uk/government/publications/gda-step-1-of-the-rolls-royce-smr-statement-of-findings/gda-step-1-statement-summary-on-the-rolls-royce-smr, accessed 5 July 2024. https://committees.parliament.uk/publications/41092/documents/200324/default/

925 - ONR, "ONR begins new SMR reactor assessment", Office for Nuclear Regulation, 7 December 2023, see https://news.onr.org.uk/2023/12/onr-begins-new-smr-reactor-assessment/, accessed 13 January 2024.

926 - ONR, "Generic Design Assessment (GDA) of new nuclear power stations", Office for Nuclear Regulation, 21 June 2024, see https://www.onr.org.uk/news/all-news/2024/01/onr-begins-new-small-modular-reactor-assessment/, accessed 16 July 2024.

927 - *WNN*, "Rolls-Royce on track for 2030 delivery of UK SMR", 11 February 2021, see https://world-nuclear-news.org/Articles/Rolls-Royce-on-track-for-2030-delivery-of-UK-SMR, accessed 5 July 2024.

928 - Science and Technology Committee, "Nuclear research and technology: Breaking the cycle of indecision", House of Lords, May 2017, see https://publications.parliament.uk/pa/ld201617/ldselect/ldsctech/160/160.pdf, accessed 5 July 2024.

929 - Rolls Royce, "Polish Government issues decision in principle on Rolls-Royce SMRs", Press Release, 14 May 2024, see https://www.rolls-royce-smr.com/press/polish-government-issues-decision-in-principle-on-rolls-royce-smrs, accessed 27 July 2024.

930 - Rolls Royce SMR, "Rolls-Royce SMR successful in Swedish nuclear selection process", Press Release, 12 June 2024, see https://www.rolls-royce-smr.com/press/rolls-royce-smr-successful-in-swedish-nuclear-selection-process, accessed 27 July 2024.

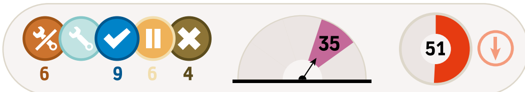
931 - Susanna Twidale, "Exclusive-UK's Rolls-Royce small nuclear program to run out of cash by end-2024", *Reuters*, 28 February 2023, section Energy, see https://www.reuters.com/article/business/energy/exclusive-uks-rolls-royce-small-nuclear-program-to-run-out-of-cash-by-end-2024-idUSKBN2V216U/, accessed 27 July 2024.

Conclusion

On the surface, the change in government will not significantly change the U.K.'s nuclear power policy, with outgoing and incoming administrations said to be committing to the completion of Hinkley and Sizewell C and interested in SMRs. However, there are significant differences in the support for renewables, energy efficiency—particularly on the household level—and for planning and market reform. If the proposed wider energy sector targets and policy objectives are met, demand for nuclear produced electricity would significantly reduce, and without load-following from any future nuclear power plant, grid congestion and the need for storage would increase.

However, there remains a huge gulf between election pledges and implementation of projects and policies, and the new Labour administration will have a tough time in meeting its highly ambitious targets.

UKRAINE FOCUS



The war in Ukraine, following Russia's aggression and full-scale invasion in February 2022, continues to cause destruction and death on a level not seen in continental Europe for close to 80 years.

Ukraine has 15 operating or operable reactors, two of which are VVER-440 designs, and the rest are VVER-1000s. These include six units at Zaporizhzhia that have been closed for nearly two years and enter the LTO category as of end-2022.[932]

Nuclear power provided 49.8 TWh or about 51 percent of power generation in the country in 2023, according to the Statistical Review of World Energy[933]; this is a fall from over 80 TWh before the war partly because the control of the Zaporizhzhia power plant in the East, which houses six VVER-1000 reactors, has been under the control of the Russian military.

The country has four closed reactors at the Chornobyl nuclear power plant, including Unit 4, which underwent a disastrous accident in 1986. Three nuclear reactors (two VVER-440s and one VVER-1000) at Rivne have been granted lifetime extensions of 20 years,[934] and three units at South Ukraine, one at Khmelnytskyi and five units at Zaporizhzhia for ten years respectively. Following its 10-year extension, the license of Unit 1 at the South Ukraine plant was set to expire in December 2023, but it was extended in November of that year for another ten years.[935]

932 - SNRIU, "Report on the State of Nuclear and Radiation Safety in Ukraine in 2023", State Nuclear Regulatory Inspectorate of Ukraine, June 2024, see https://snriu.gov.ua/storage/app/sites/1/uploaded-files/annual%20report%202023.pdf, accessed 24 July 2024.

933 - Energy Institute, "Statistical Review of World Energy 2024 - Consolidated Dataset", 2024, see https://www.energyinst.org/__data/assets/excel_doc/0004/1540552/merged_narrow.xlsx, accessed 24 June 2024.

934 - WNA, "Nuclear Power in Ukraine", World Nuclear Association, 25 March 2024, see https://world-nuclear.org/information-library/country-profiles/countries-t-z/ukraine, accessed 1 July 2024.

935 - SNRIU, "The Board of the State Nuclear Regulatory Inspectorate of Ukraine considers it possible to further safe operation of reactor unit N° 1 of the South Ukrainian NPP", State Nuclear Regulatory Inspectorate of Ukraine, 3 November 2023, see https://snriu.gov.ua/en/news/the-board-of-the-state-nuclear-regulatory-inspectorate-of-ukraine-considers-it-possible-to-further-safe-operation-of-reactor-unit-1-of-the-south-ukrainian-npp, accessed 26 July 2024.

Licenses of even more units will expire before 2030, and all others will expire before 2040.[936] Ukraine has carried out a safety upgrade program for all its reactors at an estimated cost of €1.45 billion (US$$_{2013}$1.9 billion) in total, of which the European Bank for Reconstruction and Development (EBRD) and Euratom contributed €600 million (US$$_{2013}$797 million) in loans between them.[937]

Newbuild Projects

Two reactors, Khmelnytskyi-3 and -4 (IAEA spelling, also spelled Khmelnytskyi) have been officially under construction since 1986 and 1987 respectively, but WNISR removed them from the construction list as no active work has been reported in over three decades, despite several attempts to revive the project. While preparatory work seems underway, according to a knowledgeable Ukrainian source, no actual construction activity is being carried out. The Ukrainian Government appears however determined to have the units finished as they believe this is a way to address the current energy crisis, but it seems to some experts as misguided.[938]

In 2018, the government approved a feasibility study announcing an 84-month construction schedule, allowing for commissioning the first unit in 2025.[939] Reportedly, preparatory works resumed in August 2020.[940] In September 2020, a Presidential decree instructed the Cabinet to submit a series of legislative bills for Ukraine's power sector, including a long-term program for developing nuclear energy to 2035 and addressing the two units' "location, design, and construction".[941] At the time, suggestions were that the total cost of completing Khmelnytskyi-3 and -4 was estimated at UAH76.8 billion (US$$_{2020}$2.8 billion).[942] There has been no independent evaluation of the cost estimate, that some Ukrainian experts—who do not wish to be named—say could be "much higher".

In January 2023, the Cabinet of Ministers approved a feasibility study for constructing two Westinghouse AP-1000 reactors, Khmelnytskyi-5 and Khmelnytskyi-6, with preparatory work to continue until 2025 when construction officially begins and to have them operational in 2032, with an expectation that they would cost around US$5 billion each. Reportedly, Ukraine's

936 - IAEA, "Country Nuclear Power Profile—Ukraine—Nuclear Power Situation", 2020, see https://cnpp.iaea.org/public/countries/UA/profile/preview; and SNRIU, " Report on Nuclear and Radiation Safety in Ukraine for 2021", State Nuclear Regulatory Inspectorate of Ukraine, see https://snriu.gov.ua/storage/app/sites/1/uploaded-files/Annual%20NRS%20Report%202021_EN_compressed.pdf, accessed 26 July 2024.

937 - EBRD, "Ukraine Nuclear Safety Upgrade—About the Ukraine Nuclear Safety Upgrade", European Bank for Reconstruction and Development, 2013, see https://www.ebrd.com/what-we-do/sectors/ukraine-nuclear-safety-upgrade.html, accessed 1 July 2024; and EBRD, "Nuclear Power Plant Safety Upgrade Program", approved 12 March 2013, see https://www.ebrd.com/work-with-us/projects/psd/nuclear-power-plant-safety-upgrade-program.html, accessed 26 July 2024.

938 - Sergiy Makogon and Daniel D. Stein, "Ukraine's Nuclear Folly", Center for European Policy Analysis, 17 June 2024, see https://cepa.org/article/ukraines-nuclear-folly/, accessed 1 July 2024.

939 - *NEI Magazine*, "Ukraine approves a feasibility study for Khmelnitsky 3&4", *Nuclear Engineering International*, 31 July 2018, see https://www.neimagazine.com/news/newsukraine-approves-a-feasibility-study-for-khmelnitsky-34-6271521, accessed 1 July 2024.

940 - *NEI Magazine*, "Ukraine's president orders draft bill on development of nuclear energy", *Nuclear Engineering International*, 24 September 2020, see https://www.neimagazine.com/news/ukraines-president-orders-draft-bill-on-development-of-nuclear-energy-8148257/, accessed 1 July 2024.

941 - Presidential Office of Ukraine, "УКАЗ ПРЕЗИДЕНТА УКРАЇНИ №406/2020 ["Presidential Decree No 406/2020"], 22 September 2020, see https://www.president.gov.ua/documents/4062020-35109, accessed 26 July 2024.

942 - *NEI Magazine*, "Working group reports on situation at Ukraine's Khmelnitsky nuclear plant", *Nuclear Engineering International*, 6 October 2020, see https://www.neimagazine.com/news/working-group-reports-on-situation-at-ukraines-khmelnitsky-nuclear-plant-8166180/, accessed 1 July 2024.

Energy Minister stated on that occasion, "We hereby finally renounce Russian nuclear technologies in our nuclear power industry."[943] The timeline and cost do not appear realistic if compared with historic experiences, e.g. the U.S. Vogtle plant that took more than 10 years to complete at a cost over three times the amount announced for Ukraine.

In January 2024, Energy Minister German Galushchenko announced that Ukraine intended to build four plants at Khmelnytskyi, with construction to start in 2024. This would include completing two Russian designed VVERs with equipment from Bulgaria, cannibalizing the part-build Belene power plant, as well as the two Westinghouse AP-1000s.[944] In February 2024, Energoatom stated they had almost wholly restored Unit 3, and the onsite equipment was ready to be installed.[945] Ukrainian experts questioned by WNISR claim that the equipment is "not complete" and that there would be, so far, "no agreements to manufacture the missing equipment". The same experts state that as of mid-2024, "there is no law authorizing the construction of Units 3 and 4, no design, no safety report, no construction license".

In April 2024, it was announced that a "symbolic cubic meter" of concrete was poured in front of U.S. and Ukrainian officials. The CEO of Westinghouse, the French elite engineer Patrick Fragman, was reported by Energoatom as saying that "The two twin units that were recently commissioned in Georgia, the US state, [Vogtle-3 and -4] are identical to the power units that will be built here, at the Khmelnytsky NPP."[946] According to the same Ukrainian sources previously quoted, the current situation is similar to that of Units 3 and 4, that is a lacking feasibility study, no safety report, no construction license.

In April 2023, the Cabinet of Ministers approved a new Energy Strategy for Ukraine until 2050.[947] In an attempt to increase energy security and meet climate commitments by phasing out the use of fossil fuels, it targets nuclear power providing at least 50 percent of power and renewables providing 27 percent of final energy by 2030.[948]

Ukraine has deployed efforts to move away from dependency on Russia for its nuclear fuel, with Westinghouse providing fuel for some VVER 1000 reactors since 2005. (See also Russia

943 - *Ukrainian Energy*, "The government makes a decision to build two AP1000 power units at Khmelnytskyi NPP", 20 January 2023, see https://ua-energy.org/en/posts/20-01-2023-fcb4edf0-01a2-4c5a-8c1a-6b66691d742f, accessed 1 July 2024.

944 - *NEI Magazine*, "Ukraine plans four new units for Khmelnitsky NPP", *Nuclear Engineering International*, 31 January 2024, see https://www.neimagazine.com/news/ukraine-plans-four-new-units-for-khmelnitsky-npp-11477072/, accessed 2 July 2024; and Ministry of Energy, "After the construction of new units, Khmelnytsky NPP will become the most efficient in Europe, says German Galushchenko", Government of Ukraine, 29 January 2024, see https://www.kmu.gov.ua/en/news/pislia-budivnytstva-novykh-blokiv-khmelnytska-aes-stane-naipotuzhnishoiu-v-ievropi-herman-halushchenko, accessed 26 July 2024.

945 - Energoatom, "The activities on preparation for the further construction of power unit 3 is almost completed at the Khmelnytsky NPP", 16 February 2024, see https://energoatom.com.ua/en/post/1525, accessed 26 February 2024.

946 - *NEI Magazine*, "Ukraine begins construction of new units at Khmelnitsky NPP", *Nuclear Engineering International*, 17 April 2024, see https://www.neimagazine.com/news/ukraine-begins-construction-of-new-units-at-khmelnitsky-npp-11690350/, accessed 17 April 2024; and Energoatom, "At the Khmelnytsky NPP, a project on the construction of Units 5 and 6 using the American Westinghouse technology started", 15 April 2024, see https://energoatom.com.ua/en/post/1713, accessed 26 July 2024.

947 - Cabinet of Ministers of Ukraine, "Розпорядження від 21 квітня 2023 р. № 373-р—Про схвалення Енергетичної стратегії України на період до 2050 року" ["Order No. 373 dated April 21, 2023 On approval of the Energy Strategy of Ukraine for the period up to 2050"], Government of Ukraine, 21 April 2023 (in Ukrainian), see https://www.kmu.gov.ua/npas/pro-skhvalennia-enerhetychnoi-stratehii-ukrainy-na-period-do-2050-roku-373r-210423, accessed 26 April 2024.

948 - Ministry of Economy of Ukraine, "Ukraine has presented the report on the decarbonization of the energy sector by 2050 and the preliminary version of the National Energy and Climate Plan at the UN Framework Convention on Climate Change COP 28", Government of Ukraine, 22 December 2023, see https://me.gov.ua/News/Detail?lang=en-GB&id=479ea0f7-64b7-4f15-be37-537009be900d&title=UkraineHasPresentedTheReportOnTheDecarbonizationOfTheEnergySectorBy2050-AndThePreliminaryVersionOfTheNationalEnergyAndClimatePlanAtTheUnFrameworkConventionOnClimateChangeCop28, accessed 27 July 2024.

Nuclear Dependencies). In June 2022, Energoatom and Westinghouse signed a contract covering the fuel supply for all 15 Ukrainian reactors and any future AP-1000 units.[949] In September 2023, the first VVER 440 fuel assemblies delivered by Westinghouse were loaded at the Rivne plant,[950] and in March 2024, VVER 1000 fuel assemblies were delivered to the Khmelnytskyi facility.[951]

In September 2023, Energoatom and Westinghouse signed an MoU on the development and deployment of an AP300, an SMR. The MoU established a joint working group to develop licensing, contracting, and local supply chains. Westinghouse is hoping that certification could take place by 2027 and construction start in 2030.[952]

Power Sector in War Conditions

From the outset of the full-scale invasion of Ukraine by Russia, starting in February 2022, energy infrastructure has been targeted and seriously damaged. The consequences of the war on the energy sector were further impacted by two factors, firstly that Russia (26 percent) and Belarus (22 percent) supplied nearly half majority of Ukraine's imported energy, and secondly that the now-occupied regions in the East of Ukraine host the country's largest nuclear power station, at Zaporizhzhia, as well as 30 percent of Ukraine's solar capacities and 90 percent of its wind power capacities.[953]

In the first few months of 2024, Russia increased the intensity of its attacks on Ukraine's infrastructure, particularly energy, resulting in the damage or destruction of up to 90 percent of fossil fuel and 60 percent of hydropower plants.[954] Other figures suggest that 35 GW out of a total capacity of 55 GW of generating capacity in the power sector is inoperable.[955] This has resulted in the introduction of power rationing, even as this was written in the summer of 2024, raising serious concerns over the up-and-coming winter and the consequences for the population and economy.[956]

949 - Westinghouse, "Energoatom and Westinghouse Reaffirm Clean Energy Partnership, Announce Expanded Cooperation on Westinghouse-supplied VVER Fuel and AP1000® Plants to be Built in Ukraine", Press Release, Westinghouse Electric, 3 June 2024, see https://info.westinghousenuclear.com/news/energoatom-and-westinghouse-reaffirm-clean-energy-partnership, accessed 1 July 2024.

950 - Westinghouse, "Westinghouse Delivers First VVER-440 Fuel Assemblies to Energoatom", Press Release, 12 September 2023, see https://info.westinghousenuclear.com/news/westinghouse-delivers-first-vver-440-fuel-assemblies-to-energoatom, accessed 17 November 2023.

951 - *NEI Magazine*, "First batch of Westinghouse fuel arrives at Ukraine's Khmelnitsky NPP", *Nuclear Engineering International*, 21 March 2024, see https://www.neimagazine.com/news/first-westinghouse-fuel-arrives-at-ukraines-khmelnitsky-npp-11621031/, accessed 2 July 2024.

952 - Westinghouse, "Westinghouse and Ukraine's Energoatom Pursuing Deployment of AP300TM Small Modular Reactor to Meet Climate, Energy Security Goals", Press Release, 12 September 2023, see https://info.westinghousenuclear.com/news/westinghouse-and-ukraines-energoatom-pursuing-deployment-of-ap300-small-modular-reactor-to-meet-climate-energy-security-goals, accessed 5 August 2024.

953 - Andrian Prokip, "The State of Ukraine's Energy Sector after Ten Years of War", Wilson Center, 8 February 2024, see https://www.wilsoncenter.org/blog-post/state-ukraines-energy-sector-after-ten-years-war, accessed 1 July 2024.

954 - Sergiy Makogon and Daniel D. Stein, "Ukraine's Nuclear Folly", Center for European Policy Analysis, 17 June 2024, op. cit.

955 - *BNE Intellinews*, "Ukraine looks to Europe to increase power imports this winter", 11 June 2024, see https://www.intellinews.com/ukraine-looks-to-europe-to-increase-power-imports-this-winter-329268/, accessed 1 July 2024.

956 - Kateryna Chursina and Olesia Safronova, "Ukraine Faces More Electricity Rationing After Russian Strikes", *Bloomberg.com*, 4 June 2024, see https://www.bloomberg.com/news/articles/2024-06-04/ukraine-faces-more-electricity-rationing-after-russian-strikes, accessed 1 July 2024.

The international community has recognized the seriousness of the situation, and the G7 and Energy Coordination Group, at the "Ukraine Recovery Conference" in June 2024, vowed to "commit to continue to support Ukraine with significant emergency assistance to help repair and stabilize the energy grid and restore power generation, first and foremost in preparation for the next winter," and further noted that the G7 and partners had made available US$3 billion for the Ukrainian energy sector. The statement further said that they "collectively reaffirm our unwavering commitment to supporting Ukraine's goal of rebuilding its energy system to be secure, sustainable, more decentralised and smarter, fit for a Net Zero future and integrated with the European market."[957]

There is increased focus on rebuilding Ukraine's power sector with a more decentralized renewable energy approach to meet decarbonization targets but also to add security, as Germany's Minister for Economic Affairs and Climate Action, Robert Habeck, reportedly explained at the Ukraine Recovery Conference, "renewable energies also have a safety aspect. One nuclear power plant is an easy target, 10,000 solar panels are more difficult to shoot."[958]

Before the Russian invasion, proposals were developed to introduce a direct power line from Khmelnytskyi-2 to the European market. The Ukraine-E.U. Energy Bridge project, with an estimated cost of €243.5 million (US$$_{2019}$273 million), was to be carried out in the form of a public-private partnership between the Ukrainian state and an investor consortium consisting of Westinghouse Electric Sweden, Luxembourg-based Polish Polenergia International, and U.K.-based EDF Trading.[959] However, on 24 February 2022, Ukraine decoupled its grid from Russia and operated in isolation until 16 March 2022, when it became synchronized to the E.U.'s grid.[960]

While initially connections to the West enabled some electricity exports from Ukraine to raise revenues, they are now used to import. Recently, Ukrainian authorities called for an increase in capacity from 1.7 GW in June 2024 to 2.3 GW before the winter 2024–25, which would also require strengthening of the grid and export links from Romania and Hungary.[961]

957 - G7+ Energy Coordination Group and Government of Ukraine, "Statement from the G7+ Energy Coordination Group and the Government of Ukraine at the Ukraine Recovery Conference 2024 in Berlin", Press Release, as published by the European Union External Action Service, 12 June 2024, see https://www.eeas.europa.eu/eeas/statement-g7-energy-coordination-group-and-government-ukraine-ukraine-recovery-conference-2024_en, accessed 1 July 2024.

958 - Nathan Canas, "Industry and government leaders eye renewables as basis for Ukrainian reconstruction", *Euractiv*, 13 June 2024, see https://www.euractiv.com/section/energy/news/industry-and-government-leaders-eye-renewables-as-basis-for-ukrainian-reconstruction/, accessed 1 July 2024.

959 - Ukraine Energy, "Winner of 'Ukraine-EU Energy Bridge' project is determined", 15 August 2019, see https://ua-energy.org/en/posts/15-08-2019-2370f1a2-3ba4-439b-b2d0-b8b382d349ab, accessed 1 July 2024.

960 - Anna Blaustein, "How Ukraine Unplugged from Russia and Joined Europe's Power Grid with Unprecedented Speed", *Scientific American, 23 March 2022, see* https://www.scientificamerican.com/article/how-ukraine-unplugged-from-russia-and-joined-europes-power-grid-with-unprecedented-speed/, accessed 1 July 2024; and ENTSO-E, "Continental Europe successful synchronisation with Ukraine and Moldova power systems", Press Release, European Network of Transmission System Operators for Electricity, 16 March 2022, see https://www.entsoe.eu/news/2022/03/16/continental-europe-successful-synchronisation-with-ukraine-and-moldova-power-systems/, accessed 27 July 2024.

961 - *BNE Intellinews*, "Ukraine looks to Europe to increase power imports this winter", 11 June 2024, see https://www.intellinews.com/ukraine-looks-to-europe-to-increase-power-imports-this-winter-329268/, accessed 1 July 2024.

In June 2022, Ukraine was granted candidate status to the E.U., and its first intergovernmental conference was held in June 2024.[962] The Accession process will require considerable changes to Ukraine's energy sector, including issues around energy market reform, energy efficiency, and the deployment of renewable energy. Ukraine will need to implement an ambitious national energy and climate plan in line with the 2030 Energy Community energy and climate targets. Some requirements concern directly the nuclear power sector, e.g. turning Energoatom into a joint stock company of the public sector and appointing an independent supervisory board, which is in the direction of the E.U.'s framework on nuclear safety. However, as the European Commission noted, "Gaps exist in the field of radiation protection of personnel, the population and the environment and on radioactive waste and spent fuel management."[963]

Russian Attacks on Nuclear Facilities

Russia invaded Ukraine from several directions: from the North via Belarus, from the South through Crimea and from the East through Donetsk and Luhansk. Russian forces (accompanied from day one by Rosatom staff) immediately sought to take control of nuclear facilities, first the Chornobyl facility in the North on 24 February 2022, but troops were withdrawn on 31 March as Ukrainian troops were approaching. Then, the unprecedented attack on an operating civil nuclear power plant at Zaporizhzhia (ZNPP), Europe's largest by installed capacity, took place on 4 March 2022, followed by a military takeover of the facility. The same month, attempts of a military takeover of the South Ukraine nuclear power plant were thwarted by Ukrainian Forces.[964]

In September 2022, President Putin formally declared that the regions of Luhansk, Donetsk, Kherson and Zaporizhzhia were part of Russia and then in October 2022, in violation of international law, Vladimir Putin signed a decree that transferred ZNPP to Russian jurisdiction managed by Rosenergoatom, a Rosatom subsidiary. Rosenergoatom established a "Russian Federal State Unitary Enterprise ZNPP" to operate the plant.[965] The IAEA has acknowledged that they have no authority to enforce any of the resolutions that have been passed by the United Nations organization calling on Russia to withdraw from the power plant.[966]

962 - European Council, "European Council conclusions on Ukraine, the membership applications of Ukraine, the Republic of Moldova and Georgia, Western Balkans and external relations, 23 June 2022", Press Release, Council of the European Union, 23 June 2022, see https://www.consilium.europa.eu/en/press/press-releases/2022/06/23/european-council-conclusions-on-ukraine-the-membership-applications-of-ukraine-the-republic-of-moldova-and-georgia-western-balkans-and-external-relations-23-june-2022/; and European Council, "EU opens accession negotiations with Ukraine", Press Release, 25 June 2024, see https://www.consilium.europa.eu/en/press/press-releases/2024/06/25/eu-opens-accession-negotiations-with-ukraine/; both accessed 27 July 2024.

963 - Directorate-General for Neighbourhood and Enlargement Negotiations, "Ukraine Report 2023", European Commission, 8 November 2023, see https://neighbourhood-enlargement.ec.europa.eu/ukraine-report-2023_en, accessed 1 July 2024.

964 - Esme Stallard and Victoria Gill, "Nuclear plant: How close was nuclear plant attack to catastrophe?", *BBC News*, 4 March 2022, see https://www.bbc.com/news/world-60609633, accessed 21 July 2024; and IAEA, "Nuclear Safety, Security and Safeguards in Ukraine—February 2022–February 2023", International Atomic Energy Agency, 23 February 2023, see https://www.iaea.org/sites/default/files/documents/nuclear-safety-security-and-safeguards-in-ukraine-feb-2023.pdf, accessed 27 July 2024.

965 - *The Kyiv Independent*, "Putin signs a decree to formalize Russia's illegal seizure of Zaporizhzhia Nuclear Power Plant", 5 October 2022, see https://kyivindependent.com/putin-signs-a-decree-to-formalize-russias-illegal-seizure-of-zaporizhzhia-nuclear-power-plant/, accessed 2 July 2024; and Kateryna Tyshchenko, "Russia to create new "enterprise" at the occupied ZNPP", *Ukrainska Pravda*, 8 October 2022, see https://www.pravda.com.ua/eng/news/2022/10/8/7370938/, accessed 27 July 2024.

966 - Ukrinform, "IAEA has no powers to force Russia to leave ZNPP - Grossi", 20 June 2024, see https://www.ukrinform.net/rubric-economy/3876778-iaea-has-no-powers-to-force-russia-to-leave-znpp-grossi.html, accessed 20 June 2024.

In June 2023, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) issued an order for all six reactors of the ZNPP to be put into cold shutdown.[967] However, Russia decided to keep one unit in hot shutdown (generating steam but no power), which serves "various nuclear safety purposes including the processing of radioactive waste collected in storage tanks," according to the IAEA.[968] The situation changed in April 2024 at the end of the winter heating season, as the remaining unit was used to heat the nearby city of Enerhodar (home to power plant staff), and as of mid-2024 it was in cold shutdown.[969]

The concerns over the safety and security of ZNPP are related to the ongoing operation/management of the facility, the use of the facility as a launchpad for military operations and the threats of deliberate or accidental attacks on the facility.

The war is affecting the ability of the plant management to undertake the necessary maintenance of the plants due to the lack of permanent staff—the IAEA noted that in May 2024, the plant employed 5,000 people, with a further 800 positions remaining unfilled[970]—absence of external contractors, and lack of spare parts, including critical components. The IAEA stated that in April 2023, at the Zaporizhzhia plant, there was only about one-quarter of its regular maintenance staff, which affected safety and security.[971] The IAEA reported also that supply chain logistics remain fragile.[972] IAEA Director General Grossi stated in May 2024:

> The world's attention is rightly focused on the continued danger of Europe's largest nuclear power plant being hit or losing its off-site power. But there are several other challenging areas that we must continue to monitor closely to help prevent the risk of a nuclear accident, including maintenance, as well as staffing and the availability of spare parts. They all form part of our deep concern regarding nuclear safety and security at the plant.[973]

Research undertaken by the Ukrainian NGO Truth Hounds documents cases of systematic detention, mistreatment, and torture of citizens associated with the ZNPP.[974]

In its February 2023-report, the IAEA documents 13 occasions in the first year of the conflict in which the power station was either shelled or mined and 16 occasions where it was fully

967 - SNRIU, "SNRIU Order restricts operation of ZNPP Unit 5 to cold shutdown condition", State Nuclear Regulatory Inspectorate of Ukraine, 9 June 2023, see https://snriu.gov.ua/en/news/snriu-order-restricts-operation-of-znpp-unit-5-to-cold-shutdown-condition, accessed 27 July 2024.

968 - *WNN*, "Zaporizhzhia: Unit 4 in hot shutdown, IAEA reports mines", 25 July 2023, see https://world-nuclear-news.org/Articles/Zaporizhzhia-Unit-4-in%C2%A0hot-shutdown,%C2%A0IAEA-reports, accessed 2 July 2024.

969 - IAEA, "Update 223 – IAEA Director General Statement on Situation in Ukraine", Press Release 36/2024, 13 April 2024, see https://www.iaea.org/newscenter/pressreleases/update-223-iaea-director-general-statement-on-situation-in-ukraine; and IAEA, "Nuclear Safety, Security and Safeguards in Ukraine—Report by the Director General", GOV/2024/30, 27 May 2024, see https://www.iaea.org/sites/default/files/documents/gov2024-30.pdf; also IAEA, "Update 238-IAEA Director General Statement on Situation in Ukraine", Press Release 64/2024, see https://www.iaea.org/newscenter/pressreleases/update-238-iaea-director-general-statement-on-situation-in-ukraine; all accessed 27 July 2024.

970 - IAEA, "Update 227 – IAEA Director General Statement on Situation in Ukraine", Press Release 45/2024, 9 May 2024, see https://www.iaea.org/newscenter/pressreleases/update-227-iaea-director-general-statement-on-situation-in-ukraine, accessed 27 July 2024.

971 - IAEA, "Update 154 – IAEA Director General Statement on Situation in Ukraine", Press Release 25/2023, 21 April 2023, see https://www.iaea.org/newscenter/pressreleases/update-154-iaea-director-general-statement-on-situation-in-ukraine, accessed 27 July 2024.

972 - Ibidem.

973 - IAEA, "Nuclear Safety, Security and Safeguards in Ukraine—Report by the Director General", GOV/2024/30, 27 May 2024, see https://www.iaea.org/sites/default/files/documents/gov2024-30.pdf, accessed 2 August 2024.

974 - Truth Hounds, "In A Nuclear Prison: How Rosatom Turned Europe's Largest Nuclear Power Plant into a Torture Chamber and How Can The World Stop It", September 2023, see https://truth-hounds.org/en/cases/in-a-nuclear-prison-how-rosatom-turned-europes-largest-nuclear-power-plant-into-a-torture-chamber-and-how-can-the-world-stop-it/, accessed 21 July 2024.

or partially disconnected from the grid—external power is needed to continuously cool the reactors and spent fuel even if the reactors are shut down (see Nuclear Power and War in WNISR2022).[975] The IAEA noted in early 2024 that "the status of the off-site power supply to the ZNPP remained vulnerable throughout the reporting period."[976] In a later report, the IAEA also documented occasions in which the facility was attacked by drones, including in April 2024, when it was observed that there was damage, but not critical to nuclear safety, to the containment dome of Unit 6, which, according to the IAEA, was the first time since November 2022 that the facility had come under direct attack.[977]

There are no continuous independent observers at nuclear facilities in Ukraine. It is thus impossible to make affirmative, definitive assessments of the situation. Only the IAEA has representatives at the Ukrainian nuclear power plants.

It is not just direct attacks on the nuclear facilities that threaten their safety. The IAEA also reported that on 23 and 24 November 2022, the Rivne, South Ukraine, and Khmelnytskyi nuclear power plants were automatically disconnected from the grid due to decreased grid frequency.[978]

In early June 2023, an explosion at the Russian-controlled Kakhovka dam in Southern Ukraine resulted in its breech and the flooding of vast amounts of land and numerous settlements, but the dam also retained the cooling water, the ultimate heat sink, for Zaporizhzhia.[979] As ZNPP was not operational at the time and mainly in cold shutdown, there was only a limited immediate impact on the plant. Following the explosion, the Ukrainian nuclear regulator issued the previously mentioned order for the remaining reactor in hot shutdown, Unit 5, to be moved to cold shutdown, but the Russian occupiers of the plant ignored the request.[980] The destruction of the dam was described in June 2023 as " the worst act of ecocide that Russia has committed since the beginning of its full-scale invasion of Ukraine" by the Ukrainian Environment Minister, Ruslan Strilets, referring to the destruction caused by the flooding and resulting pollution.[981]

975 - IAEA, "Nuclear Safety, Security and Safeguards in Ukraine—February 2022–February 2023", February 2023, op. cit.

976 - IAEA, "Nuclear Safety, Security and Safeguards in Ukraine—Report by the Director General", GOV/2024/9, 27 February 2024, see https://www.iaea.org/sites/default/files/documents/gov2024-9.pdf, accessed 27 July 2024.

977 - IAEA, "Nuclear Safety, Security and Safeguards in Ukraine—Report by the Director General", GOV/2024/30, op. cit.; and IAEA, "Update 224 – IAEA Director General Statement on Situation in Ukraine", Press Release 37/2024, 18 April 2024, see https://www.iaea.org/newscenter/pressreleases/update-224-iaea-director-general-statement-on-situation-in-ukraine, accessed 27 July 2024.

978 - IAEA, "Nuclear Safety, Security and Safeguards in Ukraine—February 2022–February 2023", February 2023, op. cit.

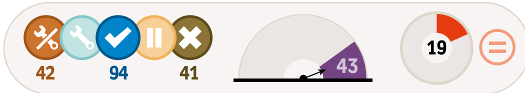
979 - François Diaz-Maurin, "Ukrainian dam is destroyed; nuclear plant lives in a 'grace period'", *Bulletin of the Atomic Scientists*, 6 June 2023, see https://thebulletin.org/2023/06/ukrainian-dam-is-destroyed-nuclear-plant-lives-in-a-grace-period/, accessed 2 July 2024.

980 - SNRIU, "Russian occupants prevent ZNPP Unit 5 from switching to cold shutdown", 13 June 2023, see https://snriu.gov.ua/en/news/russian-occupants-prevent-znpp-unit-5-from-switching-to-cold-shutdown, accessed 27 July 2024; and Truth Hounds, "Study of the Destruction of the Kakhovka Dam and Its Impacts on Ecosystems, Agrarians, Other Civilians, and International Justice", 6 June 2024, see https://truth-hounds.org/en/cases/submerged-study-of-the-destruction-of-the-kakhovka-dam-and-its-impacts-on-ecosystems-agrarians-other-civilians-and-international-justice/, accessed 2 July 2024.

981 - Ministry of Environmental Protection and Natural Resources, "Ruslan Strilets: The blowing up of the Kakhovka Hydroelectric Power Plant dam is the worst act of ecocide that russia has committed since the beginning of its full-scale invasion of Ukraine", Government of Ukraine, 7 June 2023, see https://www.kmu.gov.ua/en/news/ruslan-strilets-pidryv-damby-kakhovskoi-hes-tse-naibilshyi-akt-ekotsydu-iakyi-rosiia-vchynyla-z-pochatku-povnomasshtabnoho-vtorhnennia-v-ukrainu, accessed 27 July 2024.

Despite the international condemnation and the clear and immediate danger of the shelling and bombing of a nuclear facility as well as its power and water supplies, reportedly, attacks and threats of attacks have continued.

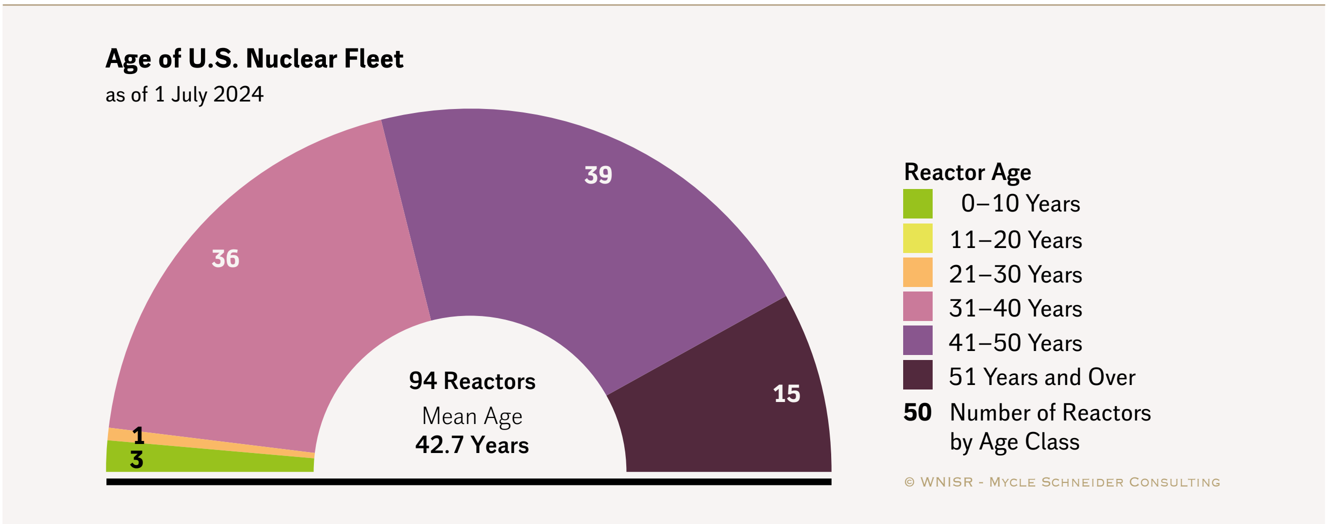
UNITED STATES FOCUS



Overview

With 94 commercial reactors operational as of 1 July 2024, the United States still has the largest nuclear fleet in the world. Nuclear energy generation in 2023 increased slightly—+0.5 percent—to 775.3 TWh[982], (+0.9 percent, according to IAEA-PRIS). The sector's share of utility-scale electricity generation increased correspondingly to 18.6 percent, rebounding slightly from the 35-year low of 2022. Despite two new reactor startups between July 2023 and April 2024, the U.S. fleet continues to age, with a mid-2024 average of 42.7 years, making it amongst the oldest in the world: 54 units have operated for 41 years or more (of which 15 for more than 51 years) and all but four for 31 years or more (see Figure 47).

Figure 47 · Age Distribution of U.S. Nuclear Fleet



Sources: WNISR, with IAEA-PRIS, 2024

After 11 years of construction, the second of two new Westinghouse AP-1000 reactors at Plant Vogtle—Unit 4—was connected to the grid on 1 March 2024.[983] Startup of the reactor was delayed by several months due to the failure of a main feedwater pump during initial operations in September 2023, which had to be replaced with one of the spare pumps stockpiled onsite.[984]

982 - U.S. EIA, "Monthly Energy Review July 2024—Table 8.1 Nuclear Energy Overview", U.S. Energy Information Administration, July 2024, see https://www.eia.gov/totalenergy/data/monthly/pdf/sec8_3.pdf, accessed 8 August 2024.

983 - Georgia Power, "Vogtle Unit 4 connects to electric grid for the first time", Press Release, 1 March 2024, see https://www.prnewswire.com/news-releases/vogtle-unit-4-connects-to-electric-grid-for-the-first-time-302077540.html, accessed 15 March 2024.

984 - *Power Engineering*, "Vogtle Unit 4 startup date pushed back after motor fault discovered in reactor coolant pump", 9 October 2023, see https://www.power-eng.com/nuclear/vogtle-unit-4-startup-date-pushed-back-after-motor-fault-discovered-in-reactor-coolant-pump/, accessed 15 July 2024.

Costs continued to increase as a result of additional maintenance and final delays. Based on filings Georgia Power submitted to the Georgia Public Service Commission, total costs of the project stood at US$36.85 billion in February 2024,[985] when accounting for US$3.7 billion in rebates then-Westinghouse-owner Toshiba paid to the co-owners in 2017.[986]

The availability of federal subsidies continues to create uncertainty about the overall rate of retirements among U.S. reactors. A proposal to extend operation of the Diablo Canyon-1 and -2 reactors for five years has progressed since reported in WNISR2023, with Pacific Gas and Electric Company's (PG&E) submission of the license renewal application in November 2023.[987] Measures to restart the Palisades reactor from its retirement in May 2022 have progressed, with the approvals of US$1.8 billion in state and federal financing, and owner Holtec navigating first-of-its-kind licensing measures with the Nuclear Regulatory Commission. In recent months, owners of the retired Duane Arnold (2020)[988] and Three Mile Island-1 (2019) reactors have also stated they are considering pursuing restarts.[989]

Owners of 50 of the 91 operating reactors built before the year 2000 have decided to pursue Subsequent License Renewals in recent years

Several factors have led to a perception that new market opportunities are opening up for nuclear generation in the U.S.: the availability of federal financing and subsidies; expressions of political and economic support from state government officials; and projections of sharply increasing electricity demand. Consistent with these developments, applications for license extensions are trending upward. Subsequent license renewal[990] applications for six reactors were submitted between July 2023 and July 2024, and owners of 29 more reactors have notified the NRC they intend to file them in the coming years.[991] Between applications that are approved, currently under review, or pending submission, owners of 50 of the 91 operating reactors built before the year 2000 have decided to pursue Subsequent License Renewals in recent years plus the new owner of Palisades-1 if its proposed restart is approved.[992]

985 - Patty Durand, Kim Scott and Glenn Carroll "Plant Vogtle: The True Cost of Nuclear Power in the United States", Cool Planet Solutions, Georgia Women's Action for New Directions and Nuclear Watch South, May 2024, see https://truthaboutvogtle.com/wp-content/uploads/2024/06/Truth-about-Vogtle-report.pdf, accessed 15 July 2024, based on Georgia Power, "Thirtieth Semi-annual Vogtle Construction Monitoring Report", filed with Georgia Public Service Commission, Docket 29849, 15 February 2024, see https://services.psc.ga.gov/api/v1/External/Public/Get/Document/DownloadFile/217538/98678, accessed 15 July 2024.

986 - Jeff Amy, "Georgia nuclear rebirth arrives 7 years late, US$17B over cost", *The Associated Press*, 25 May 2023, see https://apnews.com/article/georgia-nuclear-power-plant-vogtle-rates-costs-75c7a413cda3935dd551be9115e88a64, accessed 21 July 2023.

987 - U.S. NRC, "Diablo Canyon - License Renewal Application", United States Nuclear Regulatory Commission, 29 May 2024, see https://www.nrc.gov/reactors/operating/licensing/renewal/applications/diablo-canyon.html, accessed 15 July 2024.

988 - Spencer Kimball, "NextEra considers restarting Iowa nuclear plant amid rising demand for carbon-free energy", *CNBC*, 24 July 2024, see https://www.cnbc.com/2024/07/24/nextera-weighs-restarting-iowa-nuclear-plant-amid-demand-for-carbon-free-energy.html, accessed 28 July 2024; and Erin Jordan, "NextEra CEO says he'd 'consider' restarting Duane Arnold nuclear power plant", *The Gazette*, 27 June 2024, see https://www.thegazette.com/energy/nextera-ceo-says-hed-consider-restarting-duane-arnold-nuclear-power-plant/, accessed 15 July 2024.

989 - Evan Halper, "A nuclear accident made Three Mile Island infamous. AI's needs may revive it.", *The Washington Post*, 10 July 2024, see https://www.washingtonpost.com/business/2024/07/10/three-mile-island-nuclear-artificial-intelligence/; both accessed 15 July 2024.

990 - Subsequent license renewal is the designation the U.S. Nuclear Regulatory Commission (NRC) uses for second license extensions, authorizing operation of a reactor beyond 60 years to 80 years. Initial license renewal (ILR) refers to extensions of operating licenses beyond the original 40-year license period, to as much as 60 years.

991 - U.S. NRC, "Status of Subsequent License Renewal Applications", United States Nuclear Regulatory Commission, 15 May 2024, see https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html, accessed 21 May 2024.

992 - Ibidem.

Subsidies and Financing for Nuclear Power

States and the federal government continue to provide large volumes of financial support for both new and existing reactors. In March 2024, the U.S. Department of Energy (DOE) authorized US$1.5 billion in loan guarantee financing for the restart of the Palisades reactor in Michigan.[993] Together with US$300 million in subsidies from the state of Michigan, a total of US$1.8 billion in government financing and subsidies has been committed to Holtec for the restart effort.[994]

In California, a budgetary dispute between the state Senate and the Governor resulted in a possible cancellation of the remaining portion of a US$1.4 billion forgivable loan to PG&E to finance the continued operation of Diablo Canyon.[995] However, the final budget passed by the legislature in late June 2024 included continued authorization of the loan.[996]

The Internal Revenue Service (IRS) is responsible for implementing several of the tax incentives for energy technologies under the Inflation Reduction Act of 2022 (IRA). The principal subsidies of interest to the nuclear energy industry are:

- the Nuclear Power Production Credit (Nuclear PTC), which provides tax credit subsidies to nuclear reactors built before 16 August 2022;
- the Clean Electricity Production Credit (CE PTC) and the Clean Electricity Investment Credit (CE ITC), which provide tax credits to new "clean" generation sources, including new reactors;
- the Clean Hydrogen Production Credit (H2 PTC), tax credits for producing hydrogen through processes with low/zero greenhouse gas (GHG) emissions.

IRS has not yet issued final regulations on any of these programs. 2024 is the first tax year for which the Nuclear PTC subsidy can be claimed, and it has perhaps the greatest implications for the industry, essentially underwriting the continued operation of existing reactors[997] by creating a type of revenue floor through 2032 as the industry faces ever-stiffer competition from wind, solar, electricity storage, and other fast-growing resources. Under the language of the IRA, the value of the subsidy is reduced for reactors that earn revenues over US$25/MWh

993 - Robert Walton, "DOE makes $1.5B conditional loan commitment to help Holtec restart Palisades nuclear plant", *Utility Dive*, 27 March 2024, see https://www.utilitydive.com/news/doe-conditional-loan-commitment-holtec-palisades-nuclear/711498/, accessed 19 July 2024; and Department of Energy, "Biden-Harris Administration Announces $1.5 Billion Conditional Commitment to Holtec Palisades to Support Recommission of Michigan Nuclear Power Plant", U.S. Government, 27 March 2024, see https://www.energy.gov/articles/biden-harris-administration-announces-15-billion-conditional-commitment-holtec-palisades, accessed 5 August 2024.

994 - Sheri McWhirter, "Closed nuclear plant on Lake Michigan gets another $150 million from state", *mlive*, 19 July 2024, see https://www.mlive.com/environment/2024/07/closed-nuclear-plant-on-lake-michigan-gets-another-150-million-from-state.html, accessed 19 July 2024.

995 - Michael R. Blood, "California legislators break with Gov. Newsom over loan to keep state's last nuclear plant running", *The Associated Press*, 13 June 2024, see https://apnews.com/article/diablo-canyon-nuclear-newsom-reactors-california-45f15ac6e3a39f4fe7bbd05a9fd30d8b, accessed 30 July 2024.

996 - Amanda Wernik, "Concern grows as state lawmakers approve a $400 million loan to extend Diablo Canyon", *KCBX*, 29 June 2024, see https://www.kcbx.org/government-and-politics/2024-06-28/concern-grows-as-state-lawmakers-approve-a-400-million-loan-to-extend-diablo-canyon, accessed 30 July 2024.

997 - *WNN*, "Nuclear tax credits underpin growth, says Constellation", *World Nuclear News*, 27 February 2024, see https://world-nuclear-news.org/Articles/Nuclear-tax-credits-underpin-growth-Constellation, accessed 16 July 2024.

during the tax year, zeroing out at US$43.75/MWh.[998] However, the industry has lobbied for IRS to implement the program with rules that are loose enough to allow reactor owners to maximize their claims.[999]

There has been controversy over the IRS's decision to set strong emissions standards for the H2 PTC. The draft rule issued in December 2023[1000] incorporated a framework that would preclude hydrogen producers from qualifying if their production process utilizes electricity from existing renewable and nuclear generation facilities, recognizing that the generation capacity would need to be replaced. The nuclear industry strongly objected to the proposed rules after they were published. Constellation, by far the largest reactor owner in the U.S., has viewed hydrogen production (and the H2 PTC in particular) as a key driver of future profits, given limited opportunities to expand its market share with its nuclear-dominated generation portfolio (see United States Focus in WNISR2023).[1001] In April 2024, Constellation announced that, if the final H2 PTC rule does not allow producers using electricity from existing reactors to qualify, it would file for the credits anyway and sue IRS if it denied the claim.[1002]

The U.S. Congress has continued to enact measures to promote the expansion of nuclear energy, the development and licensing of new reactor designs, and exports of nuclear reactors. President Biden signed the Prohibition on Russian Uranium Act in May 2024, which contains provisions that unlock US$2.7 billion for domestic production and/or procurement of enriched uranium from non-Russian sources, including High-Assay Low-Enriched Uranium (HALEU).[1003] The legislation offers the industry waivers through 2028, if reactor owners continue to rely on Russia for fuel. In another budgetary measure enacted in March 2024, Congress renewed and extended the Price-Anderson Act nuclear liability statute for another forty years.[1004] A previous extension enacted in 2005 already guarantees Price-Anderson coverage to all existing reactors in perpetuity, but industry desired the new extension to cover reactors built after 2025.

998 - U.S. Congress, "Public Law 117-169—An Act to Provide for Reconciliation Pursuant to Title II of S. Con. Res. 14", approved 16 August 2022, see https://www.congress.gov/bill/117th-congress/house-bill/5376/text, accessed 16 July 2024.

999 - Brian Martucci, "Congressional Democrats press Treasury for 'well-functioning' 45U nuclear tax credit", *Utility Dive*, 19 April 2024, see https://www.utilitydive.com/news/congressional-democrats-press-treasury-nuclear-energy-tax-credit/713741/, accessed 16 July 2024.

1000 - IRS, "Section 45V Credit for Production of Clean Hydrogen; Section 48(a)(15) Election To Treat Clean Hydrogen Production Facilities as Energy Property", Internal Revenue Service, *Federal Register*, Vol 88, No. 246, 26 December 2023, see https://www.govinfo.gov/content/pkg/FR-2023-12-26/pdf/2023-28359.pdf, accessed 5 August 2024.

1001 - Constellation, "Constellation Sets Industry Record for Blending Hydrogen with Natural Gas to Further Reduce Emissions", Press Release, 24 May 2023, see https://www.constellationenergy.com/newsroom/2023/Constellation-sets-industry-record-for-blending-hydrogen-with-natural-gas-to-further-reduce-emissions.html; and Allison Good, "Constellation to build $900M green hydrogen production facility", S&P Global, 16 February 2023, see https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/constellation-to-build-900m-green-hydrogen-production-facility-74372628; both accessed 1 August 2023.

1002 - Emma Penrod, "Constellation prepared to 'visit with the courts' about proposed hydrogen tax credit rules", *Utility Dive, 18 April 2024, see* https://www.utilitydive.com/news/constellation-prepared-to-visit-with-the-courts-about-proposed-hydrogen-t/713551/, accessed 16 July 2024.

1003 - Paul Day, "Ban on Russian uranium aims to revive American supply", *Reuters*, 4 June 2024, see https://www.reuters.com/business/energy/ban-russian-uranium-aims-revive-american-supply-2024-06-04/, accessed 16 July 2024; and U.S. Congress, "Public Law 118–62–May 13, 2024—Prohibiting Russian Uranium Import Act", approved 13 May 2024, see https://www.congress.gov/118/plaws/publ62/PLAW-118publ62.pdf, accessed 5 August 2024.

1004 - Alex Polonsky and Molly Mattison, "Congress Gives 40-Year Extension for Price-Anderson Nuclear Liability Framework", Morgan Lewis, 3 April 2024, see https://www.morganlewis.com/blogs/upandatom/2024/04/congress-gives-40-year-extension-for-price-anderson-nuclear-liability-framework, accessed 16 July 2024.

In July 2024, President Biden enacted a bill, S. 870,[1005] which includes the Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act of 2024, an omnibus nuclear energy bill.[1006] The ADVANCE Act does not contain any direct subsidies for nuclear energy, but it includes several measures intended to promote nuclear energy and relax regulations on nuclear safety and licensing. It supports a U.S. Government agenda to compete with Russia and China for reactor exports, through tasking the NRC with creating the "International Nuclear Export and Innovation Branch" (within the Office of International Programs) to collaborate with domestic agencies involved in nuclear export deals, interact with international governance bodies, and assist other countries in establishing their own regulatory systems. It also relaxes the Section 810 procedures for authorizing nuclear technology exports.

The ADVANCE Act does away with the prohibition on foreign ownership of nuclear power plants in the U.S. for OECD (Organization for Economic Cooperation and Development) members and India, while prohibiting NRC from approving imports of enriched uranium from Russia and China without prior authorization by the Secretary of Energy and Secretary of State. The new statute also requires the NRC to modify its mission statement to include language stating that:

> licensing and regulation of the civilian use of radioactive materials and nuclear energy be conducted in a manner that is efficient and does not unnecessarily limit—
>
> (1) the civilian use of radioactive materials and deployment of nuclear energy; or
>
> (2) the benefits of civilian use of radioactive materials and nuclear energy technology to society.

The act requires NRC to hire more employees to review license applications, expedite and relax its licensing procedures, and to exclude more topics from consideration in environmental reviews by expanding NRC's practice of issuing "categorical exclusions."

Cancellation of First-Mover SMR Project

In November 2023, NuScale canceled its flagship Carbon Free Power Project (CFPP), which has shaken the field of SMR and non-light water reactor (nLWR) development. The 6-reactor, 462 MW power plant was originally proposed in 2015, when NuScale entered into a development agreement with the Utah Association of Municipal Power Systems (UAMPS), a state government agency that provides electricity to small public power companies in the western U.S. Following NuScale's announcement in January 2023 that the cost of the project had jumped from US$5.3 billion to US$9.3 billion, the developer stated that it needed to increase subscription agreements from 26 percent to 80 percent of CFPP's generation capacity by the end of the year. (See United States Focus in WNISR2023.)

1005 - U.S. Congress, "S. 870—An Act To authorize appropriations for the United States Fire Administration and firefighter assistance grant programs, to advance the benefits of nuclear energy, and for other purposes.", approved 9 July 2024, see https://www.congress.gov/bill/118th-congress/senate-bill/870/text, accessed 5 August 2024.

1006 - Ibidem; and Andres Picon, "E&E News: How a nuclear bill became this Congress' first big energy win", *E&E News/Politico,* 20 June 2024, see https://subscriber.politicopro.com/article/eenews/2024/06/20/how-a-nuclear-bill-became-this-congress-first-big-energy-win-00164046, accessed 16 July 2024.

NuScale submitted a series of applications to the NRC in 2022 and 2023, for approvals that were necessary to begin construction of the CFPP:

- standard design approval of the 77-MW, 6-reactor VOYGR design;[1007]
- a limited work authorization (LWA) to begin preparing the site for construction;[1008] and
- an exemption to allow for foundation shoring work not normally permissible under LWAs.[1009]

NuScale had not yet applied for a combined Construction and Operating License (COL) before canceling the project, but the path through which it was pursuing licensing was unusual. In order to meet its construction schedule, NuScale was proposing that NRC review the Standard Design Approval (SDA) and COL applications simultaneously, contending that the agency could complete the necessary phases of the SDA review before they would be necessary to review the COL application.[1010]

In October 2023, investment analysis firm Iceberg Research released a report questioning NuScale's financial viability.[1011] It projected the company had only 15 months of cash on hand and no significant sources of revenue or new investment capital to draw upon, except its shareholders' equity. Iceberg's analysis was occasioned by NuScale's announcement[1012] that it had inked a US$37 billion deal to construct twenty-four VOYGR reactors with a third-party energy project developer (ENTRA1), which would sell power under contract to a datacenter firm (Standard Power). Iceberg concluded the "contract has zero chance of being executed" because ENTRA1 and Standard Power exhibited little financial ability to finance construction of the reactors and to procure the power. The report also noted that NuScale's stock value had steadily declined, and the company had announced no new subscriptions for the CFPP, while NuScale insiders (former Chief Financial Officer, Chris Colbert, and his wife) had sold most of their own shares in the company.

1007 - U.S. NRC, "NuScale Power, LLC—Action: Standard design approval application; acceptance for docketing; request for comment", Notice 88 FR 51874, Docket No. 52–050; NRC–2023–0027, United States Nuclear Regulatory Commission, *Federal Register*, Vol. 88, No. 149, 4 August 2023, see https://www.federalregister.gov/documents/2023/08/04/2023-16679/nuscale-power-llc, accessed 26 July 2024.

1008 - U.S. NRC, "NuScale Power, LLC; Carbon Free Power Project—Action: Limited work authorization application; receipt.", Notice 88 FR 56054, Docket No. 99902052; NRC–2023–0143, United States Regulatory Commission, *Federal Register*, Vol. 88, No. 158, 17 August 2023, see https://www.federalregister.gov/documents/2023/08/17/2023-17723/nuscale-power-llc-carbon-free-power-project, accessed 26 July 2024.

1009 - U.S. NRC, "Pre-Application Activities for the Carbon Free Power Project", United States Nuclear Regulatory Commission, Updated 16 November 2023, see https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/pre-application-activities/idaho-national-labs-preapp.html, accessed 5 August 2024.

1010 - Carbon Free Power Project, "NuScale Power, LLC, Submittal on Behalf of CFPP LLC Carbon Free Power Project (CFPP) Combined License Application (COLA) Entitled, 'Carbon Free Power Project (CFPP) Regulatory Engagement Plan For Early Construction,' PL-135470-P, PL-135470-NP, Revision 0", Docket No. 99902052, addressed to the United States Nuclear Regulatory Commission, 22 March 2023, see https://www.nrc.gov/docs/ML2308/ML23081A094.pdf, accessed 16 July 2024.

1011 - Iceberg Research, "NuScale Power ($SMR): A Fake Customer and a Major Contract in Peril Cast Doubt on NuScale's viability", 19 October 2023, see https://iceberg-research.com/2023/10/19/nuscale-power-smr-a-fake-customer-and-a-major-contract-in-peril-cast-doubt-on-nuscales-viability/, accessed 20 October 2023.

1012 - NuScale, "Standard Power Chooses NuScale's Approved SMR Technology and ENTRA1 Energy to Energize Data Centers", 6 October 2023, see https://www.nuscalepower.com/en/news/press-releases/2023/standard-power-chooses-nuscales-approved-smr-technology-and-entra1-energy-to-energize-data-centers, accessed 5 August 2024.

NuScale issued a statement a few days later, rejecting the report's conclusions.[1013] It then canceled the CFPP two weeks later, acknowledging that subscriptions had not increased, and the project was not financially viable. Law firms representing investors quickly announced investigations of NuScale,[1014] and class action lawsuits have since been filed alleging e.g. that the company "made materially false and/or misleading statements and failed to disclose material adverse facts about the Company's business, operations, and prospects."[1015]

NuScale has continued to pursue the SDA after canceling the CFPP. A follow-up report by Iceberg Research in May 2024 accuses NuScale of deceiving its investors by misrepresenting the certification status and NRC's reviews of its reactor designs.[1016] In 2020, NRC issued a design certification for a 50-MW, 12-reactor version of its SMR, but without approving three significant aspects of the reactor, including the steam generators.[1017] NuScale is no longer marketing that reactor, since switching the design of the CFPP to the "uprated" 77-MW reactor,[1018] but the company continually states that it has "the first and only SMR to receive design approval."[1019] Iceberg also notes that NuScale is burning through its cash at a slightly slower rate, but still has no firm contracts or new investment deals, while its largest equity holder (engineering firm Fluor, at 55.8 percent[1020]) wants to significantly reduce its ownership share but is having little success recruiting new investors to do so.

1013 - NuScale, "NuScale Power Comments on Inaccurate Short-Seller Report", Press Release, NuScale Power, 24 October 2023, see https://nuscale-prod-pbpdt9uqe-nuscale-power.vercel.app/news/press-releases/2023/nuscale-power-comments-on-inaccurate-short-seller-report, accessed 8 November 2023.

1014 - Peter Judge, "Lawyers circle nuclear startup NuScale over claims a 24-reactor SMR deal will fail", *Data Center Dynamics*, 27 October 2023, see https://www.datacenterdynamics.com/en/news/lawyers-circle-nuclear-startup-nuscale-over-claims-a-24-reactor-deal-will-fail/, accessed 23 July 2024.

1015 - Pomerantz LLP, "SHAREHOLDER ALERT: Pomerantz Law Firm Reminds Shareholders with Losses on their Investment in NuScale Power Corporation of Class Action Lawsuit and Upcoming Deadline - SMR", Press Release, as published on *PR Newswire*, 14 January 2024, see https://www.prnewswire.com/news-releases/shareholder-alert-pomerantz-law-firm-reminds-shareholders-with-losses-on-their-investment-in-nuscale-power-corporation-of-class-action-lawsuit-and-upcoming-deadline--smr-302033226.html; and Levi & Korsinsky LLP, "SHAREHOLDER ALERT: Levi & Korsinsky Notifies NuScale Power Corporation(SMR) Investors of a Class Action Lawsuit and Upcoming Deadline", Press Release, as published on *PR Newswire*, 16 January 2024, see https://www.prnewswire.com/news-releases/shareholder-alert-levi--korsinsky-notifies-nuscale-power-corporationsmr-investors-of-a-class-action-lawsuit-and-upcoming-deadline-302035015.html; both accessed 23 July 2024.

1016 - Iceberg Research, "NuScale ($SMR) Has Deceived Investors about the Certification of its Reactor", 16 May 2024, see https://iceberg-research.com/2024/05/16/nuscale-smr-has-deceived-investors-about-the-certification-of-its-reactor/, accessed 21 May 2024.

1017 - Arjun Makhijani and M. V. Ramana, "Questions for NuScale VOYGR Reactor Certification: When Will It Be Done? And then, Will It Be Safe?", Environmental Working Group, 2023, see https://static.ewg.org/upload/pdf/FINAL_NuScale_analysis_for_EWG.pdf, accessed 20 July 2023.

1018 - U.S. NRC, "Design Certification - NuScale US600", United States Nuclear Regulatory Commission, 23 May 2023, see https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/nuscale.html, accessed 30 July 2023.

1019 - NuScale, "VOYGR Power Plants", 2024, see https://www.nuscalepower.com/en/products/voygr-smr-plants, accessed 5 August 2024.

1020 - Iceberg Research, "NuScale Power ($SMR): A Fake Customer and a Major Contract in Peril Cast Doubt on NuScale's viability", 19 October 2023, see https://iceberg-research.com/2023/10/19/nuscale-power-smr-a-fake-customer-and-a-major-contract-in-peril-cast-doubt-on-nuscales-viability/, accessed 20 October 2023.

New Reactors: Proposals, Planning, and Policy Developments

As one insider put it to *Reuters* news agency in 2021, "There's a deepening understanding within the [Biden] administration that it needs nuclear to meet its zero-emission goals."[1021] With the completion of Vogtle Unit 3 and 4, no new reactors are under construction in the U.S. for the first time in over a decade. The majority of federal and state government investments are going toward prolonging the operation of existing reactors rather than into new construction, and only one of the major nuclear generators (Tennessee Valley Authority, or TVA) has made an investment decision to build a new reactor: a GE-Hitachi BWRX-300 at Clinch River,[1022] a site for which TVA received an early site permit to build an unspecified SMR in 2019.[1023] However, the BWRX-300 design is not even licensed. As of mid-2024—since 2019—it was still in NRC's "Pre-Application review" stage.[1024]

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These indicators suggest the U.S. industry is focused on treading water rather than on significant amounts of new reactor construction within the next decade.

However, the significant amount of financial support in the Inflation Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA)—and media coverage driven by venture capital investment in startup companies that are developing reactor designs—has generated widespread interest in new reactors. Since the IIJA was enacted, several states have enacted legislation and initiated programs to promote nuclear energy, and several utilities have initiated feasibility studies or included deployment of new reactors in their official long-range system plans (referred to in many states as Integrated Resource Plans or IRPs).

As reported in WNISR2023, the official schedules for the major commercial reactor demonstration projects have slipped to 2030, under DOE awards funded by the IIJA to the TerraPower and X-energy plants. They had been selected in 2020 as the flagship projects of DOE's Advanced Reactor Demonstration Program (ARDP), with a goal of bringing reactors online in 5–7 years.[1025] The ARDP is also supporting development of eight other reactor designs, with goals for deployment of demonstration reactors in the early- to mid-2030s, at the soonest.

1021 - Timothy Gardner and Jarrett Renshaw, "U.S. eyes nuclear reactor tax credit to meet climate goals -sources", *Reuters*, 5 May 2021, see https://www.reuters.com/business/sustainable-business/white-house-eyes-subsidies-nuclear-plants-help-meet-climate-targets-sources-2021-05-05/, accessed 22 July 2021.

1022 - TVA, "Tennessee Valley Authority, Ontario Power Generation, and Synthos Green Energy Invest in Development of GE Hitachi Small Modular Reactor Technology", Press Release, 23 March 2023, see https://www.tva.com/newsroom/press-releases/tennessee-valley-authority-ontario-power-generation-and-synthos-green-energy-invest-in-development-of-ge-hitachi-small-modular-reactor-technology, accessed 5 August 2024.

1023 - U.S. NRC, "Issued Early Site Permit - Clinch River Nuclear Site", Updated 21 September 2022, see https://www.nrc.gov/reactors/new-reactors/large-lwr/esp/clinch-river.html, accessed 5 August 2024.

1024 - U.S. NRC, "GEH BWRX-300", United States Nuclear Regulatory Commission, Updated 30 April 2024, see https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/pre-application-activities/bwrx-300.html, accessed 7 August 2024.

1025 - Office of Nuclear Energy, "Advanced Reactor Demonstration Program", U.S. Department of Energy, Undated, see https://www.energy.gov/ne/advanced-reactor-demonstration-program, accessed 5 August 2023, Office of Nuclear Energy, "INFOGRAPHIC: Advanced Reactor Development", U.S. Department of Energy, 15 December 2020, see https://www.energy.gov/ne/articles/infographic-advanced-reactor-development, accessed 5 August 2024.

The U.S. Department of Defense is also sponsoring development of three microreactors through two procurement processes, with projected operation dates in or around 2027.[1026]

Ten states have enacted policy changes or initiated planning processes to promote nuclear energy since July 2023. The measures range from authorizing CWIP (Construction Work In Progress) financing and providing direct subsidies, to classifying nuclear for clean energy incentives and conducting feasibility and planning studies:

- **Connecticut:** in May 2024, the legislature enacted a bill (S. 385) that requires SMR projects (authorized under 2022 legislation) to involve at least two other states in procuring power from the reactors.[1027]
- **Florida:** enacted in May 2024, HB1645 directs the Public Service Commission to undertake a feasibility study of advanced reactors and make policy recommendations by April 2025.[1028]
- **Kentucky:** legislation from April 2024 directs the Public Service Commission to make organizational adjustments in preparation for reviewing nuclear construction projects,[1029] and another bill creates the Kentucky Nuclear Energy Development Authority to promote development of the industry and workforce in the state.[1030]
- **Michigan:** the legislature and governor approved in Summer 2024 an additional US$150 million subsidy to support the restart of the Palisades reactor,[1031] bringing the total of state funds for the project to US$300 million.
- **Oklahoma:** SB 1535 enrolled in April 2024 adds nuclear energy to the scope of the Oklahoma Low Carbon Energy Initiative, making reactor projects eligible for incentives.[1032]
- **Texas:** Governor Greg Abbott issued an order in August 2023 to the Texas Public Utility Commission, directing it to conduct a feasibility assessment of new reactors and to

1026 - U.S. Department of Defense, "DOD Exercises Option on Second Micro Nuclear Reactor Design", Press Release, United States Government, 13 September 2023, see https://www.defense.gov/News/Releases/Release/Article/3524458/dod-exercises-option-on-second-micro-nuclear-reactor-design/https%3A%2F%2Fwww.defense.gov%2FNews%2FReleases%2FRelease%2FArticle%2F3524458%2Fdod-exercises-option-on-second-micro-nuclear-reactor-design%2F; and Eielson Air Force Base, "Eielson Micro-reactor Quarterly Newsletter—05.03.2024", U.S. Air Force, 3 May 2024, see https://www.eielson.af.mil/Portals/40/ENVIRONMENT/Micro-Reactor/07_MR%20Quarterly%20Newsletter_May%202024.pdf?ver=xE8xcn-4bufNg6uEJ-tfbA%3D%3D; both accessed 9 August 2024.

1027 - Connecticut State Legislature, "Substitute Senate Bill No. 385—Public Act No. 24-38—An Act Concerning Energy Procurements, Certain Energy Sources and Programs of the Public Utilities Regulatory Authority.", signed 21 May 2024, see https://legiscan.com/CT/text/SB00385/id/2997043/Connecticut-2024-SB00385-Chaptered.pdf, accessed 28 July 2024.

1028 - The Florida Senate, "CS/CS/HB 1645: Energy Resources", signed 16 May 2024, see https://www.flsenate.gov/Session/Bill/2024/1645, accessed 28 July 2024.

1029 - Kentucky General Assembly, "Senate Joint Resolution 140—A Joint Resolution directing the Public Service Commission to make all staffing, organizational, and administrative preparations necessary to be ready to discharge its regulatory duties relating to applications for the siting and construction of nuclear energy facilities in the Commonwealth.", signed 4 April 2024, see https://apps.legislature.ky.gov/record/24rs/sjr140.html, accessed 28 July 2024.

1030 - Kentucky General Assembly, "Senate Bill 198—An Act relating to nuclear energy development.", 12 April 2024, see https://apps.legislature.ky.gov/record/24rs/sb198.html, accessed 28 July 2024.

1031 - Office of the Governor of the State of Michigan, "Governor Whitmer Signs Balanced Bipartisan FY25 Budget", Press Release, 24 July 2024, see https://www.michigan.gov/whitmer/news/press-releases/2024/07/24/governor-whitmer-signs-balanced-bipartisan-fy25-budget, accessed 5 August 2024.

1032 - Oklahoma State Legislature, "Bill Information for SB 1535— Oklahoma Low Carbon Energy Initiative; modifying duties and membership of the Low Carbon Energy Initiative Board. Effective date.", signed 18 April 2024, see http://www.oklegislature.gov/BillInfo.aspx?Bill=sb1535&Session=2400, accessed 28 July 2024.

make policy recommendations for how the state can facilitate deployment of "advanced reactors," in a report that is due in December 2024.[1033]

- **Utah:** HB 124 signed in March 2024 authorizes nuclear energy projects to receive emissions reduction tax credits.[1034]
- **Virginia:** the state legislature enacted two bills in April 2024 (HB 1491 and SB 454) authorizing CWIP for SMR projects undertaken by the investor-owned utilities in the state, Dominion and AEP.[1035]
- **Washington:** HB 1924 signed in March 2024 adds fusion to the list of clean energy sources in state energy policies.[1036]

Extended Reactor Licenses

Under the Atomic Energy Act (AEA) and NRC regulations, the NRC issues initial operating licenses for commercial power reactors for 40 years. Regulations provide for license extensions in increments of up to 20 additional years. Due to the advanced age of the U.S. reactor fleet, reactor owners have begun applying for second license extensions, to permit operation out to as much as 80 years.

As of mid-2024, 84[1037] of the 94 operating U.S. units had already received 20-year Initial License Renewals (ILRs), which permit reactor operation beyond 40 and up to 60 years. Since 2022, owners have submitted ILR applications for six of the remaining ten,[1038] three of which were filed between December 2023 and February 2024 (Diablo Canyon-1 and -2 and Clinton-1, respectively).[1039] The remaining operating reactors have not been operating long enough to warrant seeking ILR, yet: Watts Bar-1 and -2, which began operation in 1996 and 2016, respectively; and Vogtle-3 and -4, which entered commercial operation within the last 12 months.

1033 - Robert Walton, "Texas regulators explore how to attract advanced nuclear projects, structure SMR incentives", *Utility Dive*, 5 March 2024, see https://www.utilitydive.com/news/texas-incentives-advanced-nuclear-SMR-PUCT-working-group-NEI/709277/, accessed 28 July 2024; and Governor Greg Abbott, Letter addressed to Public Utility Commission of Texas, 16 August 2023, see https://gov.texas.gov/uploads/files/press/Jackson,_Kathleen_08.16.23.pdf, accessed 5 August 2024.

1034 - Utah State Legislature, "H.B. 124 Energy Infrastructure Amendments", signed 12 March 2024, see https://le.utah.gov/~2024/bills/static/HB0124.html, accessed 28 July 2024.

1035 - Virginia State Legislature, "SB 454 Electric utilities; recovery of development costs associated with small modular reactor.", Virginia's Legislative Information System, signed 17 April 2024, see https://lis.virginia.gov/cgi-bin/legp604.exe?ses=241&typ=bil&val=sb454, accessed 21 February 2024; and Virginia State Legislature, "HB 1491 Phase I Utility; recovery of development costs associated with small modular nuclear facility", Virginia's Legislative Information System, signed 17 April 2024, see https://lis.virginia.gov/cgi-bin/legp604.exe?241+sum+HB1491, accessed 28 July 2024.

1036 - Washington State Legislature, "HB 1924 - 2023-24— Promoting the integration of fusion technology within state clean energy policies.", signed 28 March 2024, see https://app.leg.wa.gov/billsummary?BillNumber=1924&Initiative=false&Year=2023, accessed 28 July 2024.

1037 - 86 as of 30 July 2024, with Comanche Peak-1 and -2 receiving their ILR.

1038 - Six of the remaining eight as of 30 July 2024.

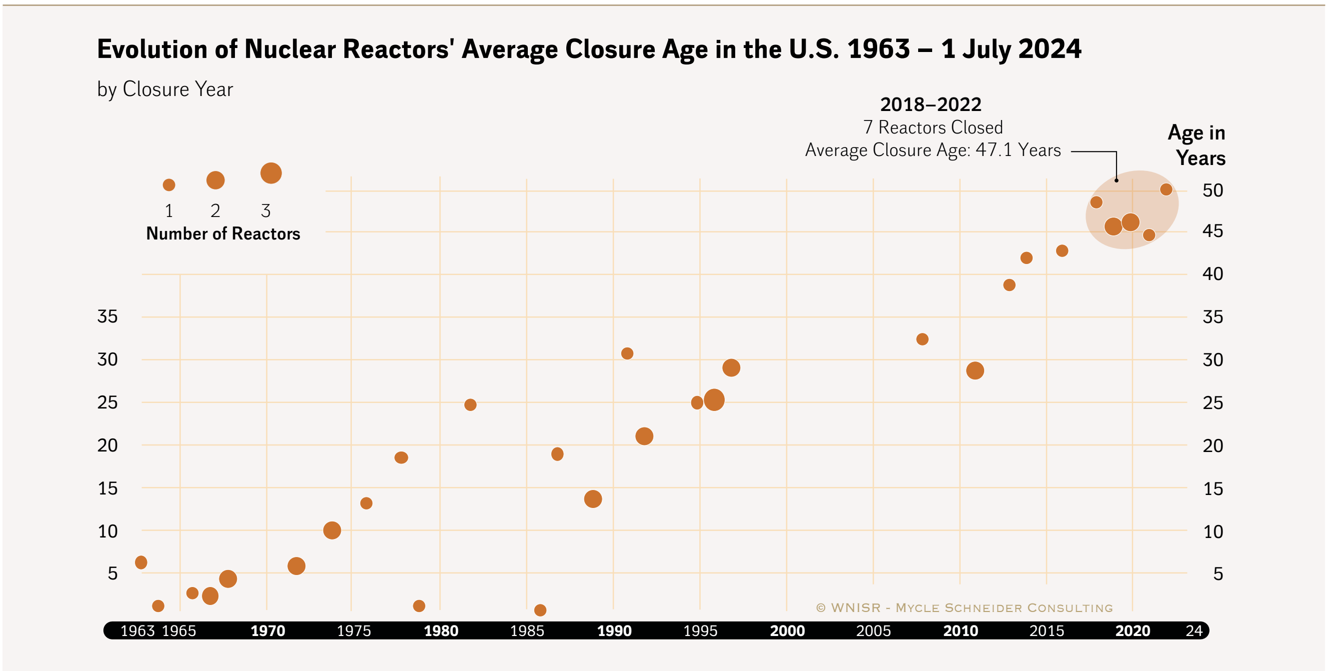
1039 - U.S. NRC, "Status of Initial License Renewal Applications and Industry Initiatives", United States Nuclear Regulatory Commission, 8 May 2024, see https://www.nrc.gov/reactors/operating/licensing/renewal/applications.html, accessed 11 July 2024.

As of mid-2024, the NRC had granted Subsequent License Renewals (SLR) to six reactors,[1040] which would permit operation from 60 to 80 years. Applications for a further sixteen reactors are under review,[1041] and owners have notified of their intentions to submit applications for a further 29 reactors between 2025 and 2034—representing nearly 60 percent of currently operating reactors that have already received an ILR.[1042] It is unclear how owners' plans to submit SLR applications may change if the Nuclear PTC subsidy program created by the Inflation Reduction Act is not extended past its current expiration date of 2032.

Reactor Closures and Proposed Restarts

The average age of the seven reactors closed in the U.S. over the five-year period 2018–2022—no unit was closed since—was 47.1 years (see Figure 48), significantly below their licensed lifetimes of 60 years.

Figure 48 · Evolution of Average Reactor Closure Age in the U.S.



Sources: WNISR with IAEA-PRIS, 2024

The retirement of Palisades in May 2022 marked the thirteenth closure in ten years, starting with the retirements of four reactors in the first half of 2013. With the effort to extend the operation of Diablo Canyon-1 and -2, there are no further anticipated closures before 2029, when the operating licenses of the oldest reactors in operation expire (Nine Mile Point-1 and Ginna-1).

1040 - Turkey Point-3 and -4 (2019), Peach Bottom-2 and -3 (2020), and Surry-1 and -2 (2021).
See U.S. NRC, "Status of Subsequent License Renewal Applications", Updated 8 July 2024, see https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html, accessed 5 August 2024.

1041 - North Anna-1 and -2 (2020); Point Beach-1 and -2 (2020); Oconee-1, -2, and -3 (2021); St. Lucie-1 and -2 (2021), Moticello-1 (2023), V.C. Summer-1 (2023), Browns Ferry-1, -2 and -3 (2024), Dresden-2 and -3 (2024).
See U.S. NRC, "Status of Subsequent License Renewal Applications", Updated 8 July 2024, op. cit.

1042 - Ibidem.

Restarts of Retired Reactors

The effort by Michigan officials to bring Palisades-1 out of retirement would make it the first reactor in the U.S.—and only the second in the world after the restart of Armenian-2 (also Metsamor-2) in Armenia, several years after its closure in 1989—to return to operation after entering decommissioning. In recent months, there have been reports that two other reactor owners are considering restarts: NextEra has said it is considering bringing Duane Arnold-1 back into service[1043]; and Constellation is contemplating restarting Three Mile Island-1[1044], respectively closed in 2020 and 2019. In both cases, the idea has surfaced in connection with anticipated growth in electricity demand with the development of energy-intensive data centers and artificial intelligence technology.

The proposed restart of Palisades-1 would establish regulatory pathways and test the practical feasibility of the practice for the rest of the industry. Holtec faces significant obstacles to doing so[1045]: it has no experience building or operating nuclear reactors; and its core businesses are in developing and manufacturing irradiated fuel storage systems and, since 2018, in managing the decommissioning of reactors. In order to meet the technical qualifications requirements for an operating license, Holtec would either have to hire an experienced nuclear operating company to manage Palisades or find one willing to take ownership of the plant entirely. Palisades is known to have a long list of maintenance needs, such as the control rod drive seals, which would require significant expense for a new owner to take on. Most of the skilled workforce that ran Palisades retired or took jobs elsewhere,[1046] so Holtec or a new operator must recruit hundreds of workers to a plant whose future is still uncertain.

Because the restart of a reactor that has entered decommissioning is unprecedented, the NRC licensing process may take longer than expected and be subject to interventions and legal challenges. Since July 2023, Holtec has submitted seven applications for license amendments, technical specification changes, and other approvals necessary to resume operations.[1047] NRC projects that all of these reviews will be completed before July 2025, but most of them are still in the preliminary stages. It is also unclear how long it would take Holtec to restart the reactor after receiving NRC approvals, with potentially significant investments in repairs and upgrades that will likely be required.[1048]

1043 - Spencer Kimball, "NextEra considers restarting Iowa nuclear plant amid rising demand for carbon-free energy", *CNBC*, July 2024, op. cit.

1044 - Rachel McDevitt, "Three Mile Island considers nuclear restart", *StateImpact Pennsylvania* as published by *WHYY/PBS*, 12 July 2024, see https://whyy.org/articles/three-mile-island-considers-nuclear-restart/, accessed 28 July 2024.

1045 - David Eggert, "Michigan dangles US$150M toward restarting nuclear plant, but what else would it take?", *Crain's Detroit*, 7 August 2023, see https://www.crainsdetroit.com/energy/will-michigan-nuclear-plant-restart-state-money, accessed 10 August 2023.

1046 - Entergy, "Entergy's Palisades team finishes strong as facility shuts down", Press Release, 20 May 2022, see https://www.entergynewsroom.com/news/entergy-s-palisades-team-finishes-strong-as-facility-shuts-down/, accessed 20 May 2022.

1047 - U.S. NRC, "Palisades Nuclear Plant", United States Nuclear Regulatory Commission, 19 July 2024, see https://www.nrc.gov/info-finder/reactors/pali.html, accessed 28 July 2024.

1048 - Audrey Whitaker, "Neighbors show concern about possible restart of Palisades nuclear plant", *mlive*, 18 April 2024, see https://www.mlive.com/public-interest/2024/04/neighbors-show-concern-about-possible-restart-of-palisades-nuclear-plant.html, accessed 28 July 2024.

Industry Restructuring and Emerging Business Models

WNISR2023 detailed intersecting trends related to ownership changes and business strategies within the U.S. nuclear industry. Further corporate restructuring is still expected, particularly through mergers and reactor ownership transfers in the merchant nuclear sector. There has been a significant development in one of the ownership transfers reported last year, i.e., NRG's sale of its interest in South Texas Project-1 and -2 to Constellation. Minority owners sued NRG and Constellation over the deal,[1049] asserting their right of first refusal. The parties settled in May 2024. The deal requires Constellation to transfer 2 percent of its interest to CPS Energy (leaving each with a 42 percent share and Austin Energy with the remaining 16 percent),[1050] and to sell an additional 200 MW of the reactors' output to CPS Energy under a long-term power purchase agreement.[1051]

There has also been a significant development affecting the trend of co-location and power supply deals between nuclear generators and data center developers. In March 2024, Amazon Web Services (AWS) agreed to pay Talen Energy US$650 million for the rights to a large data center development planned at Talen's 2514-MW Susquehanna Nuclear Power Plant in Pennsylvania.[1052] The data-center campus includes options to expand in subsequent phases to consume as much as 960 MW, 40 percent of Susquehanna's capacity. The Amazon-Talen project has become controversial, following an agreement with grid operator PJM that permits AWS to classify the first 480 MW of its data-center load as located "behind-the-meter," enabling Amazon to avoid costs associated with grid interconnections, transmission system upgrades, and approvals.[1053] Transmission owners Exelon and American Electric Power (AEP) have filed a complaint with the Federal Energy Regulatory Commission (FERC) to void the deal and require AWS to go through the interconnection process, arguing that the data center will continue to draw power from the grid during times when Susquehanna is offline and that other consumers will bear up to US$140 million in transmission and generation costs affected by AWS's load.[1054]

The resolution of this case has implications for the nuclear industry's foray into other off-grid power-supply arrangements, including hydrogen production. In addition to the aforementioned uncertainty about whether the IRS's final rule on the H2 PTC will permit currently operating reactors to qualify for the subsidy, the status of large loads co-located ("behind-the-meter") with nuclear power plants could apply equally to hydrogen production, desalination, and other

1049 - Paul Ring, "Texas Muni Utilities Seek To Stop Sale Of STP Nuclear Plant Ownership Share Among Retail Supplier Parents", *EnergyChoiceMatters.com*, 1 August 2023, see http://www.energychoicematters.com/stories/20230801a.html, accessed 9 August 2024.

1050 - CPS Energy is the municipal utility of San Antonio, TX.

1051 - Sara DiNatale, "CPS adds 250 megawatts of generation power in deal with Constellation", *San Antonio Express-News*, 6 May 2024, see https://www.expressnews.com/business/article/cps-energy-nuclear-power-south-texas-constellation-19441748.php, accessed 28 July 2024.

1052 - Dan Swinhoe, "AWS acquires Talen's nuclear data center campus in Pennsylvania", *Data Center Dynamics*, 4 March 2024, see https://www.datacenterdynamics.com/en/news/aws-acquires-talens-nuclear-data-center-campus-in-pennsylvania/, accessed 28 July 2024; and Talen Energy Corporation, "Q4 2023 and FY 2023 Earnings Presentation", 15 March 2024, see https://ir.talenenergy.com/static-files/84443b81-b2ab-4774-9ce2-d87a47e8dbb5, accessed 5 August 2024.

1053 - Ethan Howland, "Talen urges FERC to reject AEP-Exelon protest over interconnection pact for Amazon data center", *Utility Dive*, 8 July 2024, see https://www.utilitydive.com/news/talen-ferc-aep-exelon-interconnection-amazon-data-center-nuclear-power/720672/, accessed 28 July 2024.

1054 - Ethan Howland, "AEP, Exelon oppose Talen-Amazon interconnection pact to protect rate base growth potential: Constellation", *Utility Dive*, 24 July 2024, see https://www.utilitydive.com/news/aep-exelon-talen-amazon-interconnection-rate-base-ferc-constellation/722246/, accessed 28 July 2024.

industries. Hydrogen production and desalination might be able to operate more intermittently around grid operator's resource adequacy and other needs for reliability services, but it is unclear how that would affect the economics of those arrangements. Hydrogen production and desalination, for instance, are still very expensive and capital-intensive. The H2 PTC, should existing reactors qualify, would provide a hefty subsidy in electricity price terms, but for hydrogen production to have sufficient economic value for nuclear plants, the co-located facilities would have to be of large capacity, likely making their economics dependent on baseload-like operation, similar to nuclear reactors themselves.

Reactor Construction

« The cost increases and schedule delays have completely eliminated any benefit [of Vogtle-3 and -4] on a life-cycle cost basis. »

Testimony on behalf of the Georgia Public Service Commission Public Interest Advocacy Staff, 22 June 2023[1055]

The only two commercial reactors in the U.S. that began construction after the 1970s—and have not been abandoned during construction—have now been completed and are connected to the grid: the AP-1000 reactors, Vogtle-3 and -4. The reactors are located in Burke County, near Waynesboro, in the state of Georgia, in the southeastern U.S. and are owned by a consortium of Georgia utility companies and cooperatives, led by controlling owner Georgia Power (a subsidiary of Southern Company). Construction of the reactors began, respectively, in March and November 2013.[1056] At construction start of Unit 3, the schedule had already slipped by one year, with completion then expected in 2017 and 2018.[1057] The projected cost of the two-unit project was around US$14 billion. The actual cost skyrocketed to US$36.85 billion by the time fuel had been loaded at Vogtle-4.[1058] A main feedwater pump failure during initial startup operations further delayed Unit 4's grid connection to March 2024.[1059] Nearly seven years late and at 250 *percent* of the original budget, the failures of the project were only slightly mitigated by a US$3.68 billion settlement with Westinghouse that reduced the co-owning utilities' costs to around US$33 billion.

1055 - Tom Newsome, Philip Hayet and Lane Kollen, "In the Matter Of: Georgia Power Company's Twenty-Eighth Semi-Annual Vogtle Construction Monitoring ('VCM') Report—Direct Testimony and Exhibits", on Behalf of the Georgia Public Service Commission Public Interest Advocacy Staff, Before the Georgia Public Service Commission, 22 June 2023, see https://services.psc.ga.gov/api/v1/External/Public/Get/Document/DownloadFile/204891/86214, accessed 26 August 2023.

1056 - WNISR, "Construction Start on US Vogtle Unit 4", World Nuclear Industry Status Report, 25 November 2013, see https://www.worldnuclearreport.org/Construction-Start-on-US-Vogtle.html, accessed 20 July 2021.

1057 - WNISR, "Construction Start at Vogtle Reactor in the US", World Nuclear Industry Status Report, 16 March 2013, see https://www.worldnuclearreport.org/Construction-Start-at-Vogtle.html, accessed 7 September 2022.

1058 - Patty Durand, Kim Scott and Glenn Carroll "Plant Vogtle: The True Cost of Nuclear Power in the United States", Cool Planet Solutions, Georgia Women's Action for New Directions and Nuclear Watch South, May 2024, op. cit.; based on Georgia Power, "Thirtieth Semi-annual Vogtle Construction Monitoring Report", filed with Georgia Public Service Commission, 15 February 2024, op. cit.

1059 - Dave Williams, "Completion delay at Plant Vogtle pushes back start date of Unit 4 reactor to next year", *The Augusta Chronicle*, 6 October 2023, see https://www.augustachronicle.com/story/news/environment/2023/10/06/startup-of-unit-4-nuclear-reactor-at-plant-vogtle-delayed-to-2024/71088605007/, accessed 29 July 2024.

DOE Secretary Jennifer M. Granholm commented on the startup of Vogtle:

> To reach our goal of net zero by 2050, we have to at least triple our current nuclear capacity in this country. That means we've got to add 200 more gigawatts by 2050. Okay, two down, 198 to go![1060]

If past experience is of any indicative value, that goal is impossible to reach. Previous WNISR editions have detailed the long series of mistakes, delays, cost increases, and legal challenges to Vogtle-3 and -4, as well as those of its twin project: the Summer-2 and -3 reactors, which were canceled in 2017 after over US$9 billion had been spent and Westinghouse declared bankruptcy, subsequently abandoning its role in both projects.

As detailed above, construction has not begun on any other commercial power reactor in the U.S., no utility has filed an application for a construction license for a commercial plant. Only one application for a prototype power reactor has been submitted. In March 2024, TerraPower applied for a construction permit to the NRC for its Natrium reactor to be built in Wyoming, with hopes of receiving approval in time to begin construction and have the reactor online in 2030. However, the Natrium design has not been approved by the NRC yet.

Only one prototype non-power test reactor and one demonstration microreactor are currently approved for construction. Nuclear startup firm Kairos received a construction permit to build its Hermes 1 test reactor in December 2023, though as of mid-2024 the company has not announced the start of construction.[1061] The BWXT portable microreactor is being developed under a procurement program initiated by the Department of Defense (DoD), called Project Pele. DoD officials have reported to government officials in the territories of Guam and the Marianas that BWX Technologies has begun fabrication of the reactor, which the department is considering locating at one of its military bases in the Pacific.[1062]

Criminal Investigations of Nuclear Power Corporations

Since 2017, the U.S. Justice Department has opened three separate investigations against utility corporations over criminal activities related to nuclear power. The cases have resulted in indictments of corporate executives, lobbyists, and state officials. The cases have been accompanied by additional lawsuits and state-level investigatory proceedings, and they have had political ramifications which appear to have had further impacts on the industry, economically, as well as legally and politically. For detailed backgrounds on these cases see WNISR2023. There have been significant developments in all three, in recent months:

SCANA-Westinghouse fraud case. The last remaining criminal indictment was resolved in December 2023, when former Westinghouse Vice-President Jeffrey Benjamin pleaded guilty for his role in covering up mounting delays and cost overruns during the construction of the

1060 - Jennifer M. Granholm, "Remarks as Delivered by Secretary Jennifer M. Granholm on Startup of Vogtle Unit 4 and Growth of U.S. Nuclear Industry", Secretary of Energy, U.S. Department of Energy, United States Government, 31 May 2024, see https://www.energy.gov/articles/remarks-delivered-secretary-jennifer-m-granholm-startup-vogtle-unit-4-and-growth-us, accessed 24 August 2024.

1061 - U.S. NRC, "NRC to Issue Construction Permit for Kairos Hermes Test Reactor in Tennessee", Press Release, 12 December 2023, see https://www.nrc.gov/cdn/doc-collection-news/2023/23-078.pdf, accessed 5 August 2024.

1062 - John O'Connor, "Project Pele officials speak with senators", *Marianas Variety News & Views*, 28 January 2024, see https://www.mvariety.com/news/project-pele-officials-speak-with-senators/article_e3b80bf4-bd88-11ee-b068-43a50b130006.html, accessed 29 July 2024.

V.C. Summer-2 and -3 reactors, which were canceled in 2017 after US$9+ billion were spent.[1063] The sentencing hearing has yet to be scheduled, but under the plea deal, Benjamin will either get probation or up to 12 months in jail and/or up to US$100,000 in fines.

Exelon-Commonwealth Edison corruption case. The final suspect to be indicted in the corruption case involving nuclear bailout and utility legislation in Illinois is former Speaker of the state House of Representatives, Michael Madigan. The trial was originally scheduled to begin in April 2024, but was postponed until October 2024 in deference to a pending U.S. Supreme Court decision in a criminal case involving so-called "gratuities" paid to elected officials, which may have superseded the prosecution's case against Madigan.[1064] The federal prosecutor recently stated that the court ruling will not affect Madigan's prosecution. [1065] The ruling in the Trump case, issued in July 2024, largely exempts U.S. presidents from prosecution for crimes they commit while in office, but the court's constitutional rationale does not apply to other elected offices.

FirstEnergy corruption case. Former Speaker of the Ohio House of Representatives, Larry Householder, and three lobbyists are serving prison sentences for their role in a bribery and corruption scandal that unfolded between 2017 and 2019. FirstEnergy gave Householder, his associates, and his political action committee, Generation Now, US$61 million to pass HB6, a bill that provided a US$1.05 billion bailout to two reactors that FirstEnergy owned at the time.

The case continues to unfold, with further federal and state indictments since December 2023. That month, federal prosecutors brought charges against Sam Randazzo, the former Chairman of the Public Utility Commission of Ohio (PUCO), who allegedly accepted US$4.3 million from FirstEnergy and helped to draft and implement HB6.[1066] In February 2024, Ohio Attorney General Dave Yost filed charges against Randazzo and two former FirstEnergy executives, then-CEO Chuck Jones and then-Vice-President Michael Dowling.[1067] In April 2024, Randazzo died by suicide.[1068] He is the second suspect indicted in the case who has taken his own life before going to trial.

1063 - Caitlin Ashworth, "Ex-Westinghouse exec pleads guilty to charge in failed SCANA nuclear plant", *Post and Courier, 14 December 2023, see* https://www.postandcourier.com/columbia/news/vc-summer-westinghouse-scana-santee-cooper-charged-nuclear-plant/article_e53b9db8-9a8f-11ee-bee6-b3a9533ec1cc.html, accessed 29 July 2024; and John Monk, "Last defendant in $9 billion SCANA nuclear construction scandal pleads guilty", *The State, 14 December 2023, see* https://www.thestate.com/news/local/crime/article283048128.html, accessed 12 July 2024.

1064 - Hannah Meisel, "Madigan trial delayed until October for SCOTUS review of bribery statute", *Capitol News Illinois*, 3 January 2024, see https://capitolnewsillinois.com/news/madigan-trial-delayed-until-october-for-scotus-review-of-bribery-statute, accessed 19 July 2024.

1065 - Jason Meisner, Megan Crepeau, and Ray Long, "Prosecutors argue high court ruling on bribery does not impact Madigan case", *Chicago Tribune*, 30 July 2024, see https://www.chicagotribune.com/2024/07/30/this-dog-will-not-hunt-feds-say-supreme-court-ruling-has-no-impact-on-madigan-bribery-allegations/, accessed 31 July 2024.

1066 - Kathiann M. Kowalski, "Randazzo indictment sparks renewed calls for full regulatory review in Ohio", *Energy News Network*, 5 December 2023, see http://energynews.us/2023/12/05/randazzo-indictment-sparks-renewed-calls-for-full-regulatory-review-in-ohio/, accessed 30 July 2024.

1067 - Marty Schladen, "Ohio indictments provide a better picture of squalid relationships that spurred massive scandal", *Ohio Capital Journal*, 14 February 2024, see https://ohiocapitaljournal.com/2024/02/14/ohio-indictments-provide-a-better-picture-of-squalid-relationships-that-spurred-massive-scandal/, accessed 5 August 2024.

1068 - Marty Schladen, "Indicted former Ohio utility chair Sam Randazzo reported dead by suicide", *Ohio Capital Journal*, 9 April 2024, see https://ohiocapitaljournal.com/2024/04/09/indicted-former-ohio-utility-chair-sam-randazzo-reported-dead-by-suicide/, accessed 30 July 2024.

A joint trial for Jones and Dowling has not yet been scheduled. Reportedly, Dowling plans to call Governor Mike DeWine and Lieutenant Governor Jon Husted as witnesses.[1069] In June 2024, it was reported that text messages between DeWine and Jones suggest the governor may also have been involved in the bribery scheme. The text messages allegedly show that DeWine asked Jones for a significant campaign donation a month before the 2018 election, and messages between Dowling and Jones in 2019 state that DeWine actively worked to get the state legislature to pass HB6.[1070]

Conclusion

The number of reactors and annual nuclear generation increased slightly in 2023, with Vogtle-3's first grid connection resulting in a minimal increase of less than 1 percent in total electricity produced. Despite the startup of both new Vogtle units in 2023–2024, the average age of the U.S. reactor fleet continues to advance, reaching 42.7 years as of mid-2024. Efforts continue to restart the Palisades reactor, which was retired in 2022. Despite US$1.8 billion in federal and state investment, the project faces a complicated pathway to licensing and many technical and practical obstacles. In addition, the proposal to void a 2016 phaseout agreement to continue operation of Diablo Canyon-1 and -2 has moved forward, with review of the license renewal application underway at the NRC and re-authorization of a US$1.4 billion forgivable loan by the state of California.

Vogtle-4's first grid connection in March 2024 means there are no commercial power reactors under construction in the U.S. for the first time since 2013. The reactor's startup was delayed for several months due to a failed feedwater pump that had to be replaced. In the end, the reactors were delayed by almost seven years, and total costs reached US$36.85 billion. With the exception of TVA's investment decision for an SMR of an unlicensed design, GE-Hitachi's BWRX, no utility companies have made investment decisions to build new reactors of any type, and the cancellation of NuScale's Carbon Free Power Project in November 2023 has shaken confidence that new designs for SMRs and non-LWRs will break the pattern of cost escalation and construction delays that have plagued the U.S. industry for a half-century. A class action lawsuit against NuScale alleges that the company has defrauded its investors. Another startup company, X-energy, canceled its investment deal to go public on the stock market in November 2023, following a report casting doubt on NuScale's viability.

The U.S. industry's hopes remain fixed on the continued operation of existing reactors, supported by new federal subsidies and financing programs. With the submission of initial license renewal applications for Diablo Canyon and Clinton-1, all but the four newest reactors in the U.S. have pursued approvals to operate for up to 60 years. In addition, owners of more than half of currently operating reactors have expressed their intent to pursue subsequent license renewals, under which reactors would be authorized to operate for up to 80 years. Subsequent license renewals for six reactors have been approved, applications for a further

1069 - Morgan Trau, "FirstEnergy VP Dowling plans to call DeWine and Husted to the stand in corruption trial", *News 5 Cleveland/ABC*, 20 June 2024, see https://www.news5cleveland.com/news/politics/ohio-politics/firstenergy-vp-dowling-plans-to-call-dewine-and-husted-to-the-stand-in-corruption-trial, accessed 30 July 2024.

1070 - Morgan Trau, "New texts show FirstEnergy allegedly working with Gov. DeWine to pass House Bill 6", *Ohio Capital Journal*, 20 June 2024, see https://ohiocapitaljournal.com/2024/06/20/new-texts-show-firstenergy-allegedly-working-with-gov-dewine-to-pass-house-bill-6/, accessed 30 July 2024.

16 are under review, and licensees have notified the NRC of their intent to submit 29 more applications through 2035.

Three major corruption and fraud investigations involving both new reactors and nuclear subsidies continued developing in 2023–2024. Significant developments include the guilty plea by former Westinghouse Vice President Jeffrey Benjamin in the V.C. Summer fraud case; and, in the US$61 million FirstEnergy bribery case, federal and state indictments of former Public Utility Commission of Ohio Chairman Sam Randazzo and state indictments of two former FirstEnergy executives, ex-CEO Chuck Jones and ex-VP Michael Dowling.

FUKUSHIMA STATUS REPORT
OVERVIEW OF ONSITE AND OFFSITE CHALLENGES

ABSTRACT

No significant progress has been made in the decommissioning work in the past year since WNISR2023. Spent fuel removal from Unit 1 and 2 has not started and is currently planned for the Fiscal Year (FY) 2027–2028. Regarding fuel debris removal, Tokyo Electric Power Company (TEPCO) announced on 30 May 2024 that it would begin trial retrieval operations at Unit 2 "at some point between August and October 2024."[1071] Offsite, decontamination work in communities near Fukushima Daiichi has progressed, although portions of seven municipalities remain closed to habitation. As of 1 February 2024, according to the Fukushima Prefecture, 26,277 people were still away from home. Legal cases continue and several decisions at District Courts followed the Supreme Court ruling of 2022 dismissing responsibility of the government, while ordering TEPCO to pay compensation.

ONSITE CHALLENGES[1072]

Current Status of the Reactors

Per latest available readings dated 15 June 2024, continuous reactor cooling through water injection kept temperatures of the Reactor Pressure Vessels (RPVs) at Units 1, 2, and 3, at 22.7°C (at vessel bottom head), 30°C (at vessel wall above bottom head), and 25.6°C (at vessel bottom above skirt junction), respectively. The regulatory limit at the vessel bottom is 80°C.[1073]

Spent Fuel Removal

The removal of spent fuel from the cooling pools of Units 4 and 3 was completed in December 2014 and February 2021, respectively. Regarding Unit 1, to reduce exposure from highly radioactive substances on the southside wall, a shielding will be installed. Removal of rubble from the southside wall was completed on 25 April 2024. If the cover is installed as scheduled by summer 2025, spent fuel could be removed in FY2027–2028 as planned in the Mid-and-Long-Term Roadmap.

1071 - IRID/TEPCO, "Fukushima Daiichi Nuclear Power Station Unit 2 PCV Internal Investigation/ Preparation Status of Fuel Debris Trial Retrieval", International Research Institute for Nuclear Decommissioning, Tokyo Electric Power Company Holdings, 30 May 2024, see https://www.tepco.co.jp/en/hd/decommission/information/newsrelease/reference/pdf/2024/reference_20240530_02-e.pdf, accessed 21 August 2024.

1072 - Information and data throughout this section, unless noted otherwise, is based on the following sources: Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water, "Outline of Decommissioning, Contaminated Water and Treated Water Management", Ministry of Economy, Trade and Industry (METI), Government of Japan, 30 May 2024, see https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/mp202405.pdf, accessed 31 July 2024; and Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water, "Outline of Decommissioning, Contaminated Water and Treated Water Management", METI, Government of Japan, 30 May 2024, see https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/mp202405.pdf, accessed 22 July 2024.

1073 - TEPCO, "福島第一原子力発電所1号機　原子炉圧力容器底部温度計測状況 - 廃炉プロジェクト | データ | 東京電力ホールディングス株式会社" ["Fukushima Daiichi Nuclear Power Station Unit 1: Temperature Measurements at the Bottom of the Reactor Pressure Vessel - Decommissioning Project"], 8 August 2024, see https://tinyurl.com/2u3px2se, accessed 8 August 2024.

On 4 December 2023, decontamination of the operating floor and installation of shielding were completed inside the reactor building of Unit 2, and on the southside of the reactor building, installation of a concrete floor of the gantry as well as 43 of 45 gantry units for fuel removal was completed.

Fuel Debris Removal

Regarding the retrieval of fuel debris, the examination of the inside of the primary containment vessel at Unit 2 made progress. At the vessel penetration (X-6 penetration), deposit removal started on 10 January 2024. In addition to uncertainty of future deposit removal, development and deployment of the indispensable robotic arm will take time, as it involves processes such as mockup tests, constructing an access route, and reliability testing. In preparation of fuel removal, shielding has been installed on the top floor of the reactor building since November 2023, concrete placement was completed on 18 March 2024, and partition shielding was installed on 2 April 2024.

Early and representative sampling of fuel debris is needed to determine its characteristics. For this reason, remote-controlled telescopic-type equipment—that was used in past investigations and can be inserted prior to the completion of deposit removal—will be utilized to sample fuel debris. The trial retrieval is scheduled to start as early as August 2024, or October 2024 at the latest.

Apart from these developments, in March 2024, the Sub-Committee for the Evaluation of Fuel Debris Retrieval Methods—whose president is Toyoshi Fuketa, former chairperson of the Nuclear Regulation Authority—of the Nuclear Damage Compensation and Decommissioning Facilitation Corporation proposed three methods for debris retrieval:[1074]

- First, the "partial submersion method" which aims at "retrieving fuel debris exposed to air or immersed at a low water level."
- Second, the "submersion method" which "involves enclosing the entire reactor building with a new structure, called a shell structure, and flooding inside the reactor building to retrieve fuel debris. The water shielding would reduce radiation doses in working areas. The shell structure has a complex support made of three layers of thick steel plates and is designed as containment barrier that could support the loads of the reactor building and cooling water with sufficient seismic resistance."
- Finally, the "partial submersion method option (RPV [reactor pressure vessel] filling and solidification)" which aims at stabilizing the pedestal, filling the reactor pressure vessel with liquid, later solidifying materials, and subsequently retrieving fuel debris and reactor structures using remote operated equipment through a small opening at an operating floor. The solidified part would be recovered by drilling equipment etc., and the unsolidified part by an appropriate remotely operated machine.

The Sub-Committee stressed that it would be necessary for TEPCO to carry out a more detailed engineering study for full-scale retrieval attempts based on these recommendations, stating "In proceeding [with] the engineering study, the first action will be [the] establishment

1074 - Sub-Committee for the Evaluation of Fuel Debris Retrieval Methods, "Report on 'Sub-committee for the Evaluation of Fuel Debris Retrieval Methods', Nuclear Damage Compensation and Decommissioning Facilitation Corporation, 7 March 2024, see https://dd-ndf.s2.kuroco-edge.jp/files/user/pdf/en/committee/pdf/report/20240308reporteFT.pdf, accessed 22 July 2024.

of the organization gathering expertise inside and outside TEPCO and it is also necessary to consider the parties to be involved in constructions of facilities and operations for fuel debris retrievals in the future."

Data gathered from monitoring posts at site boundaries showed radiation levels of 0.3-1.0 microSievert per hour (µSv/h) in the period 24 April–28 May 2024, suggesting no major changes in radiation levels at the plant. As the radiation levels inside the reactor buildings are still extremely high, it has not been possible to carry out measurements at all locations.

Contaminated Water Discharge

TEPCO released approximately 31,200 tons of contaminated water in four rounds during the fiscal year through March 2024. The draft discharge plan for FY2024 includes seven releases for a total volume of water of approximately 54,600 m^3 and total amount of tritium of approximately 14 trillion Bequerel (Bq).[1075] As of mid-July 2024, the third round of releases had been completed (7,846 m^3 with 1.3 trillion Bq of tritium), and the fourth was to commence the same month.[1076]

The generation of contaminated water has been gradually decreasing due to measures such as pumping up water by sub-drains, the construction of land-side frozen walls, and rainwater-infiltration prevention measures, as well as repairing damaged portions of building roofs. As a result, the amount of contaminated water generation in 2023 declined to about 80 m^3/day from 540 m^3/day in FY2014, when the government started considering countermeasures to limit the generation of contaminated water. The decline is also partially due to 13-percent lower rainfall in 2023 (1,275 mm) than in a typical year (1,470 mm). TEPCO plans to further reduce contaminated water generation to 50–70 $m^{3/day}$ by FY2028 through various measures.[1077]

Advanced Liquid Processing Systems (ALPS) are supposed to reduce the concentration of radionuclides, except tritium, to levels below regulatory limits. However, due to malfunction and lower-than-expected ALPS performance, as of 31 March 2024, only about 36 percent (438,400 m^3) of the 1.2 million m^3 of treated water satisfied regulatory standards, and the remaining 64 percent (about 781,700 m^3) needs to be re-purified.[1078] (See Figure 49).

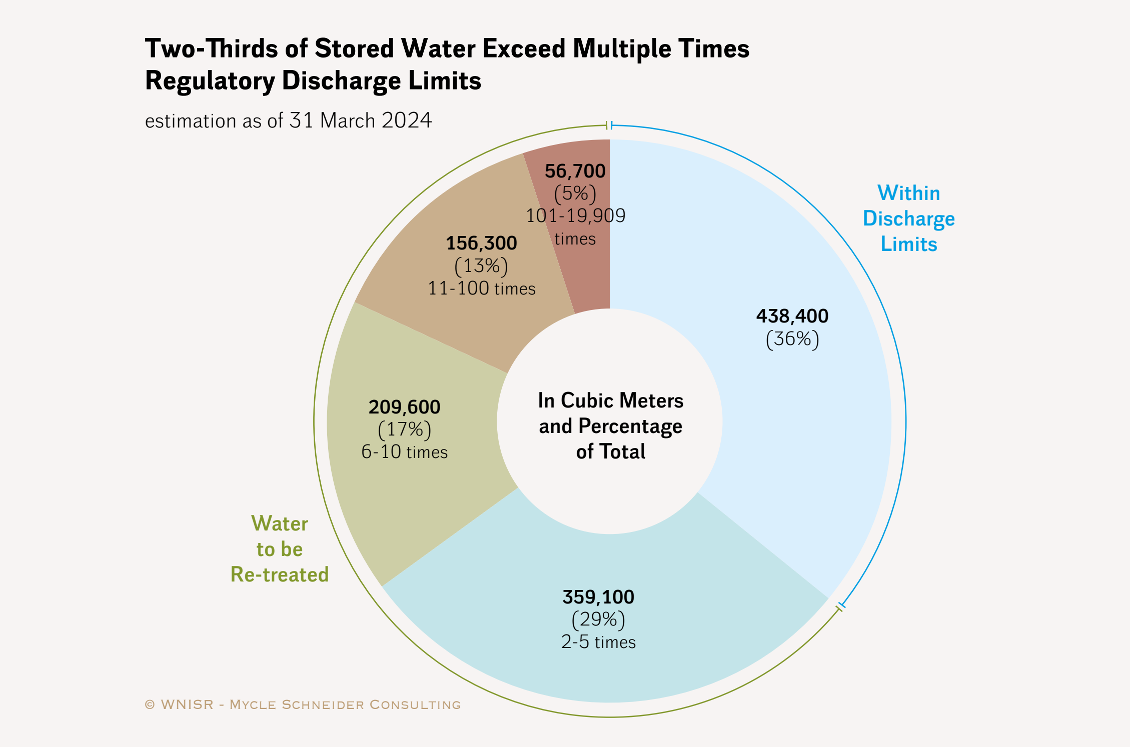
1075 - METI, "Outline of Decommissioning, Contaminated Water and Treated Water Management", 25 January 2024 and 30 May 2024, op. cit.

1076 - TEPCO, "Treated Water Portal Site—Discharge History", 2024, see https://www.tepco.co.jp/en/decommission/progress/watertreatment/performance_of_discharges/index-e.html, accessed 23 July 2024.

1077 - TEPCO, "福島第一原子力発電所の廃止措置等の進捗状況—2023年度 汚染水発生量について" ["Progress of Decommissioning of Fukushima Daiichi Nuclear Power Station—Amount of contaminated water generated in FY2023"], 15 May 2024 (in Japanese), see https://www.tepco.co.jp/decommission/visual/leaflet/pdf/kabeshimbun_20240515.pdf, accessed 21 June 2024.

1078 - TEPCO, "Contaminated Water Portal Site- Radioactive Concentration Contains in ALPS treated water, etc.", as of 11 July 2024, see https://www.tepco.co.jp/en/decommission/progress/watertreatment/alpsstate/index-e.html, accessed 23 July 2024.

Figure 49 · Percentages of Treated Water and Water to be Re-purified



Source: TEPCO Contaminated Water Portal Site, July 2024

Shortly after the beginning of the contaminated water release, China reiterated its opposition to the activity and announced a ban on imports of all seafood products from Japan.[1079] Japan's Prime Minister Fumio Kishida met with Chinese Premier Li Qiang on 26 May 2024 and agreed to accelerate working-level consultations on the discharge activity. Kishida reiterated his call for the immediate lifting of import restrictions on Japanese food products.[1080]

The IAEA established a task force to monitor the releases. The team carried out two review missions in October 2023 and April 2024, during which it "did not identify anything that is inconsistent with the requirements in the relevant international safety standards."[1081]

1079 - *Kyodo News*, "China bans Japan seafood after water release, rallies in Hong Kong, Seoul", 24 August 2023, see https://english.kyodonews.net/news/2023/08/7d810c62b8eb-china-to-boost-radiation-monitoring-after-fukushima-water-release.html, accessed 30 September 2023.

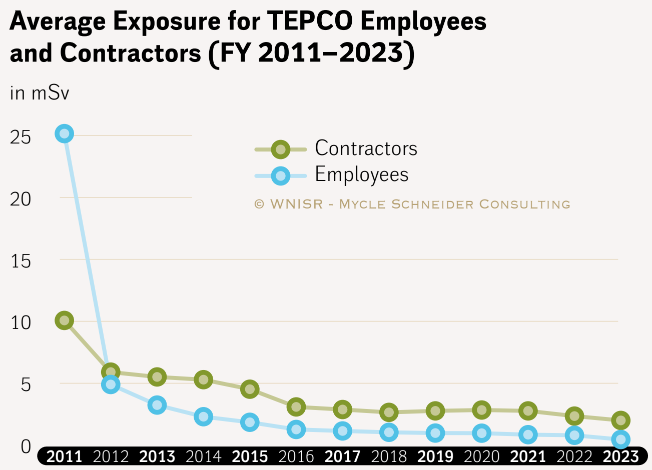
1080 - Kentaro Sugiyama, "岸田首相、日本産食品の輸入規制撤廃求める 日中首脳が会談" ["Prime Minister Kishida Calls for Removal of Import Restrictions on Japanese Food Products, Japan and China Leaders Meet"], *Reuters*, 26 May 2024 (in Japanese), see https://jp.reuters.com/markets/japan/funds/BV74I4ZTIVI6VMLMHRS4NLLMSU-2024-05-26/, accessed 31 May 2024.

1081 - IAEA, "IAEA Review of Safety Related Aspects of Handling ALPS-Treated Water at TEPCO's Fukushima Daiichi Nuclear Power Station—Report 1: Report 1: First Review Mission to Japan after the Start of ALPS Treated Water Discharge (October 2023)", International Atomic Energy Agency, January 2024, see https://www.iaea.org/sites/default/files/first_review_mission_report_after_start_of_alps_treated_water_discharge_oct_23.pdf; and IAEA, "IAEA Review of Safety Related Aspects of Handling ALPS-Treated Water at TEPCO's Fukushima Daiichi Nuclear Power Station—Report on the Mission to Japan conducted in April 2024", July 2024, see https://www.iaea.org/sites/default/files/2024-07-17_mission_report-april_2024.pdf; both accessed 24 July 2024.

Worker Exposure

TEPCO has published data on worker exposure every month since the Fukushima accidents began. According to the latest report for FY2023 (April 2023–March 2024), the average cumulative dose rate for TEPCO employees (1,416 employees) was 0.59 millisievert (mSv), while for contractors (10,529 contractors) it was 2.39 mSv, resulting in a total worker average of 2.18 mSv compared to 2.16 mSv in FY2022 (April 2022–March 2023), see Figure 50.[1082] The maximum estimated dose for a TEPCO employee was 13.92 mSv (11.84 mSv in FY2022), while that for contractors was 17.01 mSv (17.6 mSv in FY2022). As illustrated in Figure 50, contractors typically receive about two to four times higher radiation doses than TEPCO employees.

Figure 50 · Contractors More Exposed to Radiation than TEPCO Staff



Source: TEPCO, 2024

OFFSITE CHALLENGES

Current Status of Evacuation

As of 1 May 2024, 25,959 (27,020 as of May 2023) residents of the Fukushima Prefecture are still living as evacuees (5,908 within the prefecture, 20,046 outside the prefecture, 5 at unknown locations).[1083] The number of evacuees stood at 164,865 in May 2011.

In 2022, evacuation orders were lifted for the first time for parts of the so-called "difficult to return areas" where annual estimated radiation levels are higher than 50 mSv per year. Those areas were designated as "reconstruction and revitalization areas" and receive special government funding. Evacuation orders were lifted for parts of Katsurao Village on 12 June 2022, followed by parts of Okuma Town on 30 June 2022, and Futaba Town on

1082 - TEPCO Holdings, "Evaluation of the exposure dose of workers engaged in radiation work at the Fukushima Daiichi Nuclear Power Station", 30 April 2024, see https://www.tepco.co.jp/en/hd/decommission/information/newsrelease/exposure/pdf/2024/exposure_20240430-e.pdf, accessed 23 July 2024.

1083 - Fukushima Prefectural Government, "Transition of the number of evacuees", 27 June 2024, see https://www.pref.fukushima.lg.jp/site/portal-english/en-1-4-1.html, accessed 19 July 2024.

30 August 2022.[1084] In 2023, evacuation orders were lifted for parts of Tomioka Town on 1 April and 30 November, as well as for parts of Namie Town on 31 March and Iitate Village on 1 May. As a result, "Difficult-to-Return-Zones" now cover about 2.2 percent of the Fukushima Prefecture surface compared to 12 percent in 2012.[1085]

Food Contamination Monitoring

Inspections for food contamination continue, with a total of 43,643 samples analyzed in FY2023 (36,309 in FY2022) of which 162 (135 in FY2022) from 12 prefectures exceeded the radionuclide concentration limit,[1086] according to national data published by the Ministry of Health, Labor and Welfare.[1087] Of these 162 contaminated samples, 86 were from wild animal meat (found in four prefectures), 67 from wild plants and mushrooms (from ten prefectures), 6 products categorized as "others", mainly dried fruits and mushrooms (from three prefectures), and remarkably only two fishery products and one agricultural (all three from Fukushima Prefecture). The nationwide number of analyzed items "drastically decreased in FY2020, due to the conclusion of all-cattle-monitoring in four prefectures, i.e. Iwate, Miyagi, Fukushima and Tochigi."[1088] Further careful independent analysis is needed to determine whether the results provided by the government can be considered representative.

WNISR2023 noted a perplexingly drastic reduction in monitoring despite a growing number of contaminated samples, especially in the Fukushima Prefecture where sampling was more than halved in FY2022, bringing it to a volume below both the Miyagi and Iwate Prefectures that year. In FY2023 however, the number of analyzed samples in Fukushima Prefecture more than doubled over the previous year (from 5,936 to 16,380), thus reaching a volume larger than both Miyagi and Iwate Prefectures *combined*. Despite the very significant increase in testing, the number of identified contaminated products in Fukushima Prefecture decreased from 51 in FY2022 to 48 in FY2023.

Fukushima Prefecture still accounted for the highest number of contaminated items in FY2023. Out of the 48 samples with contamination levels exceeding limits, 39 were wild animal meat (45 in FY2022). While the absolute number of items found to be improper for consumption is low, only 311 analyses on wild animal meat had been conducted in Fukushima Prefecture (115 more than the previous year), meaning that about 12.5 percent of these animal samples were contaminated beyond legal limits (23 percent in FY2022).

1084 - *NHK*, "【解説】東日本大震災・原発事故「帰還困難区域」ゼロからわかる福島のいま 第１１回" ["The Great East Japan Earthquake and Nuclear Power Plant Accident—'Difficult to Return Areas': Understanding the current situation on the ground in Fukushima–Part １１"], 21 February 2023, see https://www.nhk.or.jp/fukushima/lreport/article/000/31/, accessed 3 September 2023.

1085 - Fukushima Prefectural Government, "Transition of the number of evacuees", 27 June 2024, op. cit.; and Fukushima Revitalization Information Portal, "About the Specified Reconstruction and Revitalization Base Areas & the Specified Living Areas for Returnees", Updated 29 March 2024, see https://www.pref.fukushima.lg.jp/site/portal-english/en-1-3-3.html, accessed 15 July 2024.

1086 - The standard value established by the Ministry of Health, Labor and Welfare for the level of radioactive cesium is 100 Bq/kg for food, 10 Bq/kg for drinking water, 50 Bq/kg for milk, and 50 Bq/kg for infant food.

1087 - MHLW, "Sum up of radionuclide test results reported in FY 2023", Ministry of Health, Labor and Welfare, Government of Japan, April 2024, see https://www.mhlw.go.jp/english/topics/2011eq/dl/Sum_up_March_2024.pdf, accessed 31 May 2024; and MHLW, "Sum up of radionuclide test results reported in FY2022", as of 31 March 2023, see https://www.mhlw.go.jp/english/topics/2011eq/dl/Sum_up_March_2023.pdf, accessed 23 July 2024.

1088 - Pharmaceutical Safety and Environmental Health Bureau, "Radionuclides in foods—Current situation and protective measures", Ministry of Health, Labour and Welfare, Government of Japan, see https://www.mhlw.go.jp/english/topics/2011eq/dl/food-130926_1.pdf, 2022, accessed 20 July 2023.

By comparison, Gunma Prefecture had only one less excessively contaminated item than Fukushima Prefecture, even though only 787 samples were analyzed there compared to 16,380 in Fukushima. This suggests that a high number of contamination cases may be found if much larger numbers of samples were tested in Gunma.[1089] The various paradoxes, the discrepancies in sampling over time, and the relatively low number of analyzed samples throughout Japan raise questions about the representativity of the data.

As of 30 May 2024, 49 countries, regions and territories had dropped import restrictions imposed after the beginning of the Fukushima disaster in 2011. Still, six countries (or regions) including Russia, China, Hong Kong, Macao, South Korea, and Taiwan maintain import restrictions. Russia is requiring test certificates for all food items from some prefectures. China, Hong Kong, Macao, South Korea, and Taiwan suspended imports from some prefectures. In addition, after the contaminated water release from Fukushima Daiichi started, China and Russia banned imports of all fishery products from all prefectures. Hong Kong banned the import of fishery products from 10 prefectures, while Macao suspended imports of fresh produce from 10 prefectures.[1090]

Decontamination and Contaminated Soil

Decontamination work for the Special Decontamination Area of Fukushima Prefecture[1091] under the direct control of the national government was completed in March 2018. However, the reality is that decontamination has only been conducted over a small percentage of the overall contaminated land area.[1092]

The effectiveness of the decontamination operations remains questionable as 71 percent of the Fukushima Prefecture is forested, and decontamination was done only for areas within 20 meters of the so-called "living areas". So only 2 percent of the area designated for decontamination was actually decontaminated. Limited storage capacity for decontaminated soil also restricted the overall decontamination targets. Another issue is the dismantlement and removal of contaminated and/or damaged houses. As of August 2020, 69 percent of houses that were requested to be dismantled were actually demolished.[1093] More recent numbers could not be identified.

Decontamination in the designated reconstruction and revitalization base area has been underway since December 2017, but only the status of construction orders has been disclosed

1089 - MHLW, "Sum up of radionuclide test results reported in FY 2023", as of 31 March 2024, op. cit.; and MHLW, "Sum up of radionuclide test results reported in FY2022", as of 31 March 2023, op. cit.

1090 - Ministry of Agriculture, Forestry and Fisheries, "原発事故に伴う諸外国・地域の食品等の輸入規制の概要" ["Overview of import restrictions on food and other products following the nuclear power plant accident"], 30 May 2024 (in Japanese), see https://www.maff.go.jp/j/export/e_info/attach/pdf/hukushima_kakukokukensa-71.pdf, accessed 31 May 2024.

1091 - A high dose area within a 20-km radius of the power plant, located around the difficult-to-return zone.

1092 - Aaron Clark, "Decade after Fukushima disaster, Greenpeace sees cleanup failure", *Bloomberg*, as published by *The Japan Times*, 4 March 2021, see https://www.japantimes.co.jp/news/2021/03/04/national/fukushima-greenpeace-radiation-health-3-11/; Greenpeace East Asia, "Fukushima Daiichi 2011-2021: The decontamination myth and a decade of human rights violations", March 2021, see https://www.greenpeace.org/static/planet4-japan-stateless/2021/03/ff71ab0b-finalfukushima2011-2020_web.pdf; both accessed 19 August 2021.

1093 - Kota Kawasaki, "除染に関する課題と教訓ー 福島原発事故から 10 年目を迎えて" ["Issues and Lessons Concerning Decontamination—Ten Years after Fukushima Nuclear Power Pant Accident"], Proceedings of Japan Association for Disaster Recovery, No. 18July 2021 (in Japanese), see https://www.jstage.jst.go.jp/article/jsdrr/18/0/18_1/_pdf.

as the progress of the decontamination. As of October 2020, the ratio of the area ordered for decontamination to the area designated for reconstruction and revitalization reached 100 percent in Katsurao Village, but only about 60–80 percent in five other municipalities.[1094] Again, these numbers could not be updated.

The biggest issue is what to do with the huge amount of contaminated soil shipped to interim storage sites. The government designated a total of 1,600 hectares of land as "interim storage sites", and as of May 2022, 80 percent of the area (1,286 ha) had been "contracted" for the establishment of storage facilities.[1095] As of mid-2024, four out of a total of ten storage facilities were saturated (i.e. stored to capacity), and about 90 percent of total storage capacity is now filled with decontaminated soil (see Table 10).[1096]

Table 10 · Status of Interim Storage Facilities for Decontaminated Soil as of 30 June 2024

Area	Okuma-1	Okuma-2	Okuma-3	Okuma-4	Okuma-5	Futaba-1	Futaba-2	Futaba-3	Total
Number of facilities	1	2	1	1	1	2	1	-	10
Storage Capacity (106 m^3)	1.0	3.3	2.1	1.6	2.0	1.4	0.9	0.8	13.1 (100%)
Stored amount (106 m^3)	1.07	2.92	1.49	1.57	2.13	1.01	0.93	0.66	11.78 (89.9%)
Status of facility	Completed (December 2022)	Completed (October 2023)	Completed (November 2023)	Completed (November 2023)	Completed (January 2024)	Completed (February 2024)	Completed (October 2022)	Operating	

Source: Ministry of the Environment, 2024[1097]

In order to reduce the final volume of decontaminated soil to be disposed of, in 2016, the government published a plan to "reuse" such soil which is considered "safe" for certain purposes.[1098] Demonstration projects have been conducted in Minami-soma and Iidate Village, Fukushima Prefecture.[1099] The Ministry of the Environment planned to start a demonstration project, outside of Fukushima Prefecture, for the first time, at Saitama Prefecture's "Environmental Research and Training Center" by the end of FY2022, but eventually decided to postpone the project due to opposition from the local population. The Mayor of Tokorozawa city of the Saitama Prefecture has expressed disapproval of the plan, as the majority of local neighborhood associations were opposed to it.[1100] Since the residents of other localities strongly oppose reusing decontaminated soil from Fukushima Prefecture, the Environment Ministry

1094 - Ibidem.

1095 - Ministry of the Environment, "中間貯蔵施設の概要" ["Outline of Interim storage facilities"], Government of Japan, March 2023 (in Japanese), see http://josen.env.go.jp/chukanchozou/about/#section03, accessed 26 June 2023.

1096 - Ministry of the Environment, "中間貯蔵施設の整備の現状" ["Current Status of Interim Storage Facilities"], Government of Japan, 30 June 2024 (in Japanese), see https://josen.env.go.jp/plaza/info/data/pdf/data_2407_04.pdf#page=2, accessed 25 July 2024.

1097 - Ministry of the Environment, "Current Status of Interim Storage Facilities", 25 July 2024, op. cit.

1098 - Ministry of the Environment, "除去土壌の再生利用について" ["Regarding the Reuse of Decontaminated Soil"], Undated (in Japanese), see http://josen.env.go.jp/chukanchozou/facility/recycling/, accessed 26 June 2023.

1099 - Ministry of the Environment, "What Does 'Recycling of Removed Soil' Mean?", October 2022, see http://josen.env.go.jp/chukanchozou/material/pdf/removed-soil_recycling-en_2205.pdf, accessed 19 July 2023.

1100 - *NHK*, "Reuse of decontaminated soil Demonstration project outside Fukushima Prefecture Postponed to start before the end of fiscal year", as published on *Teller Report*, 25 February 2023, see https://www.tellerreport.com/life/2023-02-24-reuse-of-decontaminated-soil-demonstration-project-outside-of-fukushima-prefecture-postponed-to-start-before-the-end-of-the-fiscal-year.B1DNJoUoj.html, accessed 26 June 2023.

intends to develop standards for recycling or final disposal of decontaminated soil by the end of FY2024 following an assessment by the International Atomic Energy Agency (IAEA).[1101]

Legal Cases, Resident Health, Compensation

After the Supreme Court decision in 2022, (see detailed explanation in WNISR2022 – Fukushima Status Report), several lower court decisions in 2023 also ruled out government responsibility:

- On 22 November 2023, the Nagoya High Court ruled that the government is not responsible in a lawsuit filed by residents, who were forced to evacuate to the Tokai region due to the accidents at TEPCO's Fukushima plant, seeking compensation from the government and TEPCO. This followed the Supreme Court's ruling in June 2022 over a similar lawsuit. The court found that the "long-term assessment" of earthquake forecasts published by the government in 2002 was credible. In addition, it was considered "highly likely" that in the case of appropriate government orders, TEPCO would have had to implement preemptive measures such as the installation of seawalls. However, since the tsunami of 2011 was much larger than expected, it was concluded that even if seawalls had been installed, "it cannot be recognized that the accident could have been avoided." However, TEPCO was found liable for a total of about ¥319 million (US$$_{2023}$2.3 million) in compensation to 120 residents.[1102]
- On 22 December 2023, in the judgment of a trial filed by people evacuated to Chiba Prefecture that suffered mental anguish due to the Fukushima accidents, the Tokyo High Court also ordered TEPCO to pay compensation but did not recognize the government's responsibility either. Following the first trial, the Tokyo High Court rejected the government's liability, stating that "even if the government had obliged TEPCO to take tsunami countermeasures based on a long-term earthquake assessment and even if TEPCO had taken countermeasures, there is a considerable possibility that a nuclear accident caused by a tsunami would have occurred." On the other hand, the court ordered TEPCO to compensate 16 of the plaintiffs for a total of ¥4.4 million (US$$_{2023}$31,000) as compensation for their lives under evacuation orders.[1103]
- Four days later, on 26 December 2023, the Tokyo High Court revoked part of the Tokyo District Court's 2018-ruling that found the government and TEPCO liable and ordered both sides to pay a total of approximately ¥59 million (US$$_{2018}$534,000) in an appeal ruling in a lawsuit filed by 47 people who evacuated from Fukushima Prefecture to Tokyo and other areas due to the accidents at Fukushima Daiichi. While the Tokyo High Court rejected

1101 - *Fukushimaminpo* "「除染土壌の県外処分」２０２４年度中の基準策定へ７項目要点案　環境省が初めて示す" ["Ministry of the Environment presents for the first time a seven-point proposal for establishing standards for "out-of-prefecture disposal of decontaminated soil" by the end of FY2024"], 13 January 2024 (in Japanese) see https://www.minpo.jp/news/moredetail/20240113113724, accessed 3 June 2024.

1102 - *Asahi Shimbun*, "福島原発事故、国の責任認めず　名古屋高裁、最高裁判断を踏襲" ["Fukushima Nuclear Power Plant Accident, Refusing to Recognize Government's Responsibility, Nagoya High Court Follows Supreme Court Decision "], 22 November 2023 (in Japanese), see https://www.asahi.com/articles/ASRCQ6S1GRCKOIPE005.html, accessed 31 May 2024; and *Jiji Press*, "High Court Rejects N-damages Claim against Govt", as published by *The Japan News/The Yomiuri Shimbun*, 23 November 2023, see https://japannews.yomiuri.co.jp/society/crime-courts/20231123-151208/, accessed 24 July 2024.

1103 - *NHK Chiba News Web*, "Chiba Genpatsuhinansyasosyo 2shin mo kuni no sekininmitomezu, Tokyokosai" ["Nuclear Power Plant Evacuees in Chiba Prefecture Lawsuit 2nd Trial Fails to Recognize Responsibility of the Government, Tokyo High Court "], 22 December 2023 (in Japanese), see https://www3.nhk.or.jp/lnews/chiba/20231222/1080022451.html, accessed 31 May 2024.

the claims against the government, it ordered TEPCO to pay a total of about ¥23.5 million (US$$_{2023}$167,000) in compensation to 44 of the 47 plaintiffs.[1104]

As of 31 May 2024, the total compensation amount paid out by TEPCO is ¥11,143 billion (~US$$_{2024}$71 billion).[1105]

CONCLUSION

The main onsite and offsite challenges of the Fukushima disaster remain similar to what they have been throughout the past 12 years (see Table 11 for a progress overview). One of the most controversial issues onsite is the commencement of discharge of contaminated water containing tritium and other radionuclides into the sea. For offsite issues, legal challenges against both the government and TEPCO continue. The lower and high court decisions tend to follow the June 2022 decisions made by the Supreme Court denying any liability of the government. Still, the courts ordered TEPCO to pay symbolic amounts of compensation to plaintiffs. Although three senior executives were acquitted in the criminal case, TEPCO's legal responsibility in civil cases seemed unavoidable.

Table 11 · Overview of Status of the Decommissioning

	Spent Fuel Remaining in Pools (in tons)					Contaminated Water Generated (tons/day)	Debris Removal (tons/year)	Number of Evacuees	Estimated Total Cost (¥ Trillion)
	Unit 1	Unit 2	Unit 3	Unit 4	Total				
2011	392	615	566	1,535	3,108	900	0	159,168	5.7
2015	392	615	566	Removal Completed in 2014	1,573	540	0	120,300	11.6
2020	392	615	Removal Completed in 2017	0	1,007	140	0	41,099	21.5
2024	392	615	0	0	1,007	80	0	26,272	23

Sources: Compiled by WNISR, with TEPCO and METI, Various years

1104 - Mari Yamaguchi, "Tokyo court only holds utility responsible to compensate Fukushima evacuees and reduces damages", *The Associated Press*, 27 December 2023, see https://apnews.com/article/japan-fukushima-nuclear-ruling-evacuees-compensation-tepco-a844a85ecdff3e2526e81e242d4c89ed, accessed 24 July 2024.

1105 - TEPCO, "賠償金のお支払い状況—原子力損害賠償のご請求・お支払い等" ["Current status of Compensation paid so far— Claims and Payment for Nuclear Damage Compensation, etc."], Tokyo Electric Power Co Holdings, 31 May 2024 (in Japanese), see https://www.tepco.co.jp/fukushima_hq/compensation/results/, accessed 31 May 2024.

DECOMMISSIONING STATUS REPORT

INTRODUCTION

In mid-2024, 213 nuclear power reactors were closed, corresponding to over 106 GW of permanently retired capacity. This compares with 408 operating reactors and 34 in Long-Term Outage (LTO). Thus, almost one third of the reactors connected to the grid in the past 70 years have been retired.

Decommissioning nuclear power plants is an important, and often overlooked, element of the nuclear electricity system. Defueling, deconstruction, and dismantling—summarized by the term decommissioning—are the final steps in the operational cycle of a nuclear power plant (excluding waste management and disposal). The process is technically complex and poses major challenges in terms of long-term planning, implementation, and financing. In the first decades of the nuclear age, decommissioning was hardly considered in the reactor design. The costs for decommissioning at the end of the lifetime of a reactor were usually discounted away, and thus largely ignored. However, as a growing number of nuclear facilities either reach the end of their operational lifetimes or have already been closed, the challenges of reactor decommissioning are increasingly attracting stakeholder and public attention.

Elements of National Decommissioning Policies

When analyzing decommissioning policies, one needs to distinguish between the process itself (in the sense of the actual implementation) and the financing. To provide a general and globally applicable overview of the progress of nuclear decommissioning, WNISR has been classifying technical decommissioning into three main stages since WNISR2018. This is necessary due to the heterogeneous nature of decommissioning regulations around the world.[1106] The three stages are defined as follows:

- The **warm-up stage** comprises the post-operational stage and the dismantling of systems that are not needed for the decommissioning process. In addition, the dismantling of higher contaminated system parts begins, including the defueling of the reactor which is crucial for any further undertakings and means removing the spent fuel from the reactor core and the spent fuel pools.
- The **hot-zone stage** comprises the dismantling activities in the hot zone, i.e., the dismantling of highly contaminated or activated parts, e.g. the reactor pressure vessel (RPV) and its internals (RVI), and the biological shield.
- The **ease-off stage** comprises the removal of operating systems as well as decontamination of the buildings. This stage concludes with the end of physical demolition work.

1106 - IAEA and European Commission, "A Taxonomy for the Decommissioning of Nuclear Facilities", International Atomic Energy Agency, with Nuclear Energy Agency, Organization for Economic Co-Operation and Development, December 2023, see https://www-pub.iaea.org/MTCD/Publications/PDF/TE-2029web.pdf, accessed 24 July 2024.

After physical demolition is completed—as far as reported by the owner or the licensing authorities—WNISR classifies reactors as "completed". This does not necessarily reflect the license termination of the site. Generally, a site can be released from regulatory oversight as a greenfield site for unrestricted use, or it can be qualified as a brownfield site in which some infrastructure remains for further nuclear or other industrial use. Different countries require different types of end-states for full license termination.[1107] WNISR classifies sites that have been partially released from regulatory oversight but still operate nuclear facilities on site, e.g., interim spent fuel and waste storage infrastructure, as brownfield sites.

The technical procedure of physically dismantling nuclear reactors, following the three stages described above, can begin after varying amounts of time following nuclear power plant closure. This depends on the strategy the operator chooses. The options include:

- *immediate dismantling*, which is characterized by a seamless transition to decommissioning activities after reactor closure,
- *deferred dismantling*, where reactors are placed into Long-term Enclosure (LTE) for several years to decades to allow for radiation levels to decline before decommissioning begins, and
- *entombment*, characterized by LTE (50 years or more) that can sometimes become permanent.

Most countries have adopted variations of these strategies, although some, like France or Germany, have placed restrictions on which strategy may be applied.[1108]

With respect to financing, five main approaches are observable: public budget, external segregated fund, internal non-segregated fund, internal segregated fund, and surety methods such as guarantees (for more details, see WNISR2018).[1109]

The goal of this chapter is to provide a global overview of nuclear decommissioning. However, information on the status and progress at individual sites can be non-transparent and available data can change over time. This may lead to simplifications regarding the classification of individual sites and reactors into different stages of the decommissioning process. WNISR aims to provide full access to the basis of our assessments and has in the past, when uncertainty arose, communicated individual classification decisions and potential statistical changes, and will continue to do so.

1107 - Rebekka Bärenbold, Muhammad Maladoh Bah et al., "Decommissioning of commercial nuclear power plants: Insights from a multiple-case study", *Renewable and Sustainable Energy Reviews*, Vol. 201, September 2024, see https://linkinghub.elsevier.com/retrieve/pii/S1364032124003472, accessed 24 July 2024.

1108 - Ibidem; and Stefan Thierfeldt, "Safe enclosure and entombment strategies in nuclear decommissioning projects", Brenk Systemplanung, in "Nuclear Decommissioning—Planning, Execution and International Experience", ed. Michele Laraia, *Woodhead Publishing*, 2012, see https://linkinghub.elsevier.com/retrieve/pii/B9780857091154500117, accessed 6 May 2024; also Tim Scherwath, Ben Wealer and Roman Mendelevitch, "Nuclear decommissioning after the German Nuclear Phase-Out an integrated view on new regulations and nuclear logistics", *Energy Policy*, 2020, see https://linkinghub.elsevier.com/retrieve/pii/S0301421519307128, accessed 8 January 2020.

1109 - Alexander Wimmers, Rebekka Bärenbold et al., "Decommissioning of Nuclear Power Plants: Regulation, Financing, and Production", Data Documentation 104, DIW Berlin, Deutsches Institut für Wirtschaftsforschung/German Institute for Economic Research, January 2023, see https://www.diw.de/documents/publikationen/73/diw_01.c.864222.de/diw_datadoc_2023-104.pdf, accessed 26 January 2023.

GLOBAL OVERVIEW

Decommissioning Worldwide

As of 1 July 2024, a worldwide total of 213 reactors, corresponding to 106.2 GW of capacity, have been closed. Since WNISR2023, one additional reactor, the second reactor at the Kursk-1 plant in Russia (900 MW) has been closed.

Of the total number of closed units, 62 percent are located in Europe (105 in Western Europe and 26 in Central and Eastern Europe), 22 percent in North America (47), and 16 percent in Asia (35).

Almost four in five or 168 reactors used one of these three technologies:

- Pressurized Water Reactors (PWRs) with 69 units or 32 percent,
- Boiling Water Reactors (BWRs) with 55 units or 26 percent, and
- Gas-Cooled Reactors (GCRs) with 44 units or 21 percent, the majority (33 units) of which are located in the U.K.

Table 12 provides an overview of the closed reactors worldwide. The table also includes the number of defueled reactors and those that are released from regulatory supervision, i.e., either as full greenfield sites or as brownfield. The Decommissioning Status Report, as the WNISR in general, exclusively covers reactors that have generated electricity and were connected to the grid. Thus, it does not cover research reactors that were not connected to the grid.

The number of facilities that will be affected will increase significantly: assuming a 40-year average lifetime, a further 120 reactors will close by 2030

Decommissioning plays an important and increasing role in nuclear politics, both in the timing and production process and the financing thereof. The number of facilities that will be affected will increase significantly: assuming a 40-year average lifetime, a further 120 reactors will close by 2030 (reactors connected to the grid between 1984 and 1990) and an additional 153 will be closed by 2064 (reactors connected 1991–2024). This does not account for the 134 reactors that have already been operating for more than 40 years (connected to the grid prior to 1984), an additional 34 reactors in Long-term Outage (LTO), and the 59 reactors under construction as of mid-2024 (see Figure 21, Figure 22 and Figure 23).

Table 12 · Overview of Reactor Decommissioning Worldwide (as of 1 July 2024)

Country	Closed Reactor	Decommissioning Status					
		Warm-up[a] (of which defueled)	Hot Zone	Ease-off	LTE	Completed (of which released as greenfield sites[b])	Completed Share of Total Closed (share of total closed released as greenfield sites[b])
U.S.[c]	41	4 (4)	6	4	10	17 (5)	41% (12%)
U.K.	36	21 (14)	9	0	6	0	0%
Germany	36	11 (5)	11	9	1	4 (3)	11% (8%)
Japan	27	26 (5)	0	0	0	1 (1)	4% (4%)
France	14	3 (0)	3	0	8	0	0%
Russia	11	4 (3)	0	0	7	0	0%
Sweden	7	2 (0)	5	0	0	0	0%
Canada	6	1 (1)	0	0	5	0	0%
Bulgaria	4	4	0	0	0	0	0%
Italy	4	2 (1)	2	0	0	0	0%
Taiwan	4	4	0	0	0	0	0%
Ukraine	4	0	0	0	4	0	0%
Slovakia	3	1 (1)	0	2	0	0	0%
Belgium	3	2	0	1	0	0	0%
Spain	3	1	0	0	1	1	33%
Lithuania	2	2 (2)	0	0	0	0	0%
South Korea	2	2	0	0	0	0	0%
Armenia	1	0	0	0	1	0	0%
India	1	1 (1)	0	0	0	0	0%
Kazakhstan	1	0	0	0	1	0	0%
Netherlands	1	0	0	0	1	0	0%
Pakistan	1	1 (0)	0	0	0	0	0%
Switzerland	1	1 (1)	0	0	0	0	0%
Total	**213**	**93 (38)**	**36**	**16**	**45**	**23 (9)**	**10% (4%)**

Sources: Various, compiled by WNISR, 2024

Notes:

(a) Reactors classified as being in the “post-operational” stage in WNISR2023 have been added to the warm-up stage.

(b) As of WNISR2024, the “Released” category only contains “greenfield released” reactors, whereas it also contained “brownfield released” reactors in previous editions (see definitions in the introduction of the chapter).

(c) The Palisades reactor in the U.S. is currently being considered for restart. As parts of the site have already been dismantled, WNISR considers the reactor in the warm-up stage until the restart is officially confirmed.

Overview of Reactors with Completed Decommissioning

As of mid-2024, 190 units globally are awaiting or in various stages of decommissioning, the same number as in WNISR2023. Since mid-2023, one additional reactor, the José Cabrera reactor in Spain, has completed the technical decommissioning process.

Of the 23 decommissioned reactors, 21 have been released from regulatory oversight, nine of those as greenfield sites (see Figure 51). Except for José Cabrera, the sites released as brownfield sites are all located in the U.S., and apart from the Shoreham reactor, all currently host interim waste storage facilities.

The average duration of the decommissioning process, independent of the chosen strategy, is around 20 years, with a very high variance: the minimum being six years for the 22-MW Elk River plant, and the maximum at 45 years for the 63-MW reactor at Humboldt Bay, both in the U.S.

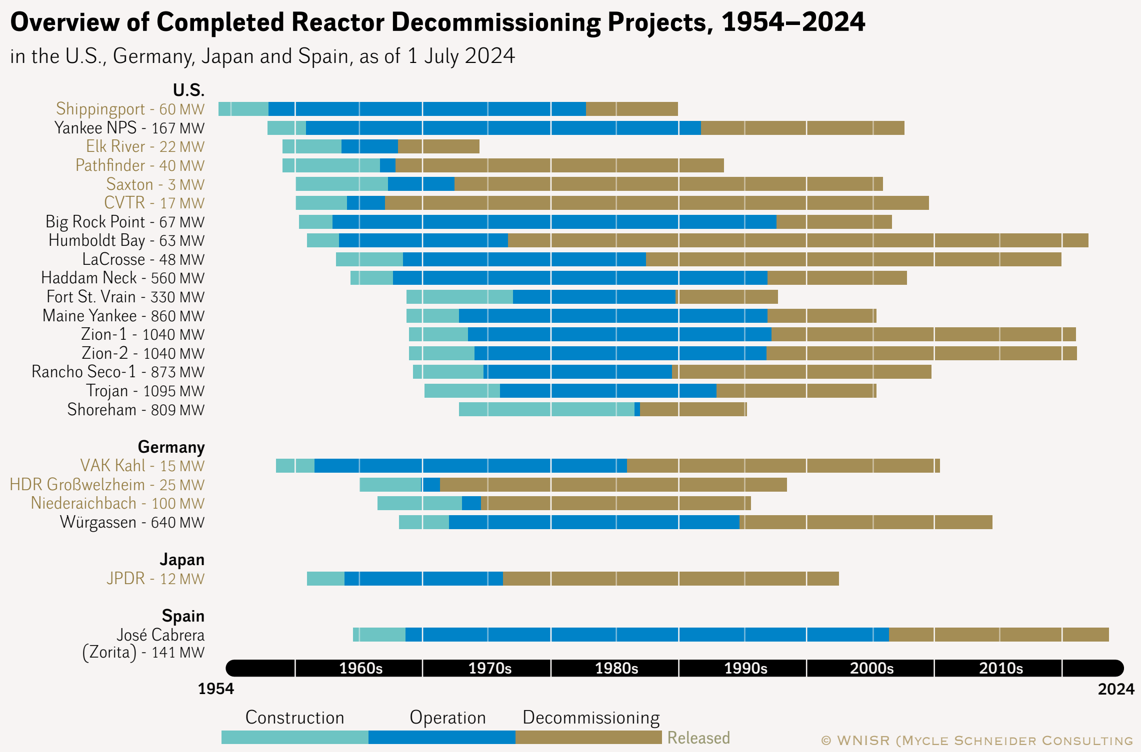
Only four countries amongst the 23 with closed power reactors have completed the technical decommissioning process of at least one reactor: the United States (17 units), Germany (4), Japan (1), and Spain (1). Some of the reactors that were most rapidly decommissioned are located in the U.S. In Germany, the HDR (Heißdampfreaktor, a superheated-steam reactor) Großwelzheim was only on the grid for one year, but decommissioning lasted well over 20 years. The German Würgassen reactor has de facto completed the technical decommissioning process but, legally, cannot be released from regulatory control as the buildings are being used for interim storage of wastes.[1110] In Japan, the only reactor to be decommissioned was a small 10-MW demonstration plant (JPDR), whereas none of the large commercial reactors has been decommissioned yet.[1111] It took over 17 years to decommission the José Cabrera reactor, Spain's first PWR that operated from 1968 to 2006.[1112] Figure 51 provides the timelines of the 23 reactors that have completed the decommissioning process.

1110 - Ines Bredberg, Johann Hutter et al., "Statusbericht zur Kernenergienutzung in der Bundesrepublik Deutschland 2018", Bfe-KE-04/19, Bundesamt für kerntechnische Entsorgungssicherheit/Federal Office for the Safety of Nuclear Waste Management (in German), 2019, see https://doris.bfs.de/jspui/bitstream/urn:nbn:de:0221-2019081919007/3/BfE-KE-04_19_Statusbericht_zur_Kernenergienutzung_2018_Rev.pdf, accessed 20 July 2023.

1111 - JAIF, "Current Status of Nuclear Power Plants in Japan", Japan Atomic Industrial Forum, as of 8 May 2024, see https://www.jaif.or.jp/cms_admin/wp-content/uploads/2024/05/jp-npps-operation20240508_en.pdf, accessed 19 August 2024.

1112 - Enresa, "Dismantling of the Jose Cabrera Nuclear Power Plant", Empresa Nacional de Residuos Radiactivos S.A./National Radioactive Waste Management Agency of Spain, 2024, see https://www.enresa.es/eng/index/activities-and-projects/dismantling-and-environmental-restoration/dismantling-of-the-jose-cabrera-nuclear-power-plant, accessed 18 August 2024.

Figure 51 · Overview of Completed Reactor Decommissioning Projects, 1954–2024



Sources: Various, compiled by WNISR, 2024

Note: As of WNISR2024, the "Released" category only contains "greenfield released" reactors, whereas it also contained "brownfield released" reactors in previous editions (see definitions in the introduction of the chapter). The LaCrosse and Shoreham reactors had in previous WNISR editions been classified as "greenfield released". However, the site at LaCrosse still contains an interim spent-fuel storage facility and is thus reclassified as a brownfield site, and while the Shoreham reactor was released from regulatory oversight, it was never dismantled and most buildings have remained intact.

Overview of Ongoing Reactor Decommissioning

This section contains a brief overview of the decommissioning status in the countries that have not been analyzed in more detail in the case studies of this or previous WNISR editions.

Following a partnership agreement with the European Union, the **Armenian** Medzamor nuclear power plant is to be completely closed as soon as possible due to safety concerns because the plant "cannot be upgraded to fully meet internationally accepted safety standards."[1113] Unit 1 had already been closed in 1989 after an earthquake, leaving one unit in operation. A pilot decommissioning project by former Rosatom subsidiary Nukem Technologies (now owned by Japanese investors),[1114] German state-owned company EWN, and

1113 - High Representative of the Union for Foreign Affairs and Security Policy, "Partnership Implementation Report on Armenia", Joint Staff Working Document, European Commission, 16 December 2020, see https://www.eeas.europa.eu/sites/default/files/armenia_partnership_implementation_report_2020.pdf, accessed 8 June 2022.

1114 - NUKEM, "NUKEM Technologies Acquisition Contract Signed by Japanese Investor", Press Release, 8 July 2024, see https://www.nukemtechnologies.de/en/news/nukem-technologies-acquisition-contract-signed-by-japanese-investor, accessed 9 July 2024.

U.S.-Australian WorleyParsons was launched in 2014.[1115] Since the addition of the project to Nukem's website in 2022, supposedly to document its completion process, there have been no publicly communicated updates regarding the progress at Unit 1, and thus, WNISR considers the reactor to be in LTE until actual dismantling begins. While Unit 2 is licensed to operate until 2026,[1116] Russia's Rosatom was contracted in December 2023 to modernize the plant and further extend its lifetime to 2036.[1117]

In **Belgium**, the prototype 10-MW reactor BR-3 in Mol, that was closed in 1987, is currently undergoing decommissioning. The reactor is in the ease-off stage[1118] and is used as a lead-and-learn site for future decommissioning projects.[1119] On 13 December 2023, utility and nuclear operator Engie signed a final agreement with the Belgian Government to extend the operational lifetime of two of the five (Doel-4 and Tihange-3) currently still operational reactors by ten years (counted from the restart date).[1120] The two reactors are to be shut down in 2025 for modernization and then restarted in November 2026.[1121] The agreement includes a cap of nuclear waste management costs of €15 billion (US$16.2 billion) to be paid by Engie.[1122] Decommissioning cost obligations estimated at €18 billion (US$$_{2021}$21.3 billion)[1123] will remain with Engie.[1124] The other three reactors will close by 2025 following the closures of

1115 - Nordic Market, "EWN: Energiewerke Nord-Know-how aus Mecklenburg-Vorpommern auch in Armenien gefragt", Press Release (in German), 21 March 2014, archived via Wayback Machine, 27 June 2021, see https://web.archive.org/web/20190627173521/https://www.nordic-market.de/news/14210/ewn_energiewerke_nord-know-how_aus_mecklenburg-vorpommern_auch_in_armenien_gefragt.htm, accessed 5 August 2024; and Nukem Technologies, "Pilot-Stilllegungsprojekt für das Kernkraftwerk Metsamor", Undated (in German), see https://www.nukemtechnologies.de/projekte/am/pilot-stilllegungsprojekt-fuer-das-kernkraftwerk-metsamor, accessed 8 June 2022.

1116 - IAEA, "IAEA Concludes Long Term Operational Safety Review at the Armenian Nuclear Power Plant", Press Release 69/2021, International Atomic Energy Agency, 4 November 2021, see https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-at-the-armenian-nuclear-power-plant, accessed 18 August 2024.

1117 - Armenian Nuclear Power Plant, "A Joint Armenian-Russian Contract Has Been Signed", 15 December 2023, see https://armeniannpp.am/en/info/noroutyounner/storagrvel-e-hay-rousakan-hamatex-paymanagir.html, accessed 18 August 2024.

1118 - SCK CEN, "Pioneering work with demolition plan and international expertise", Studiecentrum voor Kernenergie/Centre d'étude de l'énergie nucléaire/Belgian Nuclear Energy Research Center, 2022, see https://www.sckcen.be/en/about-sck-cen/annual-reports/highlights-2022/highlights-2022-dismantling-and-waste/pioneering-work-demolition-plan-and-international-expertise, accessed 30 August 2023.

1119 - Wouter Broeckx, Sven Boden et al., "Decommissioning of the BR3 biological shield: How a proper data analysis facilitates the D&D process", 15 September 2021, presented at "DEM 2021 International Conference on Decommissioning Challenges: Industrial Reality, Lessons Learned and Prospects", Société française d'énergie nucléaire/French Society for Nuclear Power, European Nuclear Society, 13–15 September 2021, see https://publications.sckcen.be/portal/en/publications/decommissioning-of-the-br3-biological-shield-how-a-proper-data-analysis-facilitates-the-dd-process(b1c1354d-e0ac-47d2-9784-595b60c12f0b).html; and SCK CEN, "Dismantling and decontamination", Undated, see https://www.sckcen.be/en/expertises/technology/dismantling-and-decontamination; both accessed 8 June 2022.

1120 - ENGIE, "Nuclear: A Major Step Forward", 19 January 2024, see https://www.engie.com/en/news/nuclear-in-belgium#:~:text=ENGIE%2C%20via%20its%20subsidiary%20Electrabel,which%20Electrabel%20is%20dismantling%20responsibly, accessed 18 April 2024.

1121 - Geert De Clercq and Charlotte van Campenhout, "Belgium to extend life of two nuclear reactors by 10 years", *Reuters*, 9 January 2023, see https://www.reuters.com/business/energy/belgium-extend-life-two-nuclear-reactors-by-10-years-2023-01-09/, accessed 16 June 2023; and AFCN/FANC, "Exploitation à long terme (LTO) de Doel 4 et Tihange 3 jusqu'en 2035", Agence fédérale de Contrôle nucléaire/Federal Agency for Nuclear Control of Belgium, Updated 23 February 2024 (in French), see https://afcn.fgov.be/fr/dossiers/centrales-nucleaires-en-belgique/exploitation-long-terme-lto-de-doel-4-et-tihange-3-jusquen, accessed 18 August 2024.

1122 - ENGIE, "ENGIE signs an agreement with the Belgian government on the extension of Tihange 3 and Doel 4 nuclear reactors and all obligations related to nuclear waste", Press Release, 2023, see https://corporate.engie.be/en/press/release/engie-signs-agreement-belgian-government-extension-tihange-3-and-doel-4-nuclear, accessed 21 July 2023.

1123 - Andreas Kockartz, "Der Rückbau der belgischen Kernkraftwerke kostet mindestens 18 Mia. €", *Belga*, as published by *vrt* (in German) June 2021, see https://www.vrt.be/vrtnws/de/2021/06/30/der-rueckbau-der-belgischen-kernkraftwerke-kostet-mindestens-18/, accessed 10 June 2022.

1124 - *Reuters*, "Belgium to Extend Life of Two Nuclear Reactors by 10 Years", 9 January 2023, op. cit.

Doel-3 on 23 September 2022 and of Tihange-2 on 31 January 2023[1125] (see Belgium Focus). At both reactors, defueling is currently underway and Engie plans to begin dismantling reactor internals in 2026.[1126]

At all four closed units of the Kozloduy nuclear plant in **Bulgaria**, turbine hall dismantling was completed in 2019.[1127] Decontamination activities on the primary circuits were started in 2022, and in December 2023, the first of a total of 24 steam generators was removed to be placed into the former turbine hall of Unit 3. By end-2024, all eleven remaining steam generators of Units 3 and 4 are to be removed and their dismantling is to begin in 2026.[1128] These tasks are still part of the "warm-up-stage". Decommissioning of all four reactors is partly funded by the Kozloduy International Decommissioning Support Fund managed by the European Bank for Reconstruction and Development. The fund has raised more than €1.2 billion (US$1.3 billion) and supports the plan to decommission all four units to a brownfield state by 2030.[1129]

Rajasthan-1 in **India**—placed in LTO (Long-Term Outage) status since 2004 and since 2014 considered as closed by WNISR—has been completely defueled and is reportedly "maintained under dry preservation."[1130] WNISR considers the reactor to be in the warm-up phase.

Decommissioning has been underway since 1998 at Aktau BN-350, a sodium-cooled fast reactor in **Kazakhstan**. The reactor will be transferred into an LTE status over a span of ten years. The plan is to then keep the reactor in LTE for 50 years, after which dismantling is to begin.[1131] Spent fuel was removed with financial support from the U.S. Government from 1999 to 2016 with several joint projects conducted over the years.[1132] In 2020, total project costs were estimated at KZT125 billion (US$$_{2020}$303 million), paid for via a fee on local residents' electricity bills.[1133]

In the **Netherlands**, the 55-MW reactor Dodewaard was placed into LTE in 2005 with the aim to begin actual dismantling activities from 2045 onwards and the objective to return the site to greenfield status.[1134] Operator Gmeenschappelijke Kernenergiecentrale Nederland (GKN), owned by Nederlands Elektriciteit Administratiekantoor (NEA), had paid a cumulative

1125 - ENGIE Electrabel, "The Shutdown of our Nuclear Power Plants—Shutdown of Doel 3 and Tihange 2", ENGIE, Undated, see https://nuclear.engie-electrabel.be/en/nuclear-energy/shutdown-our-nuclear-power-plants/shutdown-doel-3-and-tihange-2, accessed 27 May 2024.

1126 - Ibidem.

1127 - SERAW, "Decommissioning of nuclear installations", State Enterprise Radioactive Waste, 2022, see https://tinyurl.com/DPRAODecom, accessed 24 July 2022.

1128 - SERAW, "A key stage of the Decommissioning Programme of the Kozloduy NPP shutdown units", 26 December 2023, see https://tinyurl.com/yj5uk9ya, accessed 18 April 2024.

1129 - EBRD, "Kozloduy International Decommissioning Support Fund", European Bank for Reconstruction and Development, Undated, see https://www.ebrd.com/what-we-do/sectors-and-topics/nuclear-safety/kozloduy.html, accessed 18 April 2024.

1130 - NPCIL, "Rawatbhata Rajasthan Site", Nuclear Power Corporation of India Limited, Department of Atomic Energy, Undated, see https://www.npcil.nic.in/content/501_1_rawatbhatarajasthansite.aspx, accessed 18 August 2024.

1131 - Kamen Kraev, "Rosatom To Help With BN-350 Fast Neutron Reactor Decommissioning", *NucNet*, 29 July 2020, see https://www.nucnet.org/news/rosatom-to-help-with-bn-350-fast-neutron-reactor-decommissioning-7-3-2020, accessed 24 July 2023.

1132 - R. W. Schaefer, R. T. Klann et al., "Criticality Safety Issues in the Disposition of BN-350 Spent Fuel", Argonne National Laboratory, National Nuclear Center of the Republic of Kazakhstan and Kazakhstan Atomic Energy Committee, presented at the ANS 4. Embedded Topical Meeting on DOE Spent Nuclear Fuel and Fissile Material Management, 4-8 June 2000; and *NEI Magazine*, "Local residents pay for decommissioning of Kazakhstan's BN-350 reactor", 27 February 2020, see https://www.neimagazine.com/news/newslocal-residents-pay-for-decommissioning-of-kazakhstans-bn-350-reactor-7796914, accessed 30 August 2023.

1133 - *NEI Magazine*, "Local Residents Pay for Decommissioning of Kazakhstan's BN-350 Reactor", 2020, op. cit.

1134 - OECD/NEA, "Radioactive Waste Management Programmes in OECD/NEA Member Countries—Netherlands", Nuclear Energy Agency, Organisation for Economic Co-operation and Development, 2008, see https://www.oecd-nea.org/jcms/pl_33758/netherlands-profile-web, accessed 8 June 2022.

€1.5 billion (US$1.6 billion) in dividends to its shareholders Uniper, Engie, Vattenfall, and EPZ.[1135] With only €162 million (US$175 million) left in the bank, and the decommissioning of Dodewaard estimated to cost over €347 million (US$375 million), the Dutch Government intervened in 2023 and committed to paying an additional €185 million (US$200 million). As of March 2024, ownership of the plant was supposed to be transferred to the Dutch state-owned radioactive waste management company COVRA for a symbolic fee of €1.[1136] But the transfer was put on hold in April after the Lower House of the Dutch Parliament (Tweede Kamer) raised concerns over a supposedly missed ten-year safety inspection.[1137] The current developments could lead to an earlier start of decommissioning work. Currently, the money remaining on GKN's balance sheet is planned to be invested with the hope of earning sufficient interest to cover the costs of dismantling activities, which are to begin in 2045 and estimated to take only ten years. At the still operational Borssele plant, an external segregated fund is supposed to cover all decommissioning costs.[1138]

In August 2021, **Pakistan** closed its first reactor Karachi Nuclear Power Plant-1 (KANUPP-1), a 90-MW CANDU reactor that had operated for 50 years.[1139] In June 2022, the license to decommission the plant following a deferred dismantling strategy was granted. Following this, preparations to place the reactor into LTE status have begun and are expected to take approximately 15 years. The plan is to keep the reactor in LTE for 20–30 years and then dismantle it to a brownfield status within another five years.[1140] This marks the earliest completion year as 2061. With LTE preparations ongoing, WNISR considers the reactor to be in the warm-up stage to be later transferred to an LTE status.

Slovakia's decommissioning efforts are advancing, with reactor pressure vessels at Bohunice-1 and -2 having been removed in late 2021 by Westinghouse[1141] and reactor internals at both units fully dismantled by the end of July 2022.[1142] This puts both units into the ease-off stage. The remaining systems and equipment are to be dismantled by 2025, and buildings are to

1135 - Orla McDonald, "Energiebedrijven trokken €1,5 mrd uit kerncentrale Dodewaard", *Het Financieele Dagblad*, 29 May 2023 (in Dutch), see https://fd.nl/bedrijfsleven/1477103/energiebedrijven-trokken-1-5-mrd-uit-kerncentrale-dodewaard, accessed 30 August 2023.

1136 - *NOS* and *Omroep Zeeland*, "Kerncentrale Dodewaard kan ontmanteld worden dankzij overname", as published by *NOS*, 21 March 2024 (in Dutch), see https://nos.nl/artikel/2513638-kerncentrale-dodewaard-kan-ontmanteld-worden-dankzij-overname, accessed 17 May 2024.

1137 - Finance Committee, "Lijst van Vragen en Antwoorden", Document Number 36 550 (in Dutch), Tweede Kamer der Staten-Generaal/House of Representatives of the Netherlands, 31 May 2024, see https://www.tweedekamer.nl/downloads/document?id=2024D22446, accessed 22 August 2024.

1138 - Frank Straver, "De vervuiler kan niet betalen: staat gaat miljoenen bijlappen voor sloop van oude kerncentrale Dodewaard", *Trouw*, 20 March 2024 (in Dutch), see https://www.trouw.nl/binnenland/de-vervuiler-kan-niet-betalen-staat-gaat-miljoenen-bijlappen-voor-sloop-van-oude-kerncentrale-dodewaard~bb336ec5, accessed 17 May 2024.

1139 - PAEC, "Nuclear Power: A Viable Option for Electricity Generation", Pakistan Atomic Energy Commission, 2022, see https://paec.gov.pk/nuclearpower/, accessed 8 June 2022.

1140 - Javed Iqbal, "Issuance of Decommissioning License to Karachi Nuclear Power Plant (KANUPP) - PNRA Experience", Pakistan Nuclear Regulatory Authority, presented at the International Conference on Nuclear Decommissioning: Addressing the Past and Ensuring the Future, 15 May 2023, see https://conferences.iaea.org/event/288/contributions/26603/, accessed 17 May 2024.

1141 - Javys, "Contract between company JAVYS, a.s. and Consortium Westinghouse signed - Information Service - Javys, a.s.", Press Release, 27 September 2017, see https://www.javys.sk/en/information-service/news-press-release/press-releases/1871-contract-between-company-javys-a-s-and-consortium-westinghouse-signed; and Javys, "Reactor Pressure Vessel Fragmentation Completed", 29 November 2021, see https://www.javys.sk/en/information-service/news-press-release/news/2028-reactor-pressure-vessel-fragmentation-completed; both accessed 18 August 2024.

1142 - Anton Usov, "Landmark achievement for nuclear decommissioning project in Slovak Republic", European Bank for Reconstruction and Development, 2 August 2022, see https://www.ebrd.com/news/2022/landmark-achievement-for-nuclear-decommissioning-project-in-slovak-republic.html, accessed 18 August 2024.

be demolished by 2027 to allow for the reuse of the site.[1143] Bohunice A1, a 93-MW heavy water GCR-type reactor, began decommissioning in 1999. All fuel has been removed from the site since 2009. The dismantling of external structures and low- to medium-level contaminated components are scheduled to be completed by 2025, after which the reactor is planned to advance to the hot-zone stage. Decommissioning is expected to be completed by 2033.[1144]

Sweden's latest reactor closure occurred in 2020 when Unit 1 of the Ringhals plant was permanently taken off the grid. Both now-closed units at the site are currently in the warm-up stage. Westinghouse was to begin dismantling work in the third quarter of 2022 but owner Vattenfall pushed the beginning of dismantling work to 2023.[1145] As of July 2024, the dedicated Vattenfall webpage still indicated that work "is expected to start in spring 2024."[1146] At Unit 2, a consortium led by Nuvia, a subsidiary of French construction giant Vinci, was tasked with dismantling the primary loop and reactor cooling pumps, to be carried out between February and August 2024.[1147] Having signed a contract with Vattenfall in February 2024, the same company will "remove, inspect and sort" materials inside the reactor buildings of both units beginning in mid-2025 to 2031.[1148] The first Swedish reactor, Ågesta, was closed in 1974 and subsequently defueled.[1149] The plant had been used as a training facility until 2020, when Westinghouse was tasked with its dismantling.[1150] In January 2024, work began to dismantle the biological shield, advancing the project into the hot-zone stage. These tasks and the demolition of the former spent fuel storage buildings as well as the steam generator are to be completed in early 2025 at the latest.[1151] Reactors at Barsebäck and Oskarshamn are currently in the hot-zone stage. At Barsebäck-1, the reactor pressure vessel was successfully dismantled in late 2021.[1152] At Barsebäck-2, the vessel was dismantled by Westinghouse in 2018.[1153] Reactor

1143 - Javys, "Activities of the Company—V1 NPP Decommissioning—Second Stage of V1 NPP Decommissioning", Activities of the Company, Undated, see https://www.javys.sk/en/activities-of-the-company/decommissioning-of-the-v1-npp/second-stage-of-decommissioning, accessed 21 May 2024; and Christopher Booth, "Landmark reached in Slovak nuclear decommissioning project", European Bank for Reconstruction and Development, 22 July 2022, see https://www.ebrd.com/news/video/landmark-reached-in-slovak-nuclear-decommissioning-project-.html, accessed 18 August 2024.

1144 - Javys, "Annual Report 2023", 2024, see https://www.javys.sk/data/web/dokumenty/spravy-o-zp/javys-annual-report-2023.pdf, accessed 16 August 2024.

1145 - Vattenfall, "Vattenfall Annual and Sustainability Report 2021", March 2022, p.43, see https://mb.cision.com/Main/865/3534511/1555469.pdf; and Vattenfall, "Vattenfall signs decommissioning agreement for radioactive components at Ringhals 1 and Ringhals 2", Press Release, 17 August 2021, see https://group.vattenfall.com/press-and-media/pressreleases/2021/vattenfall-signs-decommissioning-agreement-for-radioactive-components-at-ringhals-1-and-ringhals-2, accessed 18 August 2024.

1146 - Vattenfall, "Avveckling Ringhals 1 och", Undated (in Swedish), see https://group.vattenfall.com/se/var-verksamhet/ringhals/produktion/avveckling-ringhals-1-och-2, accessed 30 July 2024.

1147 - Freyssinet, "Decommissioning of Ringhals Nuclear power plant Unit 2 in Sweden", Press Release, 3 April 2023, see https://www.freyssinet.com/ringhals-nuclear-plant-sweden/, accessed 16 June 2023.

1148 - VINCI, "VINCI wins contract to dismantle nuclear reactors in Sweden", Press Release, 2 February 2024, see https://www.vinci.com/vinci.nsf/en/press-releases/pages/20240202-0830.htm, accessed 18 August 2024.

1149 - Vattenfall, "Ågesta power plant", Undated, see https://history.vattenfall.com/stories/agesta-power-plant, accessed 8 June 2022.

1150 - Westinghouse Electric Company, "Westinghouse Wins Environmental Contract with Vattenfall to Dismantle Ågesta Nuclear Plant", Press Release, 17 December 2020, see https://info.westinghousenuclear.com/news/westinghouse-wins-environmental-contract-with-vattenfall-to-dismantle-%C3%A5gesta-nuclear-plant, accessed 8 June 2022.

1151 - Karin Ahlgren, "Nedmontering av de sista större delarna i Ågestaverket", Press Release (in Swedish), Vattenfall, 20 March 2024, see https://group.vattenfall.com/se/nyheter-och-press/nyheter/2024/nedmontering-av-de-sista-storre-delarna-i-agestaverket, accessed 21 May 2024.

1152 - Nukem Technologies, "First reactor pressure vessel dismantled in Sweden", 6 December 2021, see https://www.nukemtechnologies.de/en/news/first-reactor-pressure-vessel-dismantled-in-sweden, accessed 18 August 2024.

1153 - *NEI Magazine*, "Decommissioning progress at Sweden's Barsebäck", *Nuclear Engineering International*, 19 March 2018, see https://www.neimagazine.com/news/newsdecommissioning-progress-at-swedens-barsebck-6087602, accessed 8 June 2022.

internals at Oskarshamn were dismantled for both reactors in 2019 by GE Hitachi Nuclear Energy.[1154] In 2020, Spanish company GD Energy Services was contracted for four years to continue decommissioning at Oskarshamn and Barsebäck.[1155] Post-segmentation work was completed at Barsebäck and is ongoing at Oskarshamn with expected completion this year.[1156] Radiological decommissioning is planned to be completed by 2028 at both plants, after which conventional demolition tasks will remain.[1157]

Switzerland has some decommissioning experience, having completed technical decommissioning of the research reactor at Lucens in 2004.[1158] Decommissioning of the commercial reactor at Mühleberg began shortly after its closure in 2019. The site completed the defueling process in September 2023, when the final fuel rods were transferred to the Swiss interim storage facility in Aargau. All the other wastes from the decommissioning process will also be transferred to the Aargau site until 2031, when the radiological decommissioning is expected to have been completed.[1159] In March 2024, a consortium consisting of cask manufacturer GNS, Uniper Services GmbH, and Framatome GmbH (all Germany-based entities) was awarded the contract for reactor internals dismantling and packaging which is expected to begin before the end of 2025.[1160] The site is to be released as a greenfield site by 2034.[1161]

In **Taiwan**, reactors are being progressively closed under the national nuclear phaseout policy. As of mid-2024, Kuosheng-2 marks the latest reactor closure (March 2023),[1162] finalizing the retirement of the two-unit nuclear plant.[1163] For both reactors at the site, the decommissioning license application was submitted to the Nuclear Safety Commission (NSC) in December 2018, and it was approved in October 2020. The final license issuance will occur after validation

1154 - GE, "GE Hitachi Nuclear Energy Completes Reactor Decommissioning Project in Sweden", Press Release, 18 December 2018, see https://www.ge.com/news/press-releases/ge-hitachi-nuclear-energy-completes-reactor-decommissioning-project-in-sweden, accessed 18 August 2024.

1155 - Foro Nuclear, "GDES reaches a milestone with decommissioning work at Barsebäck, the Swedish nuclear power plant", Press Release, 11 April 2022, see https://www.foronuclear.org/en/updates/news/gdes-reaches-a-milestone-with-decomissioning-o-swedish-npp-barseback/, accessed 16 June 2023.

1156 - Diego Santoro, "Spanish participation in the decommissioning of Barsebäck and Oskarshamn, Sweden", Director, U.N. Desmantelamiento GDES, *Revista Nuclear España*, 17 October 2023, see https://www.revistanuclear.es/en/installations/spanish-participation-in-the-decommissioning-of-barseback-and-oskarshamn-sweden/, accessed 23 May 2024.

1157 - Uniper, "Decommissioning and dismantling nuclear power", 2022, see https://www.uniper.energy/sweden/about-uniper-sweden/nuclear-power-sweden/decommissioning, accessed 23 May 2024.

1158 - ENSI, "Serie Lucens: Der Rückbau eines Pionierwerks", Eidgenössisches Nuklearsicherheitsinspektorat/Swiss Federal Nuclear Safety Inspectorate,14 June 2012 (in German), see https://www.ensi.ch/de/2012/06/14/serie-lucens-der-rueckbau-eines-pionierwerks/, accessed 8 June 2022.

1159 - *SRF*, "Zwischenlager: Nun hat der Aargau ein «viertes» AKW", *Schweizer Radio und Fernsehen*, 13 October 2023 (in German), see https://www.srf.ch/news/schweiz/akw-rueckbau-in-muehleberg-zwischenlager-nun-hat-der-aargau-ein-viertes-akw, accessed 23 May 2024; and BKW, "The decommissioning of Mühleberg Nuclear Power Plant/Die Stilllegung des Kernkraftwerks Mühleberg", 2024 (in German), see https://www.bkw.ch/en/energy/energy-generation/decommissioning-of-the-muehleberg-nuclear-power-plant; also BKW, "Der Rückbau des Kernkraftwerks Mühleberg schreitet voran", 1 November 2023, see https://www.bkw.ch/de/ueber-uns/aktuell/blog/innovation-und-technologie/der-rueckbau-des-kernkraftwerks-muehleberg-schreitet-voran; both accessed 18 August 2024.

1160 - Michael Köbl, "Deutsches Konsortium erhält Rückbauauftrag aus der Schweiz", Press Release (in German), Gesellschaft für Nuklear-Service Mbh, 21 March 2024, see https://www.gns.de/ueber-gns/gns-aktuell/news/aktuelles/2024/muehleberg/, accessed 21 May 2024.

1161 - BKW, "Die Stilllegung des Kernkraftwerks Mühleberg", Undated, op. cit.

1162 - An additional unit, Maanshan-1, was closed on 27 July 2024, leaving only one remaining reactor operating in the country.

1163 - *WNN*, "Taiwanese reactor enters retirement", 14 March 2023, see https://www.world-nuclear-news.org/Articles/Taiwanese-reactor-enters-retirement, accessed 16 March 2023.

of the Environmental Impact Assessment (EIA) by the Environment Ministry.[1164] In July 2021, operator Taipower submitted the application to close the last two operating reactors at the Maanshan nuclear power plant by 2025.[1165] The NSC approved the decommissioning plans in April 2023, while the Environment Ministry is currently reviewing the EIA, which is indispensable for securing a decommissioning permit.[1166] Decommissioning of all Taiwanese reactors (including the two Maanshan units) is to be completed by 2043[1167], but currently, at all closed reactors, defueling is halted due to the lack of dry spent-fuel storage facilities.[1168] According to Taiwan's Atomic Energy Council, the development of a dry storage facility had been blocked by "local government and antinuclear organizations" in the past[1169] but a settlement was reportedly reached in April 2024 for the improvement and subsequent commissioning of an existing facility at the Chinshan site.[1170]

In **Ukraine**, decommissioning work at all four reactors of the Chornobyl plant resumed after Russian forces, that had occupied the plant for several weeks in 2022, left the site.[1171] During the occupation of the site, decommissioning licenses had been revoked by Ukrainian authorities, who reinstated them in August 2022, allowing work to continue.[1172] Chornobyl 1–3 completed defueling activities in 2016[1173] and are to be placed into LTE following the chosen deferred dismantling strategy from approximately 2028 to 2045.[1174] Spent fuel transfer to the newly constructed interim dry storage facility ISF-2 from the aged ISF-1 (licensed until 2028) began in 2021.[1175] At Unit 4, the so-called New Safe Confinement was completed in 2016.[1176] In

1164 - NSC, "The Review Status of the Decommissioning Plans for Taiwan's Nuclear Power Plants", Nuclear Safety Commission of Taiwan, September 2024, see https://www.nusc.gov.tw/share/file/e_safety/I~gOfR4Qtm4jzpNkpBkiYA__.pdf, accessed 21 May 2024; and NSC, "Nuclear Power Plant Decommissioning Regulations", Updated 2 August 2024, see https://www.nusc.gov.tw/english/Nuclear-Reactor-Safety/Nuclear-Power-Plant-Decommissioning-Regulations-271.html, accessed 18 August 2024.

1165 - Ibidem. Maanshan-1 was closed on 27 July 2024.

1166 - Ibidem.

1167 - *NEI Magazine*, "Taipower applies to close down Maanshan NPP", 29 July 2021, see https://www.neimagazine.com/news/newstaipower-applies-to-close-down-maanshan-npp-8946136/, accessed 9 June 2022.

1168 - NSC, "Oversight on NPP Decommissioning", Nuclear Safety Commission, 9 May 2024, see https://www.nusc.gov.tw/english/Nuclear-Reactor-Safety/Oversight-of-NPP-Decommissioning-283.html, accessed 21 May 2024.

1169 - Chin-Cheng Huang, "Carbon Neutrality and Current Status of Nuclear Power in Taiwan", Director, Mechanical & System Engineering Program, Institute of Nuclear Energy Research, Atomic Energy Council, 13 April 2023, presented at the 14th International Workshop on the Integrity of Nuclear Components, Asian Society for Integrity of Nuclear Components, 12–14 April 2023, see https://www.jwes.or.jp/wprs/wp-content/uploads/author_committees_atomic/ae-2301-1.pdf, accessed 12 September 2024.

1170 - Tung Kuang-i and Jonathan Chin, "Taipower to activate fuel storage facility at Jinshan", *The Taipei Times*, with *Central News Agency*, 3 May 2024, see https://www.taipeitimes.com/News/taiwan/archives/2024/05/03/2003817308, accessed 18 August 2024.

1171 - NEA/OECD, "Ukraine: Current status of nuclear power installations", Nuclear Energy Agency, Organisation for Economic Co-operation and Development, 7 June 2023, Updated 16 June 2023, see https://www.oecd-nea.org/jcms/pl_66130/ukraine-current-status-of-nuclear-power-installations, accessed 16 June 2023.

1172 - Chornobyl NPP, "Occupation consequences: several licenses suspended", Chornobyl Nuclear Power Plant, 4 May 2022, see https://chnpp.gov.ua/en/infocenter/news/6030-occupation-consequences-several-licenses-suspended; and Chornobyl NPP, "All Chornobyl NPP licenses for Radioactive Waste Management are resumed [UPDATED]", 18 August 2022, see https://weber.chnpp.gov.ua/en/infocenter/news/6077-most-of-chornobyl-npp-licenses-for-radioactive-waste-management-are-resumed, accessed 18 August 2024.

1173 - Chornobyl NPP, "Important stage for Chernobyl NPP: ChNPP Units are completely free of Spent Nuclear Fuel", 6 June 2016, see https://chnpp.gov.ua/en/news/3773-important-stage-for-chernobyl-npp-chnpp-units-are-completely-free-of-spent-nuclear-fuel, accessed 18 August 2024.

1174 - Chornobyl NPP, "ChNPP Decommissioning", Undated, see https://chnpp.gov.ua/en/activity/chnpp-decommissioning, accessed 25 July 2023.

1175 - Chornobyl NPP, "Interim Spent Nuclear Fuel Dry Storage Facility (ISF-2)", 11 December 2023, see https://chnpp.gov.ua/en/184-projects/current-projects/434-2434, accessed 5 August 2024.

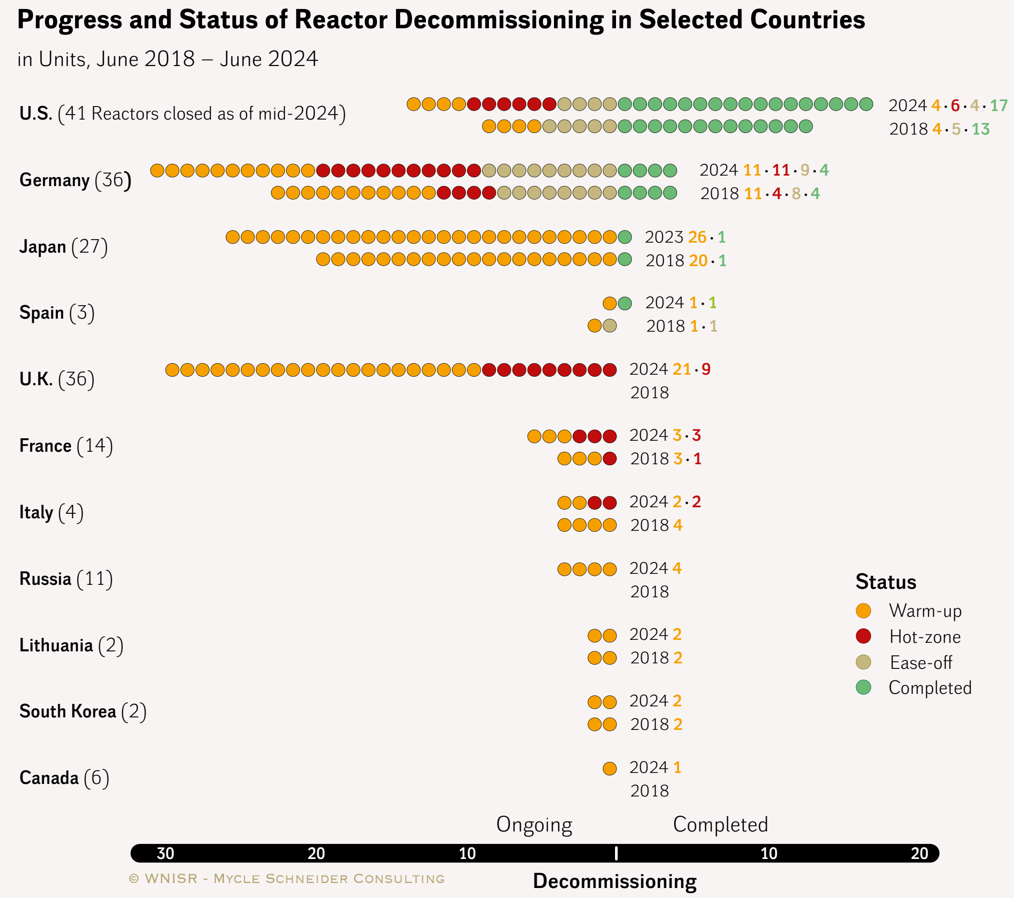
1176 - EBRD, "Chernobyl's New Safe Confinement", European Bank for Reconstruction and Development, Undated, see https://www.ebrd.com/what-we-do/sectors/nuclear-safety/chernobyl-new-safe-confinement.html, accessed 9 June 2022.

December 2023, a dismantling license for the stabilization of critical parts of the original 1986 sarcophagus, "whose collapse probability is very high", and subsequent demolition thereof was extended for another six years to 2029. The original plan had been to complete these tasks by 2023.[1177]

Decommissioning in Selected Countries

This section provides an update on the decommissioning development in eleven major countries: Canada, France, Germany, Italy, Japan, Lithuania, Russia, South Korea, Spain, the U.K., and the U.S. As in previous years, decommissioning projects encountered delays as well as cost increases. This section provides information on developments since WNISR2023 and necessary context.

Figure 52 · Progress and Status of Reactor Decommissioning in Selected Countries



Sources: Various, compiled by WNISR, 2024

Note: After a decommissioning strategy change, the U.K. has begun to move reactors from LTE to various stages of decommissioning.

1177 - Chornobyl NPP, "Service life of Shelter facility unstable building structures extended for 6 years. Regulator made amendments to license", 4 December 2023, see https://chnpp.gov.ua/en/infocenter/news/6174-service-life-of-shelter-facility-unstable-building-structures-extended-for-6-years-regulator-made-amendments-to-license, accessed 18 August 2024.

WNISR2024 counted 159 reactors currently in different decommissioning stages or awaiting decommissioning in these 11 countries; this represents 84 percent of all closed reactors, excluding completed projects. Of these reactors, 77 are in the warm-up stage, 31 in the hot-zone stage, and 13 in the ease-off stage. The early nuclear states U.K., France, Russia, and Canada are yet to fully decommission a single reactor. Initially, the U.K. and Russia put all their closed reactors into Long-Term Enclosure (LTE), postponing decommissioning into the future. The U.K. has since changed its strategy and has begun earlier decommissioning for its extensive Gas Cooled Reactors (GCR) fleet. WNISR counts a total of 45 reactors in LTE worldwide, 38 located in this selection of eleven countries.

Figure 52 reflects the slow progress of the global decommissioning industry. Over the past four years, few reactors have moved forward in their decommissioning processes. Having ended the commercial operation of nuclear power plants in April 2023, Germany is going through major developments.

COUNTRY CASE STUDIES

Canada

In Canada, no commercial reactor has been decommissioned so far. In mid-2024, six reactors (2.1 GW), i.e., five CANDU (Canadian Deuterium Uranium) reactors and one Heavy-Water Moderated Boiling Light-Water Reactor (HW BLWR), were closed. Three of these are first-generation prototype or demonstration reactors that operated for only a few years.

The 250-MW Gentilly-1 prototype HW BLWR reactor was closed in 1977 after only 183 full-power-equivalent days and was subsequentially defueled in 1984 and placed into LTE in 1986 where it has remained since.[1178] The prototype CANDU reactor at Douglas Point operated from 1967 to 1984 and was subsequently placed into LTE. Active dismantling began in 2021 with plans to complete decommissioning by 2070.[1179] While non-nuclear demolition is expected to be completed by end-2024,[1180] the removal of reactor buildings and spent-fuel canisters from the site is not scheduled to begin before 2030.[1181] The 22-MW predecessor of the Douglas Point Reactor, simply named "Nuclear Power Demonstration" (NPD) reactor, operated from 1962 to 1987. It has been defueled and placed in LTE since the early 1990s. The NPD is planned to be placed into a permanent "in-situ" state by filling the remaining structures with grout.[1182]

1178 - Government of Canada, "Gentilly-1 Waste Facility", Canadian Nuclear Safety Commission, 27 January 2020, see https://www.cnsc-ccsn.gc.ca/eng/reactors/research-reactors/other-reactor-facilities/gentilly-1-facility/, accessed 5 August 2024; and CNL, "Gentilly-1 Decommissioning Project", Canadian Nuclear Laboratories, see https://www.cnl.ca/environmental-stewardship/gentilly-1-decommissioning-project/, accessed 19 August 2024.

1179 - CNL, "Douglas Point Prototype Reactor", Canadian Nuclear Laboratories, Undated, see https://www.cnl.ca/environmental-stewardship/decommissioning-the-douglas-point-prototype-reactor/, accessed 1 November 2023.

1180 - Jill Charlebois, "Kincardine Council Receives Update On Douglas Point Decommissioning Project", *The Bruce*, 24 January 2023, see https://www.rockthebruce.ca/2023/01/24/kincardine-council-receives-update-on-douglas-point-decommissioning-project/, accessed 21 May 2024.

1181 - AECL, "Project Sites: Douglas Point Reactor", Atomic Energy of Canada Ltd, 2018, see https://www.aecl.ca/radioactive-waste/project-sites/douglas-point/, accessed 21 May 2024.

1182 - CNL, "Long-term Safety - NPD Closure Project", Canadian Nuclear Laboratories, 2020, see https://www.cnl.ca/wp-content/uploads/2020/12/NPD_Poster_Pkg.pdf, accessed 18 April 2024.

"Institutional controls" will be put in place for "at least 100 years".[1183] The only structure that will remain visible will be the ventilation stack that currently provides an important stopover for migrating birds.[1184] Since 2017, there have been environmental consultations and public engagement. The latest update on the project dates back to January 2022, when the regulator finalized its review of Canadian Nuclear Laboratories' (CNL) revised draft Environmental Impact Statement (EIS) submitted in December 2021, deeming that "insufficient information was provided."[1185] As of April 2023, CNL was expected to submit its revised EIS over the summer of the same year.[1186] No updates have been reported since.

The other three closed reactors are former commercially operated CANDU reactors. The Gentilly-2 reactor was closed in 2012 and defueled in 2013. It was subsequentially placed into LTE with dismantling to begin in 2057. The site is planned to be fully remediated by 2064, while an environmental follow-up is scheduled to conclude by 2074.[1187] In August 2023, owner-operator Hydro-Québec confirmed that it was carrying out "an assessment of the current state of the plant" to establish whether recommissioning the unit was an option.[1188] Findings of the preliminary study revealed in January 2024 reportedly found no major obstacles to restarting the reactor.[1189] However, non-nuclear buildings such as the water treatment plant were reported as slated for onsite dismantling on the company's website as of mid-2024.[1190]

As of July 2024, utility Ontario Power Generation (OPG) was holding an operational license for all eight reactors of the Pickering plant, valid until August 2028 but forbidding commercial operation beyond the end of December 2024. OPG sought approval to extend commercial operations for Units 5–8 until 31 December 2026 in June 2023. A public commission hearing on the matter was held in June 2024, but as of July 2024, a final decision had not yet been communicated.[1191] Regardless, plans are already being carried out to refurbish all four reactors

1183 - CNL, "NPD Closure project – Frequently Asked Questions", Canadian Nuclear Laboratories, Undated, see https://www.cnl.ca/environmental-stewardship/nuclear-power-demonstration-closure-project/npd-closure-project-frequently-asked-questions/, accessed 18 April 2024.

1184 - CNL, "Maintaining a habitat for NPD's Chimney Swift population", Canadian Nuclear Laboratories, Undated, see https://www.cnl.ca/environmental-stewardship/nuclear-power-demonstration-closure-project/maintaining-a-habitat-for-npds-chimney-swift-population/, accessed 18 April 2024.

1185 - Impact Assessment Agency of Canada, "Canadian Impact Assessment Registry—Nuclear Power Demonstration Closure Project", Government of Canada, Updated 2023, see https://iaac-aeic.gc.ca/050/evaluations/proj/80121, accessed 18 April 2024.

1186 - CNSC, "Update on the Nuclear Power Demonstration Closure Project", Canadian Nuclear Safety Commission, 18 April 2023, see https://www.cnsc-ccsn.gc.ca/eng/resources/news-room/feature-articles/spring-2023-update-npd-closure-project/, accessed 19 August 2024.

1187 - Hydro-Québec, "Construction Work and Projects—Decommissioning of the Gentilly-2 facilities", Undated, see https://www.hydroquebec.com/projects/decommissioning-gentilly-2/, accessed 31 August 2023; and CNSC, "Canadian National Report for the Convention on Nuclear Safety—Ninth Report", August 2022, see https://www.iaea.org/sites/default/files/23/03/canada_nr_9th_cns_and_presentation.pdf, accessed 19 August 2024.

1188 - Hydro-Québec, on X (formerly Twitter), 10 August 2023, see https://x.com/hydroquebec/status/1689658373384622080?, accessed 19 August 2024.

1189 - Thomas Gerbet, "Hydro-Québec : « Aucune barrière majeure au redémarrage de Gentilly-2 »", *Radio-Canada*, 30 January 2024 (in French), see https://ici.radio-canada.ca/nouvelle/2045564/nucleaire-hydro-quebec-etude-snc-gentilly-centrale, accessed 19 August 2024.

1190 - Hydro-Québec, "Decommissioning of the Gentilly-2 facilities - What's new?", 2024, see https://www.hydroquebec.com/projects/decommissioning-gentilly-2/whats-new.html, accessed 21 August 2024.

1191 - CNSC, "Pickering Nuclear Generating Station", Canadian Nuclear Safety Commission, 17 July 2024, see https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/nuclear-facilities/pickering-nuclear-generating-station/, accessed 5 August 2024.

by the mid-2030s for continued operation of "at least another 30 years".[1192] See also Canada in Annex 1.

Two reactors of Pickering-A, Units 2 and 3, were already closed in 1997 and have been defueled, while Units 1 and 4 will be closed by end-2024. Decommissioning is to begin in a yearly staggered approach from 2050 onwards. All four reactors are to be fully dismantled and released by 2063.[1193] For more details on the Canadian decommissioning process, see WNISR2018.

France

The closed reactor fleet in France is diverse in comparison to the largely standardized currently operational PWR fleet. In total, 14 reactors (8 GCR, 3 PWR, 1 HWGCR, 2 FBR), corresponding to approximately 5.5 GW, have been closed. Apart from decommissioning of the reactors at the Marcoule site, for which the French Alternative Energies and Atomic Energy Commission (CEA) is responsible as owner (G-2, G-3) or co-owner (Phénix, 20 percent share belongs to EDF), all reactors are decommissioned by the state-owned utility Électricité de France (EDF).[1194] Since mid-2023, there has been little apparent progress. The EL-4 reactor is the only reactor to have advanced by moving from the warm-up to the hot-zone stage. Work is ongoing at several sites:

- Three reactors are in the warm-up stage: Fessenheim-1 & -2 and Phénix.
- Three reactors are in the hot-zone stage: EL-4 (Brennilis), Chooz-A, and Superphénix.

All GCRs (Bugey-1, Chinon A-1, A-2, A-3, and Saint-Laurent-des-Eaux A-1 & A-2) remain in LTE (as well as the G-2 and G-3 reactors at Marcoule).

Despite France's official strategy of "as-fast-as-possible decommissioning", the process is advancing slowly, but the French Nuclear Safety Authority ASN (Autorité de Sûreté Nucléaire) considers that "the decommissioning or decommissioning preparation operations on the facilities other than the GCRs is progressing at a satisfactory pace." On GCRs, the regulator states, "the progress of these projects is significantly slower and the completion deadlines for the decommissioning operations envisaged by EDF remain a subject of concern for ASN."[1195]

1192 - Ontario Government, "Ontario Supporting Plan to Refurbish Pickering Nuclear Generating Station", Press Release, 30 January 2024, see https://news.ontario.ca/en/release/1004128/ontario-supporting-plan-to-refurbish-pickering-nuclear-generating-station, accessed 14 April 2024.

1193 - OPG, "Pickering Nuclear Site Preliminary Decommissioning Plan", Ontario Power Generation, January 2022, see https://www.opg.com/documents/pickering-nuclear-site-preliminary-decommissioning-plan-pdf/, accessed 18 April 2024.

1194 - ASN, "Les Appréciations de l'ASN", Autorité de sûreté nucléaire/French Nuclear Safety Authority, May 2023 (in French), see https://www.french-nuclear-safety.fr/content/download/189732/file/Appr%C3%A9ciations%20de%20l%27ASN%20-%20Rapport%20annuel%20de%20l%27ASN%202022.pdf, accessed 22 June 2023; and ASN, "Les appréciations de l'ASN", May 2024 (in French), see https://www.asn.fr/content/download/198708/file/Appr%C3%A9ciations%20de%20l%27ASN%20-%20Rapport%20annuel%20de%20l%27ASN%202023.pdf; and ASN, "ASN Report on the state of nuclear safety and radiation protection in France in 2023—Abstracts", June 2024, see https://www.french-nuclear-safety.fr/content/download/199517/file/Abstracts%20of%20the%20ASN%20Annual%20Report%202023.pdf; both accessed 19 August 2024.

1195 - Ibidem.

Concerning costs, ASN's annual reports covering the years 2021–2023 state that[1196]

> ASN underlines that the assumptions adopted for evaluating the complete costs must be reassessed in order to show reasonable caution in the scheduling of the decommissioning projects and programmes, taking account of the risks related to the unavailability of storage, treatment and disposal facilities.

In the years to come, EDF will also have to manage decommissioning activities of its large currently operational PWR fleet. When exactly these units will enter their respective decommissioning phases depends on upcoming decisions concerning lifetime extensions. EDF hopes to use the Fessenheim reactors as test sites to learn best practices that can then be applied to other PWRs and reduce costs and necessary efforts for decommissioning.[1197] Compared to other countries, EDF's cost estimates are rather low.[1198]

The EL-4 reactor at Brennilis (Monts d'Arrée), which was closed in 1985, is the only French reactor to have moved into a different decommissioning stage since WNISR2023. In 2011, it received a partial decommissioning license for parts outside the nuclear island. Since then, progress has been made, such as spent fuel removal and the dismantling of several buildings including the "fuel building" and the "effluent treatment stations".[1199] The license to proceed to final dismantling of the reactor internals was granted in September 2023 thus allowing to move the project to the "hot-zone-stage". Final site remediation is to be completed by 2040. Most recent estimates place total decommissioning costs for this single reactor at €1 billion (US$1.08 billion), an increase of €40 million (US$43 million) since last year's estimate.[1200] The project has been experiencing cost overruns since the beginning of preparatory works after closure. In 1999, provisions were increased from an earlier maximum of €30 million (US$$_{1999}$32 million) by €200 million (US$$_{1999}$213 million). By 2002, costs were estimated at €482 million (US$$_{2002}$456 million).[1201]

In other words, the *increase* in the decommissioning cost estimate between 2022 and 2023 exceeds the total amount estimated 25 years ago.

1196 - ASN, "ASN Report on the state of nuclear safety and radiation protection in France in 2021", Autorité de sûreté nucléaire/ French Nuclear Safety Authority, July 2022, see https://www.french-nuclear-safety.fr/content/download/184961/file/ASN%20Report%20on%20the%20state%20of%20nuclear%20safety%20and%20radiation%20protection%20in%20France%20in%202021.pdf, accessed 19 August 2024; and ASN, "ASN report on the state of nuclear safety and radiation protection in France in 2022", August 2023, see https://www.french-nuclear-safety.fr/content/download/191661/file/ASN%20Report%20on%20the%20State%20of%20nuclear%20safety%20and%20radiation%20protection%20in%20France%20in%202022.pdf, accessed 27 May 2024; and ASN, "La sûreté nucléaire et la radioprotection en France en 2023", May 2024 (in French), see https://www.asn.fr/l-asn-informe/publications/rapports-de-l-asn/la-surete-nucleaire-et-la-radioprotection-en-france-en-2023https://www.asn.fr/l-asn-informe/publications/rapports-de-l-asn/la-surete-nucleaire-et-la-radioprotection-en-france-en-2023, accessed 30 July 2024.

1197 - Christophe Martin, Aurélien Portelli and Franck Guarnieri, "Myths and representations in French nuclear history: The impact on decommissioning safety", presented at "22nd European Safety and Reliability Conference—ESREL 2013", 29 September–2 October 2013, see https://mines-paristech.hal.science/hal-00868830/document, accessed 25 July 2023; and "ASN, "ASN Report on the State of Nuclear Safety and Radiation Protection in France in 2020", August 2021, op. cit.

1198 - Alexander Wimmers, Rebekka Bärenbold et al., "Decommissioning of Nuclear Power Plants: Regulation, Financing, and Production", Data Documentation 2014, DIW Berlin, German Institute for Economic Research, January 2023, see https://www.diw.de/documents/publikationen/73/diw_01.c.864222.de/diw_datadoc_2023-104.pdf, accessed 26 January 2023.

1199 - EDF, "Consolidated Financial Statements at 31 December 2023", 2024, see https://www.edf.fr/sites/groupe/files/2024-02/annual-results-2023-consolidated-financial-statements-2024-02-16.pdf, accessed 26 April 2024.

1200 - Ibidem.

1201 - Mycle Schneider Consulting, "Comparison Among Different Decommissioning Funds Methodologies for Nuclear Installations—Country Report France—Final Report", Wuppertal Institut für Klima, Umwelt, Energie GmbH, on behalf of the Directorate-General Energy and Transport, European Commission, 2007, see https://epub.wupperinst.org/frontdoor/deliver/index/docId/2613/file/2613_EUDecommFunds_FR.pdf, accessed 30 August 2023.

For its six UNGG-type (Uranium Naturel Graphite Gaz) GCR reactors Bugey-1, Chinon A-1, A-2, A-3, and Saint-Laurent-des-Eaux A-1 & A-2, EDF initially adopted a deferred dismantling strategy in 2001 to flood the reactor vessel with water, followed by plans to perform decommissioning procedures underwater.[1202] However, due to the official French strategy to decommission "as rapidly as possible" (after closure) and the substantial technical challenges of underwater dismantling, EDF decided to change the strategy to in-air dismantling in 2016. Resulting changes in decommissioning plans prompted ASN to demand new decommissioning licensing applications for all six reactors in 2020,[1203] which were submitted by EDF in December 2022. As of early 2024, their approvals were expected "for the end of 2026 at the earliest."[1204] Thus, initial targets for dismantling no later than 2031 have been scrapped. EDF currently envisions opening the reactor internals at the "first-of-a-kind" project Chinon A-2 in 2034. The removal of internals and graphite blocks will begin no earlier than 2041, and the whole operation is planned to take until 2055. By 2037, all other reactors are scheduled to be placed into a "safe storage configuration" (LTE) for decommissioning to commence by 2056 with a targeted completion "between 2063 and 2093, depending on the reactors." Compared to last year's estimates, total decommissioning costs for all six GCR plants have increased by €300 million (US$324 million) to €7.3 billion (US$7.9 billion)—despite the lack of any physical progress.[1205]

The 305-MW PWR reactor at Chooz-A was closed in 1991 and has been undergoing decommissioning work since 2007. According to EDF, "The final stage of dismantling began in 2016 and involves segmentation, conditioning and removal of reactor vessel internals, followed by dismantling of the vessel itself. These operations are due to be completed in 2024."[1206] Pool drainage was completed only in 2023. According to current plans, the dismantling of the reactor vessel itself is to begin in 2025 and be completed sometime in 2026.[1207] Once this is completed, the final dismantling of remaining equipment and demolition of buildings can begin. The original plan issued in 2007 expected Chooz-A to be fully delicensed by 2047, but under the new full continuous decommissioning scenario adopted in 2021, delicensing is expected by 2035.[1208] Due to the site's unique location in a cave, unexpected difficulties have led to multiple cost increases over the years. Latest cost estimates assume total project costs of €340 million (US$368 million).[1209] A 2022 contract signed with the research agency CNRS established the

1202 - ASN, "ASN Report on the State of Nuclear Safety and Radiation Protection in France in 2020", August 2021, see https://www.french-nuclear-safety.fr/content/download/179293/file/ASN%20Report%20on%20the%20state%20of%20nuclear%20safety%20and%20radiation%20protection%20in%20France%20in%202020.pdf, accessed 19 August 2024.

1203 - ASN, "ASN Report on the state of nuclear safety and radiation protection in France in 2022", August 2023, see https://www.french-nuclear-safety.fr/content/download/191661/file/ASN%20Report%20on%20the%20State%20of%20nuclear%20safety%20and%20radiation%20protection%20in%20France%20in%202022.pdf, accessed 19 August 2024.

1204 - EDF, "Consolidated Financial Statements at 31 December 2023", 2024, op. cit.

1205 - Ibidem; and EDF, "Consolidated Financial Statements at 31 December 2022", 2023, see https://www.edf.fr/sites/groupe/files/2023-02/annual-results-2021-consolidated-financial-statements-2023-02-17.pdf, accessed 22 June 2023.

1206 - EDF, "Universal Registration Document 2021 - Including the Annual Financial Report", March 2022, see https://www.edf.fr/sites/groupe/files/2022-03/edf-2021-universal-registration-document.pdf, accessed 29 March 2022.

1207 - EDF, "Consolidated Financial Statements at 31 December 2023", 2024, op. cit.

1208 - Ibidem; and EDF, "Universal Registration Document 2021 - Including the Annual Financial Report", March 2022, op. cit.

1209 - EDF, "Consolidated Financial Statements at 31 December 2023", 2024, op. cit.

goal of implementing a large-scale neutrino research experiment called SuperChooz at the site once the reactor itself has been dismantled.[1210]

The two PWRs at Fessenheim were closed in 2020. EDF currently plans a six-year preparatory phase until the decommissioning license is obtained, which is expected in early 2026. Currently, defueling, boron removal, and the chemical decontamination of the primary circuits of both reactors are underway and on schedule. The total cost (excluding interim storage and processing of steam generators) is currently estimated at €994 million (US$1.1 billion) for both units, €6 million (US$6.5 million) less than last year.[1211]

The FBR reactor Superphénix at Creys-Malville has been undergoing decommissioning since 2006. Currently, reactor vessel internals are being dismantled. This is expected to be completed by 2026, with the current target for the whole site to be released from regulatory oversight by 2034. Cost estimations have risen again, by €200 million (US$216 million) since last year to €2.1 billion (US$2.3 billion). This figure is assumed to be "around four times as high" as for PWR dismantling.[1212] (see Decommissioning Status Report: Case Study France in WNISR2023).

Decommissioning of the FBR Phénix at Marcoule began shortly after its closure in 2009. After disruptions during the COVID-19 lockdown in 2020, work on fuel and equipment removal has continued. The safe removal of sodium—highly reactive when it comes in contact with air or water—poses the greatest challenge. Then, further dismantling can continue. Completion of fuel removal has been "pushed back a few years."[1213] Sodium from the facility will be treated in the so-called NOAH facility that is currently undergoing tests ahead of its scheduled startup in 2028. NOAH will likely process sodium from the Phénix reactor prior to that from the Superphénix.[1214]

The remaining GCR plants G-2 and G-3, also located at Marcoule, are currently in LTE after having been defueled and partly dismantled. Graphite removal was supposed to begin with the opening of a final repository that, according to 2006 legislation, was scheduled for 2025, but has been delayed by many years.[1215] The last documented target completion date for graphite removal and reactor dismantling was published in 2020 as "at best" before 2040, while the responsible operator CEA "no longer envisages to complete decommissioning before 2090."[1216]

1210 - CNRS, "Anatael Cabrera: 'The SuperChooz concept for studying neutrinos is much more ambitious than the two previous ones carried out at the Chooz power plant", Centre national de la recherche scientifique/French National Centre for Scientific Research, 30 September 2022, see https://www.in2p3.cnrs.fr/en/cnrsinfo/interview-danatael-cabrera-le-projet-superchooz-detude-des-neutrinos-est-beaucoup-plus, accessed 26 April 2024.

1211 - EDF, "Consolidated Financial Statements at 31 December 2023", 2024, op. cit.

1212 - Ibidem.

1213 - ASN, "Rapport de l'ASN sur l'état de la sûreté nucléaire et de la radioprotection en France en 2023", May 2024 (in French), see https://www.asn.fr/content/download/198727/file/Rapport%20de%20l%27ASN%20sur%20l%27%C3%A9tat%20de%20la%20s%C3%BBret%C3%A9%20nucl%C3%A9aire%20et%20de%20la%20radioprotection%20en%20France%20en%202023.pdf, accessed 19 August 2024.

1214 - Ibidem.

1215 - CEA, "Dossier de Presse—Démantèlement", Commissariat à l'énergie atomique et aux énergies alternatives/French Alternative Energies and Atomic Energy Commission, April 2015 (in French), see https://www.francetnp.gouv.fr/IMG/pdf/dossier_de_presse_demantelement_-_2015_v2.pdf, accessed 17 May 2022.

1216 - Cour des comptes, "L'arrêt et le démantèlement des installations nucléaires", French Court of Accounts, February 2020 (in French), see https://www.ccomptes.fr/system/files/2020-03/20200304-rapport-arret-demantelement-installations-nucleaires-2_0.pdf, accessed 31 August 2023.

Germany

With the closure of its last three reactors Emsland, Isar-2, and Neckarwestheim-2 on 15 April 2023, Germany is the third European country to cease the commercial operation of nuclear power plants after Italy and Lithuania (see Germany Focus in WNISR2023). Thus, the German nuclear sector is now tasked with simultaneously decommissioning 32 closed reactors corresponding to 25.6 GW.

Four additional reactors have already completed decommissioning. Of these, the 640-MW Würgassen unit is the only large commercial nuclear power plant to complete the technical decommissioning process. However, Würgassen cannot be released from regulatory control as buildings onsite are used for interim nuclear-waste storage. After plans to use the Würgassen site as a logistics hub for the low- and intermediate-waste disposal site Konrad were scrapped in late 2023, reportedly there are now plans to construct a 120-MW battery storage facility at Würgassen.[1217] The other three fully decommissioned reactors are smaller prototype or demonstration reactors HDR Großwelzheim, Niederaichbach, and VAK Kahl that have all been released from regulatory control. The prototype pebble-bed, thorium high-temperature reactor THTR-300 is the only German reactor still in LTE. The plants at Brokdorf and Emsland are still awaiting the approval of their decommissioning licenses.[1218] See WNISR2021 for further details on the German nuclear decommissioning procedure.

Currently, with one reactor in LTE, decommissioning work is being conducted at 31 reactors:

- Eleven reactors are in the warm-up stage: Biblis-A & -B (both defueled), Brokdorf, Grohnde, Gundremmingen-B (defueled) & -C, Emsland, Isar-2, Krümmel (defueled), Lingen (defueled), and Neckarwestheim-2.
- Eleven reactors are in the hot-zone stage: AVR Jülich, Brunsbüttel, Grafenrheinfeld, Isar-1, KNK II, Mülheim-Kärlich, Neckarwestheim-1, Obrigheim, Philippsburg-1 & -2, and Unterweser.
- Nine reactors are in the ease-off stage: Greifswald 1–5, Gundremmingen-A, MZFR, Rheinsberg, and Stade.

Decommissioning at both reactors of the Biblis plant has been underway since 2017. At both units, preparations for reactor internals dismantling have been conducted, such as steam generator dismantling.[1219] In February 2023, both cooling towers of Biblis-A were torn

1217 - Viktoria Koenigs, "Früherer AKW-Standort Würgassen wird zu Batteriespeicher", *Norddeutscher Rundfunk*, 19 March 2024 (in German), see https://www.ndr.de/nachrichten/niedersachsen/braunschweig_harz_goettingen/Frueherer-AKW-Standort-Wuergassen-wird-zu-Batteriespeicher,wuergassen158.html, accessed 16 May 2024.

1218 - BASE, "Nuclear Facilities in Germany - Part II: Nuclear Facilities 'In Decommissioning'", Bundesamt für die Sicherheit der nuklearen Entsorgung/Federal Office for the Safety of Nuclear Waste Management, June 2024, see https://www.base.bund.de/SharedDocs/Downloads/BASE/EN/reports/kt/nuclear-facilities-decommissioning.pdf;jsessionid=9DE997A1DBC12F72AFC0413684826F3B.internet961?__blob=publicationFile&v=34, accessed 19 August 2024.

1219 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, November 2023 (in German), see https://dserver.bundestag.de/btd/20/095/2009575.pdf, accessed 16 May 2024.

down.[1220] The remaining cooling towers of Biblis-B are scheduled to follow in 2024.[1221] Since the beginning of decommissioning at Biblis, there have been challenges related to the disposal of exempt waste, i.e., such that has been cleared of radiation or with radiation levels below certain thresholds, as no conventional facility could be found that would take on this waste.[1222] In April 2024, the administrative court in Darmstadt ruled that 3,200 tons of this waste were to be immediately disposed of at the facility Büttelborn close to the Biblis plant. This decision can still be appealed and a decision on a general ruling regarding the disposal of the remaining exempt waste is still pending with a final decision ruling likely requiring several more years.[1223]

Brokdorf was one of three reactors that were closed in December 2021. Operator PreussenElektra had applied for the decommissioning license in December 2017 and was expecting the approval for end-2023.[1224] However, this did not occur and as of April 2024, the new projected deadline was reportedly August 2024.[1225] PreussenElektra plans to take advantage of the site's proximity to offshore wind farms by installing a 100-MW battery storage facility by 2026, and potentially expanding it to 700 MW by 2036,[1226] one year before nuclear dismantling is scheduled to be completed.[1227] Defueling is to be completed by December 2025.[1228] The reactor is considered to be in the warm-up stage as preparations for decommissioning are ongoing.

The Emsland reactor was closed in April 2023. The unit is undergoing preparations for decommissioning and is, as of July 2024, still awaiting its decommissioning license approval. Operator RWE plans to complete decommissioning by 2037.[1229] At the same site, the Lingen reactor is being dismantled since 2015 after the site had been in LTE since 1988. The reactor was officially closed in 1979, but it had ceased production in 1977. It is planned to be fully decommissioned by the late 2030s.[1230]

1220 - *dpa*, "Zweiter Kühlturm am früheren AKW Biblis abgerissen", as published by *Süddeutsche Zeitung* (in German), 23 February 2023, see https://www.sueddeutsche.de/wirtschaft/umwelt-zweiter-kuehlturm-am-frueheren-akw-biblis-abgerissen-dpa.urn-newsml-dpa-com-20090101-230222-99-698212, accessed 16 May 2024.

1221 - RWE, "Rückbauanlage Biblis: Erster Kühlturm von Block A erfolgreich zu Boden gebracht", Press Release (in German), February 2023, see https://www.rwe.com/-/media/RWE/documents/07-presse/rwe-nuclear-gmbh/2023/2023-02-02-rueckbauanlage-biblis-erster-kuehlturm-erfolgreich-zu-boden-gebracht.pdf, accessed 16 May 2024.

1222 - *dpa*, "Wohin mit dem ganzen Schrott?", as published by *hessenschau* (in German) 18 August 2022.

1223 - Verwaltungsgericht Darmstadt, "Beseitigung des freigegebenen Bauschutts aus AKW Biblis", Press Release (in German), Administrative Court of Darmstadt, as published by Administrative Court of Hessen, 30 April 2024, see https://verwaltungsgerichtsbarkeit.hessen.de/presse/beseitigung-des-freigegebenen-bauschutts-aus-akw-biblis, accessed 19 August 2024.

1224 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.

1225 - *NDR*, "Ein Jahr Atom-Aus: Situation in Brokdorf", *Norddeutscher Rundfunk*, 15 April 2024 (in German), see https://www.ndr.de/nachrichten/schleswig-holstein/Ein-Jahr-Atom-Aus-Situation-in-Brokdorf,regionheidenews332.html, accessed 16 May 2024.

1226 - Preussen Elektra, "In Brokdorf könnte der größte Batteriespeicher der EU entstehen", Press Release (in German), 12 December 2023, see https://www.preussenelektra.de/de/newsroom/pressemitteilungen/pressemitteilungen-2023/brokdorf-batteriespeicher.html, accessed 19 August 2024.

1227 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.; and Preussen Elektra, "Rückbau im Fokus—Jahresbericht 2023", April 2024, see https://www.preussenelektra.de/content/dam/revu-global/preussenelektra/documents/UnsereAufgabe/Jahresbericht_PEL_2023_bf_rz-4.pdf, accessed 16 August 2024.

1228 - Preussen Elektra, "Rückbau im Fokus—Jahresbericht 2023", April 2024, op. cit.

1229 - RWE, "Kernkraftwerk Emsland", Undated, as of 24 July 2024, see https://www.rwe.com/der-konzern/laender-und-standorte/rueckbauanlage-emsland/, accessed 24 July 2024.

1230 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.

In 2017, a decommissioning license was requested for the 1360-MW PWR at Grohnde, so it could begin dismantling right after closure at the end of 2021. While waiting for the approval, several preparations for decommissioning had been conducted, including the transfer of the final spent fuel assembly from the reactor core to spent fuel pools in February 2022 and the decontamination of the primary circuit.[1231] In December 2023, the decommissioning license was finally approved. Grohnde is the third nuclear power plant in the federal state of Lower Saxony to be decommissioned by PreussenElektra, which hopes to apply lessons learned from Stade and Unterweser to bring the completion of dismantling at Grohnde forward by two years, to 2037.[1232]

Grafenrheinfeld, a 1200-MW PWR, was closed in June 2015 after having operated for 34 years. The reactor completed defueling in May 2020.[1233] In August 2023, the reactor and fuel storage pool had been emptied and all water had been treated and released, with the plant manager stating that they had now "completed close to half of the nuclear dismantling."[1234] Reactor pressure vessel dismantling began in November 2023 and was to take around eight months.[1235] The cooling towers are scheduled to be demolished in August 2024.[1236] "Nuclear dismantling" is estimated to be completed by 2032–2033, allowing for conventional demolition to begin. The plant is scheduled to be released from regulatory oversight by 2035.[1237]

At the Gundremmingen plant, that comprises three individual reactors A, B, and C, decommissioning is advancing. Gundremmingen-A has been undergoing decommissioning since 1983. Gundremmingen-B was closed in 2017 and defueled in September 2022; this milestone is planned to be achieved for Gundremmingen-C in the mid-2020s as this reactor was closed only in December 2021. The whole site is planned to be released from regulatory oversight in the early 2040s.[1238] End-2023, operator RWE was granted permission to begin the

1231 - Ibidem.

1232 - PreussenElektra, "PreussenElektra erhält Genehmigung zur Stilllegung und zum Abbau des Kernkraftwerks Grohnde", Press Release (in German), 11 December 2023, see https://www.preussenelektra.de/de/newsroom/pressemitteilungen/pressemitteilungen-2023/kwg-erhalt-erste-sag.html, accessed 19 August 2024; and German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.

1233 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.

1234 - PreussenElektra, "Kernkraftwerk Grafenrheinfeld erreicht Rückbau-Meilenstein „Wasserfreiheit"", Press Release (in German), 24 August 2023, see https://www.preussenelektra.de/de/newsroom/pressemitteilungen/pressemitteilungen-2023/kkg-wasserfreiheit.html, accessed 19 August 2024.

1235 - PreussenElektra, "Kernkraftwerk Grafenrheinfeld: Demontage des Reaktordruckbehälters hat begonnen", Press Release (in German), 23 November 2023, see https://www.preussenelektra.de/de/newsroom/pressemitteilungen/pressemitteilungen-2023/kkg-kraftwerksgespraech-2023.html, accessed 27 July 2024.

1236 - PreussenElektra, "Sprengung der Kühltürme des Kernkraftwerks Grafenrheinfeld", Undated (in German), see https://www.preussenelektra.de/de/das-sind-wir/unsere-kraftwerke/kraftwerkgrafenrheinfeld/sprengung-der-kuehltuerme-des-kernkraftwerks-grafenrheinfeld.html, accessed 27 July 2024.

1237 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.; and PreussenElektra, "Rückbau im Fokus—Jahresbericht 2023", April 2024, op. cit.

1238 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.

construction of a waste storage building.[1239] In parallel, RWE is planning to build a gas-turbine power plant, supposedly "H2-ready", at the site.[1240]

A decommissioning license for Isar-2 was requested in 2019, and it was granted in March 2024, despite political opposition from Bavaria's Environment Minister Thorsten Glauber who said that "the closure of the last nuclear power plants in April 2023 was wrong."

The nuclear power plant Isar (also referred to as Ohu) consists of two reactors, Isar-1, an 878-MW BWR closed in 2011 and Isar-2, a 1400-MW PWR, that ceased operation in April 2023. At Isar-1, decommissioning has been underway since 2017, and current tasks involve reactor pressure vessel dismantling. Isar-1 is to be fully decommissioned by 2038.[1241] A decommissioning license for Isar-2 was requested in 2019, and it was granted in March 2024, despite political opposition from Bavaria's Environment Minister Thorsten Glauber who said that "the closure of the last nuclear power plants in April 2023 was wrong."[1242] In preparation for the license approval, spent fuel removal from the reactor core and primary circuit decontamination were already completed. The operator plans to complete the decommissioning of Isar-2 by 2040.[1243]

The reactor Krümmel was officially closed in 2011 but had not generated electricity since 2009. In 2015, the operator applied to local authorities of the state of Schleswig-Holstein to decommission the plant.[1244] The license was approved in June 2024 with a delay of several months.[1245] During the application process, the operator was allowed to defuel the plant and conduct other preparatory tasks but was beginning to "[run] out of useful and meaningful tasks."[1246] As one major post-closure step, defueling, has already been carried out, WNISR considers Krümmel to be in the warm-up stage.

At the Philippsburg site, two reactors are currently undergoing decommissioning. Philippsburg-1, a BWR that ceased operations in 2011, is currently in the hot-zone stage as reactor dismantling advances. Decommissioning has been ongoing at Philippsburg-2, a

1239 - RWE, "Baugenehmigung für TLG erteilt: Wichtiger Schritt für zügigen Abbau der Rückbauanlage Gundremmingen", Press Release (in German), 31 October 2023, see https://www.rwe.com/presse/rwe-nuclear/2023-10-31-baugenehmigung-fuer-tlg-erteilt/, accessed 19 August 2024.

1240 - Ralf Gengnagel, "RWE plant Gasmotorenkraftwerk am AKW-Standort Gundremmingen", *Günzburger Zeitung*, 9 May 2024 (in German), see https://www.augsburger-allgemeine.de/guenzburg/gundremmingen-rwe-plant-gasmotorenkraftwerk-am-akw-standort-gundremmingen-id70689681.html, accessed 16 May 2024.

1241 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.; and PreussenElektra, "Rückbau im Fokus—Jahresbericht 2023", April 2024, op. cit.

1242 - *NEI Magazine*, "Approval notice issued for dismantling of Isar 2", *Nuclear Engineering International*, 27 March 2024, see https://www.neimagazine.com/news/newsapproval-notice-issued-for-dismantling-of-isar-2-11634858, accessed 16 May 2024.

1243 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.; and PreussenElektra, "Rückbau im Fokus—Jahresbericht 2023", April 2024, op. cit.

1244 - KKK, "Kernkraftwerk Krümmel—Antrag nach §7 Abs. 3 AtG auf Stilllegung und Abbau Kernkraftwerk Krümmel", Kernkraftwerk Krümmel GmbH & Co, 24 August 2015 (in German), see https://www.schleswig-holstein.de/DE/fachinhalte/R/reaktorsicherheit/Downloads/Stillegung_Antrag_nach_AtG_KKK.pdf?__blob=publicationFile&v=1, accessed 4 July 2022; and Deutscher Bundestag, "Bericht nach § 7 des Transparenzgesetzes—Rückbau von Kernkraftwerken", Drucksache 20/42, German Bundestag, 4 November 2021, see https://dserver.bundestag.de/btd/20/000/2000042.pdf, accessed 5 April 2022.

1245 - Ministry for the Energy Transition, Climate Protection, Environment and Nature of Schleswig-Holstein, "Genehmigungsbescheid für das Kernkraftwerk Krümmel (KKK)—Stilllegung und Abbau", 20 June 2024, see https://www.schleswig-holstein.de/DE/fachinhalte/R/reaktorsicherheit/Downloads/200624_KKK_Genehmigungsbescheid_Stilllegung.pdf?__blob=publicationFile&v=3, accessed 5 August 2024.

1246 - Lilli Michaelsen, "Kernkraftwerk Krümmel: Kann der Rückbau im Sommer starten?", *Norddeutscher Rundfunk*, 1 February 2024 (in German), see https://www.ndr.de/nachrichten/schleswig-holstein/Kernkraftwerk-Kruemmel-Kann-der-Rueckbau-im-Sommer-starten-,kernkraftwerkkruemmel100.html, accessed 16 May 2024.

1400-MW PWR, since 2020.[1247] The reactor was defueled in the first half of 2023 and work has since moved on to reactor pressure vessel dismantling,[1248] also placing the reactor in the hot-zone stage.

Italy

Since 1988, Italian nuclear power plants have not produced any electricity, and the last two reactors were officially closed in 1990. Since then, decommissioning at all four facilities has been underway with the final goal of brownfield release. The work is conducted by Italian company Societa Gestione Impianti Nucleari SpA (Sogin), which in 2024, 38 years after the last nuclear power generation, signed a collaboration agreement with the European Commission's Joint Research Center "to implement and develop a common nuclear dismantling and radioactive waste management strategy."[1249]

The smallest reactor Garigliano, a 150-MW BWR, is in the hot-zone stage as reactor dismantling continues and is envisioned to be completed by 2025.[1250] A tender for the removal of activated metal plates inside the reactor was launched in 2022.[1251] Another tender, valued at €36 million (US$ $_{2023}$39 million) was launched in August 2023 with the aim of contracting underwater dismantling of the reactor vessel and its internals.[1252] This work began in December 2023, when Sogin's subsidiary Nucleco lifted the reactor pressure vessel head.[1253] For both tenders, it remains unclear who had submitted bids and who actually won.

At the Enrico Fermi (Trino) plant, decommissioning work has been ongoing since 1999. Tenders for dismantling reactor internals are being prepared.[1254] There has been no official update on the progress since WNISR2021, but in 2023, Sogin pushed the expected completion date for brownfield decommissioning back by one year to 2030.[1255] According to a news report

1247 - German Bundestag, "Bericht nach § 7 des Transparenzgesetzes - Rückbau von Kernkraftwerken", Drucksache 20/4558, 2023, op. cit.

1248 - EnBW, "Rückbau am Standort Philippsburg", Energie Baden-Württemberg AG, 2024 (in German), see https://www.enbw.com/unternehmen/konzern/energieerzeugung/kernenergie/rueckbau/rueckbau-philippsburg.html#der-rueckbau-von-block-2, accessed 16 May 2024.

1249 - Sogin, "Sogin and JRC sign a nuclear decommissioning agreement", Societa Gestione Impianti Nucleari SpA, 18 January 2024, see https://www.sogin.it/en/media/news/Sogin-and-JRC-sign-a-nuclear-decommissioning-agreement.html, accessed 19 August 2024.

1250 - Sogin, "Garigliano Nuclear Power Plant—Decommissioning Projects—Reactor dismantling", Undated, see https://www.sogin.it/en/closureoftheitaliannuclearcycle/italian-nuclear-sites/gariglianonuclearpowerplant/decommissioningprojects/reactor-dismantling.html, 19 August 2024.

1251 - Sogin, "Garigliano, launched the call for tender for the dismantling of internals", 20 April 2022, see https://www.sogin.it/en/media/news/garigliano-launched-the-call-for-tender-for-the-dismantling-of-internals.html, accessed 24 June 2022.

1252 - Sogin, "Avviate Le Gare Per Smantellare Il Reattore Della Centrale Del Garigliano E Per Realizzare L'Impianto Magnox A Latina", Press Release (in Italian), 1 August 2023, see https://www.sogin.it/SiteAssets/uploads/2023/notizie/com-stampa-Sogin-Avviate-le-gare-per-smantellare-reattore-centrale-del-garigliano-e-realizzare-impianto-magnox-a-latina.pdf, accessed 5 November 2023.

1253 - Sogin, "The first phase of the vessel dismantling has been completed at the Garigliano nuclear power plant", 21 December 2023, see https://www.sogin.it/en/media/news/Sogin-the-first-phase-of-the-vessel-dismantling-has-been-completed-at-the-Garigliano-nuclear-power-plant.html, accessed 19 August 2024.

1254 - Sogin, "Trino Nuclear Power Plant/Decommissioning Projects—Reactor Dismantling", Undated, see https://www.sogin.it/en/closureoftheitaliannuclearcycle/italian-nuclear-sites/trinonuclearpowerplant/decommissioningprojects/reactor-dismantling.html, accessed 23 June 2023.

1255 - Sogin, "Nuclear Sites—Trino Nuclear Power Plant", Undated, see https://www.sogin.it/en/closureoftheitaliannuclearcycle/italian-nuclear-sites/trinonuclearpowerplant/Pagine/default.aspx, accessed 11 September 2023.

from February 2024, reactor internals dismantling has now begun, thus placing the reactor in the hot-zone stage, and the completion date has been further postponed to 2036.[1256]

At Italy's largest reactor, the 860-MW BWR Caorso, Sogin is making progress, reporting in March 2023 that it had completed 48 percent of the planned activities since decommissioning began in 1999, a notable 10 percent progress made in 2022 alone.[1257] Reactor internal dismantling is expected to begin in 2026 and be completed by 2030,[1258] while the demolition work of the reactor building itself is to begin by the end of 2024.[1259] The release of the site as brownfield is expected for 2031. So far, the project has cost €350 million (US$378.5 million) according to Sogin.[1260]

Italy is in the process of finding a final waste repository, with radioactive waste currently being stored at ten interim storage facilities spread across the country. A map of potential locations for the final repository was released in 2022.[1261] Until this repository is available, the Latina GCR cannot be fully decommissioned. The reactor is of the Magnox design (of which several are under decommissioning in the U.K.) and thus contains several tons of highly contaminated graphite. Preparatory work of dismantling carbon dioxide monitoring and cooling as well as ventilation systems was completed in January 2024 to create space for interim storage of radioactive waste.[1262] Stage 1 of the reactor decommissioning project, which also involves the height reduction of the building (following the approach of the Windscale decommissioning project in the U.K.), is planned to be completed in 2027, and final reactor dismantling is pending the availability of a final repository for generated wastes.[1263] (See WNISR2019 and WNISR2020 for detailed information on decommissioning in Italy.)

1256 - Vanni Caratto, "Decommissioning nucleare, a Trino si è arrivati allo 'smontaggio' del reattore", *Radiotelevisione Italiana*, 23 February 2024 (in Italian), see https://www.rainews.it/tgr/piemonte/video/2024/02/viaggio-nella-centrale-di-trino-ca4c9555-f619-42a2-b9b5-aa305146516b.html, accessed 16 May 2024.

1257 - Emilia-Romagna Notizie, "Ex centrale nucleare di Caorso, lo smantellamento verso il 50%. In arrivo un accordo Sogin-Regione: circa 10 milioni di euro dalle compensazioni ambientali per la riqualificazione e la valorizzazione del tratto piacentino del Po", Press Release (in Italian), 31 March 2023, see https://notizie.regione.emilia-romagna.it/comunicati/2023/marzo/ambiente-ex-centrale-nucleare-di-caorso-lo-smantellamento-verso-il-50-in-arrivo-un-accordo-sogin-regione-circa-10-milioni-di-euro-dalle-compensazioni-ambientali-per-la-riqualificazione-e-la-valorizzazione-del-tratto-piacentino-del-po, accessed 23 June 2023.

1258 - Sogin, "Smantellamento edificio reattore", Undated (in Italian), see https://www.sogin.it/it/chiusuradelciclonucleare/sitinucleariitaliani/centraledicaorso/progettididecommissioning/Pagine/Smantellamento-edificio-reattore.aspx#, accessed 16 May 2024.

1259 - Valentina Paderni, "Centrale di Caorso, addio reattore: entro fine anno via allo smantellamento", *Libertà*, 12 May 2024 (in Italian), see https://www.liberta.it/news/cronaca/2024/05/12/centrale-di-caorso-addio-reattore-entro-fine-anno-via-allo-smantellamento/, accessed 16 May 2024.

1260 - Sogin, "Caorso Nuclear Power Plant", Undated, see https://sogin.it/en/closureoftheitaliannuclearcycle/italian-nuclear-sites/caorsonuclearpowerplant/Pagine/default.aspx, accessed 16 May 2024.

1261 - Maria Rosaria Di Nucci and Andrea Prontera, "Nuclear Waste Governance in Italy: Between Participation Rhetoric and Regionalism", in Maarten Arentsen and Rinie Van Est, "The Future of Radioactive Waste Governance", *Springer Fachmedien Wiesbaden*, 2023, pp.51–83, see https://link.springer.com/10.1007/978-3-658-40496-3_3, accessed 23 June 2023.

1262 - Sogin, "Latina: reactor building rooms vacated", 9 January 2024, see https://www.sogin.it/en/media/news/Latina-reactor-building-rooms-vacated.html, accessed 5 August 2024.

1263 - Sogin, "Dismantling of the reactor building", Latina Nuclear Power Plant, Undated, see https://www.sogin.it/en/closureoftheitaliannuclearcycle/italian-nuclear-sites/latinanuclearpowerplant/decommissioningprojects/dismantling-of-the-reactor-building.html, accessed 5 August 2024.

Japan

As of mid-2024, 27 reactors (17.1 GW) were permanently disconnected from the Japanese grid. All currently closed reactors remain in the warm-up-stage as of now. The country, one of the early adopters of nuclear power, has not completed decommissioning of a single commercial reactor as the only completed decommissioning project is the small 12-MW research reactor, Japan Power Demonstration Reactor (JPDR). Here, physical decommissioning work lasted from 1986 to 1996, and the site was used as test site for demonstration purposes.[1264] In October 2002, the JPDR was released from regulatory oversight as a greenfield site.[1265]

The decommissioning of the Magnox reactor Tokai-1 began in 2001. The dismantling of auxiliary components and buildings has begun, and in some cases, such as the turbines, it has been completed.[1266] According to a December 2023 update, the original plan of beginning hot-zone works in 2024 was postponed by five years, pushing the estimated completion date for these tasks from 2030 to mid-2034.[1267]

The decommissioning of Fugen Advanced Thermal Reactor (ATR) started in 2008. Radiological decommissioning is planned to be completed by FY2038, with reactor core dismantling to begin in FY2029, while the finalization of building demolition is expected by FY2040.[1268] Work on Hamaoka-1 and -2 began in late 2009, and the planned finalization was postponed compared to last year's plan from FY2036 to FY2042.[1269]

Mihama-1 and -2, Shimane-1, and Tsuruga-1 received their decommissioning licenses in 2017.[1270] Tsuruga-1 is to be decommissioned by FY2039, both Mihama plants by FY2045, and Shimane-1 by FY2049, marking a four-year delay compared to last year's project finalization estimates.[1271] Decommissioning at the Mihama units is advancing and is now in the second of four official stages, in which progress is advancing towards reactor internals dismantlement.[1272]

Cleanup at the Fukushima Daiichi plant is slowly advancing as fuel is being removed from the six reactors. The main challenges lie in determining the composition of debris in the damaged containment chambers of Units 1–3. In March 2024, 12 photos were published, taken via specialized drones that were flown into Unit 1. The photos show the degree of remaining

1264 - JAEA, "JPDR (Japan Power Demonstration Reactor)", Japan Atomic Energy Agency, Undated, see https://www.jaea.go.jp/english/04/ntokai/decommissioning/01/decommissioning_01_01_01.html; and JAEA, "Decommissioning Facility", Undated, see https://www.jaea.go.jp/english/04/ntokai/decommissioning/01/decommissioning_02.html; both accessed 5 November 2023.

1265 - Satoshi Yanagihara, "Outcome of the Japan Power Demonstration Reactor Decommissioning Project", Research Institute of Nuclear Engineering, University of Fukui, presented at "2019 Sino-Japanese Workshop on NPP Decommissioning Technology", Atomic Energy Council 3F, 29–30 October 2019.

1266 - JAPC, "東海発電所の廃止措置—廃止措置工事のスケジュール ["Decommissioning of Tokai NPP"]", The Japan Atomic Power Company, December 2023, see http://www.japc.co.jp/tokai/haishi/construction.html, accessed 16 May 2024.

1267 - JAPC, "東海発電所 廃止措置工程 ["Tokai power station decommissioning process"]", The Japan Atomic Power Company, December 2023, see https://www.japc.co.jp/tokai/haishi/pdf/20231221.pdf, accessed 16 May 2024.

1268 - JAEA, "Basic Schedule of Decommissioning", FUGEN Decommissioning Engineering Center, Undated, see https://www.jaea.go.jp/04/fugen/en/haishi/plan/processl/, accessed 16 May 2024.

1269 - JAIF, "Current Status of Nuclear Power Plants in Japan", as of 8 May 2024, op. cit.

1270 - *WNN*, "Decommissioning plans approved for five Japanese units", 19 April 2017, see https://www.world-nuclear-news.org/Articles/Decommissioning-plans-approved-for-five-Japanese-u, accessed 8 June 2022.

1271 - JAIF, "Current Status of Nuclear Power Plants in Japan", Japan Atomic Industrial Forum, as of 14 March 2024, op. cit.

1272 - Kansai Electric Power Group, "Integrated Report 2023", September 2023, see https://www.kepco.co.jp/english/corporate/list/report/pdf/e2023_a4.pdf, accessed 17 May 2024.

to-be-cleaned damage inside. However, the drones were not equipped with dosimeters, thus not allowing a radiological assessment of the visually observed melted materials.[1273] Work is currently ongoing to install a so-called "large cover" over Unit 1 to provide protection from high-dose radiation. As of now, this task is two years behind schedule and is planned to be completed by mid-FY2025, but this delay is said to have no effect on the planned start of fuel removal in FY2027. Contaminated debris removal at Unit 2 is further delayed from the original plan of beginning in 2021, as testing of a robot arm is still in the planning stage. The beginning of trial retrieval is now envisioned for October 2024.[1274] Whether this impacts the schedule for fuel removal at Unit 2 remains unclear. Units 3 and 4 were defueled in December 2014 and February 2021, respectively.[1275] Units 5 and 6 are to be defueled in 2031.[1276] Then, actual dismantling is to begin, and the official target for completion is defined rather vaguely as "to be completed 30-40 years after the cold shutdown in December 2011."[1277] See Fukushima Status Report for details.

Fukushima Daini, a four-unit BWR located approximately 11 kilometers south of Fukushima Daichi was shut down after the 2011 earthquake and officially permanently closed in 2019 when owner TEPCO announced its decision to decommission the plant. Decommissioning began in 2021 after the permit was granted. Fuel is to be removed over a 22-year period and shall be stored in a to-be-constructed dry cask storage facility onsite.[1278] Full decommissioning is to be completed in FY2064.[1279]

All fuel from the Fast Breeder Reactor (FBR) Monju was moved to wet storage in October 2022, completing the first of four official decommissioning stages. The next steps are to extract the liquid sodium coolant from the reactor and dismantle internal equipment. Dismantling of components is to begin in 2032. The reactor building is to be demolished by 2047.[1280]

For Units 1 and 2 at the Genkai plant, officially closed in 2015 and 2019, respectively, the end of decommissioning work is scheduled for FY2054.[1281] For the decommissioning of Genkai-1

1273 - Mari Yamaguchi, "Images taken deep inside melted Fukushima reactor show damage, but leave many questions unanswered", *The Associated Press*, 19 March 2024, see https://apnews.com/article/japan-fukushima-damaged-reactor-drone-photos-f60016bb626c1eebb63e08065d3b133d, accessed 17 May 2024.

1274 - The Inter-Ministerial Council for Contaminated Water and Decommissioning Issues, "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station", Japanese Ministry for Economy, Trade and Industry, December 2019, see https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20191227_3.pdf; and Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water and METI, "Outline of Decommissioning, Contaminated Water and Treated Water Management", Japanese Ministry of Economy, Trade and Industry, January 2024, see https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/mp202401.pdf, both accessed 17 May 2024.

1275 - Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water, "Outline of Decommissioning, Contaminated Water and Treated Water Management", Ministry of Economy, Trade and Industry, Government of Japan, April 2023, see https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/mp202304.pdf, accessed 21 June 2023.

1276 - TEPCO, "Roadmap on the Way to Decommissioning", Tokyo Electric Power Company Holdings, 2022, see https://www.tepco.co.jp/en/hd/decommission/project/roadmap/index-e.html, accessed 8 June 2022.

1277 - JAIF, "Current Status of Nuclear Power Plants in Japan", as of 8 May 2024, op. cit.

1278 - *WNN*, "Fukushima Daini decommissioning plan approved", 28 April 2021, see https://www.world-nuclear-news.org/Articles/Fukushima-Daini-decommissioning-plan-approved, accessed 17 May 2024.

1279 - JAIF, "Current Status of Nuclear Power Plants in Japan", as of 8 May 2024, op. cit.

1280 - JAEA, "Japan Atomic Energy Agency 2023 (Business Report FY2022)", Japan Atomic Energy Agency, November 2023, see https://www.jaea.go.jp/english/publication/annual_report/2023.pdf, accessed 17 May 2024.

1281 - JAIF, "Current Status of Nuclear Power Plants in Japan", as of 8 May 2024, op. cit.

and -2, operator Kyushu operates a special account that, in 2021, held approximately US$379 million,[1282] which had already been reduced to US$262 million by 2023.[1283]

At Ikata-1, decommissioning work began in January 2021, when the unit entered the first phase of decommissioning (fuel removal and dismantling of secondary system equipment), which is expected to go on until “around” FY2026. Decommissioning of Ikata-2 is following the same schedule with a three-year delay.[1284] Current estimations put completion dates at FY2056 for Ikata-1 and FY2059 for Ikata-2.[1285]

In December 2019, Units 1 and 2 of the Ohi nuclear plant received their decommissioning license approval.[1286] Both reactors are in the first of four stages in which equipment in the turbine hall is to be dismantled, and a radiological assessment is underway.[1287] Decommissioning is planned to be completed in FY2048 at both units.[1288]

While Units 2 and 3 of the Onagawa plant remain in long-term outage since 2011, Unit 1 was officially permanently closed in 2018 and is to be decommissioned in FY2053.[1289] Currently, the reactor is being defueled, which is expected to be completed by 2027.[1290]

Lithuania

In Lithuania, two reactors with 1185 MW each were closed in 2004 and 2009, respectively, as a pre-requisite for Lithuania to join the European Union. Both reactor cores are defueled, and in May 2021, the last spent fuel assemblies were removed from the pool of Unit 1 and transported to an interim dry storage facility. The complete removal of the spent fuel from Unit 2 was achieved in April 2022.[1291] Work is currently ongoing at Unit 1 in areas of the plant dubbed by operator Ignalinos Atominė Elektrinė (IAE) as “R1” and “R2” zones to prepare for the dismantling of the reactor core itself, i.e., zone “R3”. These activities are scheduled to

1282 - Kyuden Group, “Integrated Report 2021”, Kyushue Electric Power, September 2021, see https://www.kyuden.co.jp/library/pdf/en/ir/integratedreport/2021/en_integratedreport_2021.pdf, accessed 8 June 2022.

1283 - Kyuden Group, “Integrated Report 2023”, Kyushue Electric Power, 2023, see https://www.kyuden.co.jp/var/rev0/0467/5082/en_integratedreport_2023_b.pdf, accessed 17 May 2024.

1284 - Shikoku Electric Power Group, “Integrated Report 2023”, Yonden, November 2023, see https://www.yonden.co.jp/english/assets/pdf/ir/tools/ann_r/annual_e_2023.pdf, accessed 17 May 2024.

1285 - Ibidem; and JAIF, “Current Status of Nuclear Power Plants in Japan”, as of 8 May 2024, op. cit.

1286 - *WNN*, “Regulator approves decommissioning plan for Ohi 1 and 2”, 11 December 2019, see https://www.world-nuclear-news.org/Articles/Regulator-approves-decommissioning-plan-for-Ohi-1, accessed 12 September 2023.

1287 - Kansai Electric Power Group, “Integrated Report 2023”, September 2023, op. cit.

1288 - JAIF, “Current Status of Nuclear Power Plants in Japan”, as of 8 May 2024, op. cit.

1289 - Ibidem.

1290 - Tohoku Electric Power Corporation, “女川原子力発電所1号機の廃止措置に関する情報 [“Information regarding decommissioning of Onagawa Nuclear Power Plant Unit 1”]”, Undated, see https://www.tohoku-epco.co.jp/electr/genshi/safety/haishi/info.html, accessed 17 May 2024.

1291 - State Enterprise Ignalina Nuclear Power Plant, “The last cask of spent fuel was transported for temporary storage”, Press Release, 22 April 2022, see https://www.iae.lt/en/news/press-releases/the-last-cask-of-spent-fuel-was-transported-for-temporary-storage/836; and *WNN*, “Defuelling of Ignalina units completed”, 22 April 2022, see https://www.world-nuclear-news.org/Articles/Defuelling-of-Ignalina-units-completed; both accessed 5 November 2023.

receive authorization to begin at Unit 2 in 2024.[1292] In early 2023, IAE signed two contracts, valued at US$5.8 million each, with a consortium of Westinghouse Electric Spain, Jacobs Slovakia, and the Lithuanian Energy Institute, and with another consortium consisting of EDF and Graphitec, to design plans to dismantle the RBMK reactors. Physical dismantling of zone "R3", with the aim of releasing a "brownfield" site in 2038, is planned to begin in 2028.[1293] (See WNISR2019 for details on decommissioning in Lithuania.)

Russia

As of mid-2024, Russia accounts for 11 closed reactors with a combined capacity of 4.9 GW consisting of two different reactor types: eight first-generation Light-Water Gas-cooled Reactors (LWGR)—among them four RBMK Chornobyl-type reactors—and three Soviet-style PWRs.

At the Kursk plant, there are two parts, one with four units and one with two units under construction. Of the four-reactor section, two units have been closed and the two remaining reactors are scheduled to come offline by 2031 (see Russia Focus). Kursk-1 was closed in 2021, and Kursk-2 followed in January 2024, defueling at the latter has apparently already begun.[1294] Defueling of Unit 1 was completed in November 2023 after about 18 months.[1295]

Leningrad-1 and -2 were closed in 2018 and 2020, respectively. The reactors were defueled in August 2021 and August 2023, respectively.[1296] The sites are to be turned into pilot sites for RBMK dismantling.[1297] Both reactors are awaiting the dedicated decommissioning licenses to be approved, which is expected by 2025, before actual dismantling can begin. In the meantime, additional waste storage and treatment facilities are being planned to be built onsite by 2026.[1298]

Considering the long-anticipated decommissioning duration of 50 years and unclear decommissioning strategies, WNISR considers all other Russian reactors to be in LTE as long as there is no documented evidence of decommissioning progress. (See WNISR2019 for details on decommissioning in Russia.)

1292 - IAE, "Reactor Core Dismantling Project R3", Ignalinos Atominė Elektrinė/Ignalina Nuclear Power Plant, Undated, see https://www.iae.lt/en/reactor-core-dismantling-project-r3/373; and IAE, "10,000 tonnes of equipment and structures dismantled in 2023", Press Release, 18 January 2024, see https://www.iae.lt/en/news/press-releases/10000-tonnes-of-equipment-and-structures-dismantled-in-2023/1057; both accessed 17 May 2024.

1293 - State Enterprise Ignalina Nuclear Power Plant, "Ignalina NPP has signed two contracts", 12 January 2023, see https://www.iae.lt/en/news/press-releases/ignalina-npp-has-signed-two-contracts/929; and *WNN*, "Contracts for Ignalina dismantling technology", 4 January 2023, see https://www.world-nuclear-news.org/Articles/Contracts-for-Ignalina-dismantling-technology; both accessed 5 November 2023.

1294 - *WNN*, "Kursk's second unit retires after 45 years operation", 31 January 2024, see https://www.world-nuclear-news.org/Articles/Kursk-s-second-unit-retired-after-45-years-operati, accessed 31 January 2024; and Rosenergoatom, "Power unit No. 2 of the Kursk NPP was taken out of power generation mode after 45 years of successful operation", Press Release, Rosatom, 1 February 2024, see https://www.rosenergoatom.ru/en/for-journalists/highlights/45620/, accessed 20 August 2024.

1295 - Rosenergoatom, "At the Kursk NPP the last fuel assembly was unloaded from the reactor of power unit No. 1", Press Release, Rosatom, 23 November 2023, see https://rosenergoatom.ru/en/for-journalists/news/45156/, accessed 19 August 2024.

1296 - *WNN*, "Second Leningrad unit defuelled", 23 August 2023, see https://www.world-nuclear-news.org/Articles/Second-Leningrad-unit-defuelled, accessed 1 November 2023.

1297 - *NEI Magazine*, "Leningrad NPP to be pilot site for RBMK decommissioning", 30 June 2023, see https://www.neimagazine.com/news/newsleningrad-npp-to-be-pilot-site-for-rbmk-decommissioning-10978741, accessed 24 July 2023.

1298 - *NEI Magazine*, "Leningrad NPP prepares used fuel handling complex to support decommissioning", 31 January 2024, see https://www.neimagazine.com/news/newsleningrad-npp-prepares-used-fuel-handling-complex-to-support-decommissioning-11476895, accessed 17 May 2024.

South Korea

South Korea is running a large nuclear program, including 25 operating reactors, one reactor in LTO, and two units under construction. As of mid-2024, two commercial reactors had been closed. The first reactor, South Korea's oldest unit Kori-1, a 576-MW PWR, was closed in 2017. At the time, defueling was envisioned by end-2025 and the completion of plant dismantling by 2032.[1299] Operator Korea Hydro & Nuclear Power (KHNP) applied for a decommissioning license in 2021, but as of mid-2024 it had not yet been granted one. Nonetheless, first radiological assessment and decontamination work began in May 2024.[1300] The same month, KHNP was reported as using its "four-legged autonomous robot" designed to carry out radiation dose measurements (to help minimize exposure to workers) for the first time. A flying robot for the same purpose is still under development.[1301]

Wolsong-1, a 661-MW Pressurized Heavy-Water Reactor (PHWR), ceased generating power in May 2017 and was officially closed in December 2019.[1302] In November 2022, KHNP signed a Memorandum of Understanding with Canadian Candu Energy to join forces in decommissioning Wolsong-1 under a direct dismantling strategy, potentially making Wolsong-1 the first heavy-water reactor worldwide to follow an immediate decommissioning strategy.[1303] In October 2023, KHNP signed another Memorandum of Understanding with a different Canadian company, Kinectrics, and with the Canadian non-profit Nuclear Waste Management Organization (NWMO), to strengthen cooperation on PHWR decommissioning and waste management. KHNP plans to submit the final decommissioning plan for the Wolsong-1 reactor in June 2024 and commence dismantling once approval is granted.[1304]

Spain

Spain defines its national policy for reactor decommissioning in the official, periodically updated, General Radioactive Waste Plan. The Spanish administration describes decommissioning and waste management as an essential public service and assigns these tasks by law to state-owned radioactive waste-management company Enresa (Empresa Nacional de Residuos Radiactivos S.A.).[1305] Waste management and decommissioning in Spain are financed via a levy (mistakenly

1299 - Daeyong Kim, "Status of Decommissioning Preparation for Kori #1", Korea Hydro & Nuclear Power, presented at the Eleventh Annual Meeting of the International Decommissioning Network (IDN), 6 December 2017, see https://nucleus.iaea.org/sites/connect/IDNpublic/IDN%20Annual%20Forum%202017/SESSION%205_KHNP%20Status%20of%20Deccommissioning%20Preparation%20for%20Kori1__KIM.pdf, accessed 5 August 2024.

1300 - *Yonhap*, "Korea begins process to decommission country's first commercial Kori-1 nuclear reactor", as published by *The Korea Times*, 8 May 2024, see https://www.koreatimes.co.kr/www/nation/2024/05/281_374144.html, accessed 21 May 2024.

1301 - *WNN*, "KHNP deploys four-legged robot in Kori decommissioning", 13 May 2024, see https://www.world-nuclear-news.org/Articles/KHNP-deploys-four-legged-robot-in-Kori-decommissio, accessed 21 May 2024.

1302 - KHNP, "Nuclear Power Operation – Plant Status", Korea Hydro & Nuclear Power, 31 December 2018, see http://cms.khnp.co.kr/eng/content/529/main.do?mnCd=EN03020101, accessed 27 March 2019; and KHNP, "Overview", Undated, see https://www.khnp.co.kr/eng/contents.do?key=414, accessed 5 November 2023.

1303 - Cho Jeehyun, "Korea Hydro & Nuclear Power teams up with Candu Energy to retire Wolsong 1", *Pulse* by *Maeil Business News Korea*, as published by *Invest Korea*, 23 November 2022, see https://www.investkorea.org/ik-en/bbs/i-465/detail.do?ntt_sn=491939&clickArea=enmain00019, accessed 21 June 2023.

1304 - KHNP, "KHNP Enhances Expertise in PHWR Nuclear Reactor Decommissioning", Press Release, Korea Hydro & Nuclear Power, 1 November 2023, see https://www.khnp.co.kr/eng/selectBbsNttView.do?key=565&bbsNo=84&nttNo=50013&searchCtgry=&searchCnd=all&searchKrwd=&integrDeptCode=&pageIndex=2, accessed 23 May 2024.

1305 - By Article 38 bis of Law 25/1964 of the Nuclear Energy Act.

labeled as the "Enresa fee") paid per MWh by the nuclear operators. Over the years, this levy has increased from €1.88 per MWh (US$2.34 per MWh) in 2005 to €7.98 (US$8.93) in 2019. As of 1 July 2024, it was increased by another 30 percent to €10.32 (US$11.16) due to expected financial shortfalls in waste and decommissioning funds.[1306] Regardless, decommissioning is underway at several closed reactors.

While the LTE strategy is being applied to the GCR Vandellos-1 (until 2028),[1307] all LWRs are planned to be directly dismantled to a greenfield status. Enresa's website does not mention the year 2028; according to the website, decommissioning of Vandellos-1 is to be finalized by "around 2030". Whether this already indicates a delay or just unprecise phrasing, remains unclear.[1308]

In June 2022, demolition of the turbine building at the José Cabrera (Zorita) reactor, which was closed in 2006, was completed, and the demolition of the containment building in September 2023 marked the completion of demolition work at the site.[1309] The demolition of the last large building on the site allows for the upcoming release of the site. As of January 2024, 70 percent of the site had been restored,[1310] potentially allowing for its release at the end of the year.[1311] Spain thus becomes the fourth country to have completed the decommissioning of a nuclear power plant and might soon be the third to bring a site to greenfield status.

The 446-MW BWR Santa Maria de Garoña (Garoña-1) suspended operations in 2013 and was officially closed in 2017. In July 2023, the first of two dismantling licenses was granted, allowing for the first of two decommissioning stages to commence. This first stage involving the dismantling of the turbine building and the removal of spent fuel from wet storage is expected to be finalized in 2026, after which the second stage, mainly composed of radiological decommissioning, can begin. Final restoration of the site is envisioned for 2033. The whole project is expected to cost €475 million (US$514 million).[1312] Additional costs of approximately €180 million (US$196 million) are expected for the construction of an onsite interim dry

1306 - *CE Noticias Financieras,* "The Government proposes a 30% increase in the Enresa Rate, 10.32 euros/MWhour, compared to the 40% initially proposed", 3 April 2024.

1307 - Enresa, "Dismantling of the Vandellós I Nuclear Power Plant", Empresa Nacional de Residuos Radiactivos S.A./Spanish Radioactive Waste Management Agency, Undated, see https://www.enresa.es/eng/index/activities-and-projects/dismantling-and-environmental-restoration/dismantling-of-vandellos-i-nuclear-power-plant, accessed 25 July 2023.

1308 - Enresa, "Activities and Projects—Dismantling of the Vandellós I Nuclear Power Plant", 2024, see https://www.enresa.es/eng/index/activities-and-projects/dismantling-and-environmental-restoration/dismantling-of-vandellos-i-nuclear-power-plant, accessed 23 May 2024.

1309 - *NEI Magazine*, "Restoration Progress at Zorita Plant Site", 27 September 2023, see https://www.neimagazine.com/news/restoration-progress-at-zorita-plant-site-11175462/, accessed 20 August 2024.

1310 - Jesùs Blanco Orozco, "Los terrenos de la Central Nuclear de Zorita ya están restaurados en un 70%", *SER Guadalajara*, 17 January 2024 (in Spanish), see https://cadenaser.com/castillalamancha/2024/01/17/los-terrenos-de-la-central-nuclear-de-zorita-ya-estan-restaurados-en-un-70-ser-guadalajara/, accessed 21 May 2024.

1311 - Santiago Barra, "Desmantelada la primera central nuclear española, medio siglo después", *Guadalajara Diario* (in Spanish), 28 March 2023, see https://www.guadalajaradiario.es/provincia/55704-desmantelada-la-primera-nuclear-espanola-espanola-medio-siglo-despues.html, accessed 22 June 2023.

1312 - Enresa, "Dismantling of the Santa María de Garoña Nuclear Power Plant", Empresa Nacional de Residuos Radiactivos, S.A., Undated, see https://www.enresa.es/eng/index/activities-and-projects/dismantling-and-environmental-restoration/dismantling-of-the-santa-maria-de-garona-nuclear-power-plant, accessed 20 August 2024.

storage facility for spent fuel containers.[1313] (See WNISR2019 for details on the Spanish decommissioning process.)

United Kingdom

In 2022, the closure of both reactors at Hinkley Point B marked the next step of the process of gas-cooled reactor closures in the U.K. With these closures, eight Advanced Gas-cooled Reactors (AGR) remain operational: Hartlepool A-1 & -2, Heysham A-1 & A-2, Heysham B-1 & B-2, and Torness-1 & -2. These are all scheduled to be closed by 2028.[1314] However, in early 2024, EDF Energy announced it was considering applying for lifetime extensions for some of its AGR plants; the final decision is expected towards the end of year.[1315]

As of mid-2024, the U.K. had a total of 36 closed reactors (corresponding to 7.8 GW) awaiting or in various stages of decommissioning. This fleet consists of 26 GCR Magnox reactors, two Fast Breeder Reactors (FBR), seven AGRs, including the Windscale reactor at Sellafield, and one HWR at Winfrith. The Nuclear Decommissioning Authority (NDA), the responsible state agency, recently switched the decommissioning strategy from deferred to direct dismantling, moving several reactors into an active decommissioning status. Nonetheless, the NDA expects nuclear decommissioning to last well into the 22nd century.[1316] In 2024, the 100-kW research reactor at the Imperial College Reactor Centre became the first reactor site to be fully decommissioned in the U.K. under "modern regulatory controls" after being closed in 2012.[1317] As it was never connected to the grid, WNISR does not include the reactor in its statistics.

As of mid-2024, six reactors are in LTE, while the following 30 reactors are undergoing decommissioning:

- 21 reactors are in the warm-up stage: Berkeley-1 & -2 (both defueled), Chapelcross 1–4 (all defueled), Dounreay DFR, Dounreay PFR, Dungeness A-1 & A-2 (both defueled), Dungeness B-1 & B-2, Hinkley Point B-1 & B-2, Hunterston B-1 (defueled) & B-2, Trawsfynydd-1 & -2 (both defueled), Windscale (defueled), and Wylfa-1 & -2 (both defueled),
- 9 reactors are in the hot-zone-stage: Hinkley Point A-1 & -2, Hunterston A-1 & A-2, Oldbury A-1 & A-2, Sizewell A-1 & A-2, and Winfrith.

1313 - *Agencia EFE*, "Primera fase del desmantelamiento de Garoña: así se gestionan 7.000 toneladas de residuos", as published by *COPE*, 26 November 2023 (in Spanish), see https://www.cope.es/actualidad/economia/noticias/primera-fase-del-desmantelamiento-garona-asi-gestionan-7000-toneladas-residuos-20231126_3021500, accessed 21 May 2024.

1314 - Department for Energy Security and Net Zero, "Civil nuclear: roadmap to 2050", U.K. Government, Updated 26 January 2024, see https://www.gov.uk/government/publications/civil-nuclear-roadmap-to-2050/civil-nuclear-roadmap-to-2050-accessible-webpage, accessed 20 August 2024.

1315 - EDF, "UK nuclear investment: ensuring output stability until 2026", 9 January 2024, see https://www.edfenergy.com/media-centre/investment-boost-maintain-uk-nuclear-output-current-levels-until-least-2026, accessed 15 July 2024.

1316 - NDA, "Nuclear Decommissioning Authority: Business Plan 2024 to 2027", Nuclear Decommissioning Authority, 17 April 2024, see https://www.gov.uk/government/publications/nuclear-decommissioning-authority-business-plan-2024-to-2027, accessed 20 April 2024.

1317 - ONR, "ONR completes first ever full decommissioning of UK reactor site under modern regulatory controls", Office for Nuclear Regulation, 28 February 2024, see https://onr.org.uk/news/all-news/2024/02/onr-completes-first-ever-full-decommissioning-of-uk-reactor-site-under-modern-regulatory-controls/, accessed 20 August 2024.

For several years, the U.K.'s decommissioning industry had been organized in a so-called "Parent Body Organization" model that attempted to bring private industry expertise to the challenge of nuclear decommissioning for efficiency gains. After it became apparent that this goal would not be achieved, the approach was retracted from 2016 onwards for the various Site-License Companies (SLC) that acted as operators of the closed-reactor sites, and since 2021, ownership and decommissioning responsibility has fully returned to the NDA. Decommissioning is now conducted by the NDA via the individual SLCs, mainly Sellafield Ltd and Magnox Ltd.[1318]

Sellafield Ltd was the first SLC to be returned to full NDA ownership in 2016.[1319] This SLC is responsible for the cleanup at the Sellafield site, which is the oldest, largest, and most complex nuclear site in the U.K. The site houses a large number of diverse nuclear facilities including legacy spent fuel pools and storage ponds, reprocessing plants, as well as nuclear reactors Calder Hall 1–4 (in LTE) and Windscale (in warm-up). The first removal of waste from the Pile Fuel Cladding Silo in August 2023 marked the first time that waste retrieval was ongoing at all four legacy ponds and silos in parallel.[1320] In March 2023, specialist divers entered the pool for the first time in 65 years to begin sludge and debris removal in areas not accessible to robots. Pool drainage and building demolition is planned to be completed by 2039.[1321] The removal of the first of 236 zeolite waste containers from the Magnox fuel storage pond and transfer to the onsite interim storage facility in March 2024 marks the beginning of "one of the site's most challenging decommissioning programmes".[1322] Despite some progress, the site continues to make headlines because of safety, work culture, and security issues. After having been fined £400,000 (US$$_{2023}$497,000) in March 2023 for a health- and safety-risk breach that resulted in the injury of a worker,[1323] Sellafield Ltd was prosecuted for "alleged information technology security offences" following an investigation carried out by the Office for Nuclear Regulation (ONR) into potential IT security breaches. These possibly involved Russian and Chinese cyber-attacks,[1324] and according to an investigation by *The Guardian*, add to a list of "multiple [nuclear] safety and cybersecurity failings", that have led Irish, Norwegian, and

1318 - Alexander Wimmers, Rebekka Bärenbold et al., "Decommissioning of Nuclear Power Plants: Regulation, Financing, and Production", Data Documentation 104, DIW Berlin, Department of Energy, Transportation, Environment of German Institute for Economic Research, Workgroup for Infrastructure Policy at TU-Berlin, Faculty of Business and Economics at University of Basel, January 2023, see https://www.diw.de/documents/publikationen/73/diw_01.c.864222.de/diw_datadoc_2023-104.pdf, accessed 26 January 2023.

1319 - Sellafield Ltd, "Corporate Plan 2016/17-2036", April 2017, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/627566/SEL11098_corporate-plan_web.pdf, accessed 25 April 2022.

1320 - NDA, "Nuclear Decommissioning Authority: Business Plan 2024 to 2027", 17 April 2024, op. cit.

1321 - Sellafield Ltd and NDA, "Sellafield clean-up team dives into history", Nuclear Decommissioning Authority, U.K. Government, 29 March 2023, see https://www.gov.uk/government/news/sellafield-clean-up-team-dives-into-history, accessed 20 August 2024; and *BBC*, "Divers enter Sellafield nuclear pool for first time in 65 years", 30 March 2023, see https://www.bbc.com/news/uk-england-cumbria-65113701, accessed 27 May 2024.

1322 - Sellafield Ltd and NDA, "Sellafield clean-up skips ahead after triple first in legacy pond", Nuclear Decommissioning Authority, U.K. Government, 25 March 2024, see https://www.gov.uk/government/news/sellafield-clean-up-skips-ahead-after-triple-first-in-legacy-pond, accessed 20 August 2024.

1323 - ONR, "Sellafield Ltd fined after worker scaffolding ladder fall", Office for Nuclear Regulation, 6 March 2023, see https://www.onr.org.uk/news/all-news/2023/03/sellafield-ltd-fined-after-worker-scaffolding-ladder-fall/, accessed 27 May 2024.

1324 - *BBC*, "Sellafield to be prosecuted for IT security offences", 28 March 2024, see https://www.bbc.com/news/technology-68675500, accessed 27 May 2024; and ONR, "ONR notifies Sellafield Ltd of intention to prosecute", Office for Nuclear Regulation, 28 March 2024, see https://www.onr.org.uk/news/all-news/2024/03/onr-notifies-sellafield-ltd-of-intention-to-prosecute/, accessed 20 August 2024.

U.S. government officials to raise concerns.[1325] In June 2024, Sellafield Ltd plead guilty to all charges.[1326]

Magnox Ltd—now Nuclear Restoration Services—became an NDA subsidiary in 2019 and is responsible for decommissioning at Berkeley, Bradwell, Chapelcross, Dungeness A, Harwell, Hinkley Point A, Hunterston A, Oldbury A, Sizewell A, Trawsfynydd, Winfrith, and Wylfa, and since April 2023, for both FBRs at Dounreay.[1327] After changing its initial blanket strategy to a site-specific approach, the NDA has been trying to identify the best approach for each site and has selected several "lead and learn" sites.[1328] Consequently, sites are in various stages, but decommissioning dates have been pulled forward by several decades. Winfrith is planned to be the first site to be released from its nuclear license in 2036, while the estimates for most other sites range from the 2050s to 2080s.[1329]

In May 2023, it was announced that the demolition of the four "blower house structures" at the Berkeley site, in which radioactive gas had been circulated during operations, would be brought forward by 50 years. The demolition is expected to take eight years. In parallel, underground vaults containing several hundreds of (metric) tons of radioactive fuel debris and sludge are to be emptied, and repacked waste will be transferred to an onsite interim storage facility.[1330] Meanwhile, plans are being made by Rolls-Royce and the Chiltern Vital Group to "establish a low-carbon energy super cluster" at the site and develop SMR technology.[1331]

At Trawsfynydd, the designated "lead and learn site", preparations for reactor dismantling are underway, signaling a potential start of hot-zone tasks in the coming years.[1332]

April 2024 marked the completion of a 20-year intermediate-level waste removal project at the Hunterston A site, in which 2,100 metric tons of waste had been removed from underground bunkers to an interim storage site. Ongoing waste removal is now focusing on remaining sludge from spent fuel ponds and acids.[1333]

Regarding the decommissioning of the Dounreay FBRs, there were conflicting reports. While the responsible SLC said in its 2023 report that reactor dismantling could begin once

1325 - Anna Isaac and Alex Lawson, "Revealed: Sellafield nuclear site has leak that could pose risk to public", *The Guardian*, 5 December 2023, see https://www.theguardian.com/business/2023/dec/05/sellafield-nuclear-site-leak-could-pose-risk-to-public; and Anna Isaac and Alex Lawson, "Sellafield nuclear safety and security director to leave", *The Guardian*, 8 January 2024, see https://www.theguardian.com/business/2024/jan/08/sellafield-nuclear-safety-and-security-director-to-leave; both accessed 27 May 2024.

1326 - ONR, "Sellafield Ltd pleads guilty to cyber security offences", Press Release, Office for Nuclear Regulation, 20 June 2024, see https://onr.org.uk/news/all-news/2024/06/sellafield-ltd-pleads-guilty-to-cyber-security-offences/, accessed 20 August 2024.

1327 - NDA, "Business Plan—Financial year beginning April 2023 to financial year ending March 2026", SG/2023/34, April 2023, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1151390/Business_Plan_2023-2026_-_final_for_web.pdf, accessed 23 June 2023; and Nuclear Restoration Services, "Our sites", 24 October 2023, see https://www.gov.uk/government/collections/our-sites--2, accessed 20 August 2024.

1328 - NDA, "NDA Strategy - Effective from March 2021" Nuclear Decommissioning Authority, March 2021, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/973438/NDA_Strategy_2021_A.pdf, accessed 26 July 2023.

1329 - NDA, "Nuclear Decommissioning Authority: Business Plan 2024 to 2027", 17 April 2024, op. cit.

1330 - Magnox Ltd and NDA, "Magnox awards £53m clean-up contracts", 9 May 2023, see https://www.gov.uk/government/news/magnox-awards-53m-clean-up-contracts, accessed 20 August 2024.

1331 - Dave Harvey and Sammy Jenkins, "New nuclear future for Berkeley nuclear power station site", *BBC*, 29 January 2024, see https://www.bbc.com/news/uk-england-gloucestershire-68127378, accessed 27 May 2024.

1332 - NDA, "Nuclear Decommissioning Authority: Business Plan 2024 to 2027", 17 April 2024, op. cit.

1333 - Nuclear Restoration Services, "Hunterston A completes a decade of delivery and a major milestone", 11 April 2024, see https://www.gov.uk/government/news/hunterston-a-completes-a-decade-of-delivery-and-a-major-milestone, accessed 20 August 2024.

remaining radiological and chemicals hazards, such as the liquid metal coolant residues, had been removed,[1334] the NDA in their 2022 Business Plan reported on the planned completion of the Dounreay Fast Reactor (DFR) and Prototype Fast Reactor (PFR) dismantling in 2025 and 2027, respectively.[1335] These target dates have since been replaced by more moderate goals, such as DFR defueling to be completed from 2024 to 2027. The site is to be decommissioned until a so-called "interim endpoint" is reached when the site will be transferred into LTE. A residual sodium treatment facility is to be commissioned and sodium from two tanks is to be removed and treated between 2024 and 2027[1336]

EDF Energy, a subsidiary of the French state-owned utility EDF, is the owner-operator of both the closed and operational AGRs. This ownership is scheduled to be transferred to the NDA after the reactors have been defueled, with the first transfer possibly occurring "as early as 2026".[1337] Currently closed sites are Dungeness B, Hinkley Point B, and Hunterston B. For Hinkley Point B, the transfer date has been moved to 2027,[1338] and Unit 1 of the Hunterston B site completed defueling on schedule in October 2023 with the expected transfer of ownership to occur "around 2026".[1339] While the legacy fleet is financed directly from the state budget, AGR decommissioning is to be paid for by the Nuclear Liabilities Fund (NLF) after the handover from EDF Energy. The NLF has however been underperforming for years and received substantial cash injections from the U.K. Government totaling £10.7 billion (US$$_{2023}$13.3 billion) between 2020 and 2022, making up half of the fund volume.[1340] In 2021, EDF's estimate for the undiscounted costs to decommission all seven AGR plants and the Sizewell B PWR was £23.5 billion (US$$_{2021}$32.3 billion), of which 13 to 34 percent were allocated to defueling alone. A 2022-report by the National Audit Office raises concerns regarding the possible future necessity of additional taxpayer funding and the potential lack of incentives for EDF to defuel the reactors swiftly and efficiently before transferring them to NDA custody.[1341]

1334 - Dounreay, "Dounreay - Your guide to Scotland's centre of excellence in nuclear decommissioning", March 2023, see https://assets.publishing.service.gov.uk/media/64258a003d885d000cdadf47/Dounreay_2023.pdf, accessed 27 May 2024.

1335 - NDA, "Business Plan—1 April 2022 to 31 March 2025", Nuclear Decommissioning Authority, 2022, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1062302/Business_Plan_2022-2025_220322.pdf, accessed 8 April 2022.

1336 - NDA, "Nuclear Decommissioning Authority: Business Plan 2024 to 2027", 17 April 2024, op. cit.

1337 - Committee of Public Accounts, "The future of the Advanced Gas-cooled Reactors—Third report of Session 2022-23", HC 118, House of Commons, 20 May 2022, see https://committees.parliament.uk/publications/22301/documents/165594/default/, accessed 26 July 2023.

1338 - EDF, "Hinkley Point B nuclear power station", 8 May 2024, see https://www.edfenergy.com/energy/power-stations/hinkley-point-b, accessed 8 May 2024.

1339 - ONR, "Defuelling milestone for Hunterston B", 10 October 2023, see https://www.onr.org.uk/news/all-news/2023/10/key-defuelling-milestone-for-hunterston-b/, accessed 27 May 2024.

1340 - NLF, "Protecting future generations - Annual report and accounts 2023", Nuclear Liabilities Fund, 2023, see https://www.nlf.uk.net/uploads/images/NLF-Annual-report-2023_INTERACTIVE_2023-11-23-111050_enzm.pdf, accessed 27 May 2024.

1341 - NAO, "The decommissioning of the AGR nuclear power stations", HC 1017, National Audit Office, Department for Business, Energy & Industrial Strategy, 28 January 2022, see https://www.nao.org.uk/wp-content/uploads/2022/01/The-decommissioning-of-the-AGR-nuclear-power-stations.pdf, accessed 12 September 2023.

United States

The U.S. has not only the largest fleet of operating (94) and closed reactors but also the highest number of fully decommissioned units representing nearly three quarters of the global total.

In the U.S., as of mid-2024, 41 reactors (20 GW) had been closed.[1342] By 2050, at least 85 additional reactors are likely to undergo decommissioning if all units reach licensed operational lifetimes (see Figure 47 and Figure 48). Of the 41 already closed units (21 PWR, 14 BWR, 2 HTGR, 1 FBR, 1 PHWR, 2 others),[1343] 17 units or 7.1 GW have been decommissioned. Currently, decommissioning work is ongoing at 14 units:

- Four reactors are in the warm-up stage: Indian Point-1, Kewaunee, Three Mile Island-2, and Palisades (all defueled).
- Six reactors are in the hot-zone stage: Indian Point-2 & -3, San Onofre-2 & -3, Oyster Creek and Pilgrim-1.
- Four reactors are in the ease-off stage: Crystal River-3, Fort Calhoun-1, San Onofre-1 and Vermont Yankee.

Ten reactors are in LTE.

Since WNISR2023, some progress has been made in U.S. decommissioning efforts. Indian Point-1 has moved from LTE to the warm-up stage, three reactors have moved from the warm-up into the hot-zone stage (Indian Point-2 and San Onofre-2 & -3), two reactors have moved to the ease-off stage (Crystal River-3 and Fort Calhoun-1), and both reactors at the Zion plant, having completed decommissioning in 2020, were released from regulatory oversight, except for the spent fuel storage facility.[1344]

In November 2023, it was reported that "just under two-thirds" of the project at the San Onofre site had been completed with the target date of demolition completion in 2028 still in reach. Reactor internals dismantling is underway at Units 2 and 3, after which the domes are to be demolished "from the bottom up" by "chipping away" at the concrete structures with hydraulic hammers beginning in early 2026.[1345]

Three Mile Island-2 (TMI-2), where, in 1979, parts of the reactor core melted in the U.S.' worst commercial nuclear accident, has been in the warm-up stage since WNISR2023 after having been in LTE for the past 30 years. The reactor is counted as defueled as "99% of the spent nuclear fuel was cleaned up after the accident".[1346] Current owner EnergySolutions had taken over the license via its subsidiary TMI-2 Solutions with the intention of pulling

1342 - Another closed reactor is GE ESADA Vallecitos Experimental Superheat Reactor (EVESR), which is next to the GE Vallecitos BWR. Although, the reactor never produced electricity, the site was not decommissioned but has been put into LTE. U.S. NRC, "Status of the Decommissioning Program—Annual Report", 2018.

1343 - PWR: Pressurized Water Reactor; BWR: Boiling Water Reactor; HTGR: High-Temperature Gas-Cooled Reactor; FBR: Fast Breeder Reactor; PHWR: Pressurized Heavy-Water Reactor.

1344 - U.S. NRC, "NRC Releases Zion Nuclear Power Plant Site for Unrestricted Public Use", Press Release, United States Nuclear Regulatory Commission, 8 November 2023, see https://www.nrc.gov/cdn/doc-collection-news/2023/23-073.pdf, accessed 4 June 2024.

1345 - Rob Nikolewski, "Dismantling the San Onofre nuclear power plant is more than 60% completed", *San Diego Union-Tribune*, 16 November 2023, see https://www.sandiegouniontribune.com/business/story/2023-11-16/dismantling-the-san-onofre-nuclear-power-plant-is-more-than-60-completed, accessed 27 May 2024.

1346 - Rachel McDevitt, "Three Mile Island enters new phase of cleanup", *State Impact Pennsylvania, NPR*, 11 May 2023, see https://stateimpact.npr.org/pennsylvania/2023/05/11/tmi-enters-new-phase-of-cleanup/, accessed 19 June 2023.

the decommissioning completion date forward to 2037 instead of the initial target year of 2053.[1347] However, TMI-2 Solutions currently plans to terminate the site's nuclear license as late as 2052 due to "current market conditions" that necessitate a delay in fund withdrawals (and consequentially decommissioning progress) "from 2029 to 2045 as a financial mitigation measure for the [fund]".[1348] On 28 March 2024, TMI-2 Solutions provided the U.S. Nuclear Regulatory Commission (NRC) with an updated decommissioning plan.[1349] TMI-1 operated until 2019 and was placed into LTE with actual decommissioning to last from 2075 to 2079. Spent fuel is planned to be kept in dry storage until 2035 and shall then be moved to a currently non-existent consolidated storage facility.[1350] The reactor itself was completely defueled in September 2019.[1351]

In 2022, the NRC approved the license transfer of the Kewaunee site from Dominion to EnergySolutions.[1352] Subsequently, the company requested permission to use funds from the power plant's decommissioning trust fund for the "management of site restoration activities and allow trust disbursements for site restoration activities to be made without prior notice to the NRC," which was granted by the NRC.[1353] Meanwhile, the first of four decommissioning phases, that included the demolition of five buildings, was completed in 2023. The whole process is to be finalized by mid-2031.[1354]

Crystal River-3 was closed unexpectedly in 2009 and was planned to be transferred into LTE from 2013 onwards, with dismantling to begin in 2068.[1355] In 2020, Accelerated Decommissioning Partners (ADP), a joint venture of NorthStar and French state-owned company Orano, acquired the license of the plant, changed the strategy to a direct dismantling approach and began the decommissioning of the reactor.[1356] The dismantling of the reactor

1347 - U.S. NRC, "Power Reactor Sites—Three Mile Island - Unit 2", United States Nuclear Regulatory Commission, Updated 5 June 2024, see https://www.nrc.gov/info-finder/decommissioning/power-reactor/three-mile-island-unit-2.html, accessed 27 July 2024.

1348 - Ibidem; and TMI-2 Solutions, "Decommissioning Fund Status Report – Three Mile Island, Unit 2", addressed to U.S. Nuclear Regulatory Commission, 30 March 2023, see https://www.nrc.gov/docs/ML2309/ML23094A116.pdf, accessed 12 September 2023.

1349 - U.S. NRC, "Power Reactor Sites—Three Mile Island - Unit 2", Updated 5 June 2024, op. cit.

1350 - Exelon Generation, "Three Mile Island Nuclear Station, Unit 1 - Post-Shutdown Decommissioning Activities Report", addressed to U.S. Nuclear Regulatory Commission, 5 April 2019, see https://www.nrc.gov/docs/ML1909/ML19095A041.pdf, accessed 5 November 2023.

1351 - Charles Thompson, "Removal of fuel assemblies from Three Mile Island Unit One reactor is complete; long storage period ahead", *Pennsylvania Patriot News*, 27 September 2019, see https://www.pennlive.com/news/2019/09/removal-of-fuel-assemblies-from-three-mile-island-unit-one-reactor-is-complete-long-storage-period-ahead.html, accessed 12 September 2023.

1352 - EnergySolutions, "EnergySolutions Receives NRC Approval for Kewaunee Power Station License Transfer", 31 March 2022, see https://www.energysolutions.com/energysolutions-receives-nrc-approval-for-kewaunee-power-station-license-transfer/, accessed 20 August 2024.

1353 - U.S. NRC, "Kewaunee Solutions, Inc.; Kewaunee Power Station; Environmental Assessment and Finding of No Significant Impact", *Federal Register*, Vol. 89, No. 17, January 2024, see https://www.federalregister.gov/documents/2024/01/25/2024-01484/kewaunee-solutions-inc-kewaunee-power-station-environmental-assessment-and-finding-of-no-significant, accessed 27 May 2024; and U.S. NRC, "Safety Evaluation By The Office Of Nuclear Material Safety And Safeguards Related To Kewaunee Solutions, Inc., And Energysolutions, Llc., Request For Exemption To Allow Use Of Funds From The Nuclear Decommissioning Trust For Site Restoration And To Remove A Notification Requirement For The Disbursal Of Funds From The Decommissioning Trust For Site Restoration Activities", Docket No. 50-305.

1354 - Emily Matestic, "Decommissioning of Kewaunee nuclear power plant underway, no redevelopment plans yet", *Fox 11 News*, 1 February 2024, see https://fox11online.com/news/local/decommissioning-of-kewaunee-nuclear-power-plant-underway-no-redevelopment-yet-energysolutions-ron-worster-lakeshort-technical-college-spent-fuel-nrc, accessed 27 May 2024.

1355 - Duke Energy, "Crystal River Unit 3 - Post-Shutdown Decommissioning Activities Report", December 2013, see https://www.nrc.gov/docs/ML1334/ML13340A009.pdf, accessed 5 August 2024.

1356 - U.S. NRC, "Power Reactor Sites—Crystal River Unit 3 Nuclear Generating Plant", Updated 4 April 2024, see https://www.nrc.gov/info-finder/decommissioning/power-reactor/cr3.html, accessed 27 May 2024.

pressure vessel and internals was finalized by Orano in December 2023, marking the end of hot-zone tasks. Remaining building demolition tasks are now to be carried out by NorthStar.[1357] The unit is expected to be fully decommissioned by 2037.[1358]

Full decommissioning of the Fort Calhoun reactor was initially scheduled to begin in 2060, but a change in strategy officialized in December 2019 prompted work to already start onsite.[1359] With the completion of reactor-vessel segmentation in December 2023, decommissioning at the reactor advanced and the site was marked to be in the ease-off stage. Despite remaining components in the containment building, including both steam generators, the main cooling pumps, and the pressurizer awaiting dismantlement, the operator supposedly "remains on track to reach greenfield status in 2026."[1360] However, the decommissioning plans at Fort Calhoun indicate that an interim waste storage facility will remain on site after the completion of dismantling work, which does not qualify the site as "greenfield" under WNISR definition. WNISR will continue to monitor the decommissioning progress and classify the site accordingly.

Prior to Holtec's acquisition of Oyster Creek, the utility Exelon had opted for deferred dismantling.[1361] In 2018, Holtec decided to directly dismantle the site[1362] and was able to defuel the plant in 32 months.[1363] In April 2023, Holtec announced that the completion date for decommissioning had to be pushed back by four years to 2029, blaming economic conditions, such as increased labor costs.[1364] Whether this will also impact the envisioned license termination in 2035, estimated as of March 2022, has not been communicated.[1365] Meanwhile, Holtec has been fined twice by the NRC over the past year, once for the improper shipment of radioactive materials exceeding radiation limits in an open-bed truck[1366] and once for misuse

1357 - Orano, "Orano Finishes Segmentation and Packaging of Crystal River Unit 3 Reactor within Two Years on Accelerated Decommissioning Timeline", Press Release, 6 December 2023, see https://www.orano.group/usa/en/our-news/news-releases/2023/orano-finishes-segmentation-and-packaging-of-crystal-river-unit-3-reactor-within-two-years-on-accelerated-decommissioning-timeline, accessed 20 August 2024.

1358 - U.S. NRC, "Power Reactor Sites—Crystal River Unit 3 Nuclear Generating Plant", Updated 4 April 2024, op. cit.

1359 - U.S. NRC, "Power Reactor Sites— Fort Calhoun Station", Updated 7 April 2022, see https://www.nrc.gov/info-finder/reactors/fcs.html, accessed 20 August 2024.

1360 - Jason Kuiper, "Crews complete major reactor vessel work at Fort Calhoun Station", Omaha Public Power District, *The Wire*, 12 December 2023, see https://oppdthewire.com/crews-complete-major-reactor-vessel-work-at-fort-calhoun-station/, accessed 27 May 2024.

1361 - Holtec Decommissioning International, "Notification of Revised Post-Shutdown Decommissioning Activities Report and Revised Site-Specific Decommissioning Cost Estimate for Oyster Creek Nuclear Generating Station", NRC Docket Nos. 50-219 and 72-15, 28 September 2018, see https://holtecinternational.com/wp-content/uploads/2021/02/HDI-PSDAR-DCE-ML18275A116.pdf, accessed 9 June 2022.

1362 - Ibidem.

1363 - Holtec International, "Oyster Creek Sets a New World Record by Completing the Speediest Transfer of Plant's Spent Nuclear Fuel to Dry Storage", 21 May 2021, see https://holtecinternational.com/2021/05/21/oyster-creek-sets-a-new-world-record-by-completing-the-speediest-transfer-of-plants-spent-nuclear-fuel-to-dry-storage/, accessed 20 August 2024.

1364 - Amanda Oglesby, "Inflation leads Oyster Creek nuclear plant to delay decommissioning", *Asbury Park Press*, 5 April 2023, see https://eu.app.com/story/news/local/land-environment/2023/04/05/oyster-creek-nj-nuclear-plant-decommissioning-delayed/70081268007/, accessed 19 June 2023.

1365 - U.S. NRC, "Oyster Creek Nuclear Generating Station", Updated 23 March 2022, see https://www.nrc.gov/info-finder/reactors/oc.html, accessed 27 May 2024.

1366 - Steven Rodas, "Energy company fined for improperly shipping radioactive materials out of N.J.", *NJ Advance Media*, 15 November 2023, see https://www.nj.com/news/2023/11/energy-company-fined-for-improperly-shipping-radioactive-materials-out-of-nj.html, accessed 27 May 2024; and U.S. NRC, "NRC Proposes $43,750 Civil Penalty for Shipment of Equipment from Oyster Creek that Exceeded Radiation Limits", Press Release, 9 November 2023, see https://www.nrc.gov/cdn/doc-collection-news/2023/23-015-i.pdf, accessed 20 August 2024.

of decommissioning trust fund money for "community outreach activities" unrelated to actual decommissioning.[1367]

Holtec is currently also decommissioning all three units at Indian Point. The 2019-plan envisions a partial license termination for the site (apart from onsite waste storage facilities) by 2033. Full license termination is planned for 2062.[1368] License transfer to Holtec was approved in 2020. The company went on to apply for "exemptions from certain emergency preparedness and planning requirements" that would reduce the "NRC's [...] requirements for the site to a level commensurate with the permanent cessation of operations and permanent removal of fuel from the reactor vessels [at Indian Point]".[1369] The application was approved in October 2023.[1370] Some demolition activities have been ongoing at Unit 1, prompting the move to the warm-up stage. At Units 2 and 3, reactor pressure vessel segmentation remains underway.[1371]

Local residents of the Indian Point site were concerned about Holtec's plans to release 1.3-1.5 million gallons (4.9–5.7 million liters) of contaminated wastewater into the Hudson River.[1372] While Holtec said that the discharge of "monitored, processed, and treated water would not impact the environment or the health and safety of the public,"[1373] in August 2023, New York Governor Kathy Hochul signed a bill to halt the discharge into the Hudson. Holtec now claims that this new regulation might delay reactor dismantling by eight years as it would necessitate the "rezoning of [...] 60 acres".[1374]

At the Pilgrim-1 plant, Holtec required the decommissioning license in 2019 after the reactor was closed. The original plan had envisioned a partial license termination in 2027, with spent fuel remaining in onsite storage until 2062 and complete license termination in 2063.[1375] While

1367 - Stephanie A. Faughnan, "Nuke Plant Cited For Budget Issue", *Jersey Shore Online*, 13 March 2024, see https://www.jerseyshoreonline.com/southern-ocean/nuke-plant-cited-for-budget-issue/, accessed 27 May 2024.

1368 - Holtec Decommissioning International, "Post Shutdown Decommissioning Activities Report including Site-Specific Decommissioning Cost Estimate for Indian Point Nuclear Generating Units 1, 2, and 3", addressed to U.S. Nuclear Regulatory Commission, 19 December 2019, see https://www.nrc.gov/docs/ML1935/ML19354A698.pdf, accessed 12 September 2023.

1369 - U.S. NRC, "Indian Point Nuclear Generating Unit 2", Updated 11 April 2021, United States Nuclear Regulatory Commission, 2 March 2023, see https://www.nrc.gov/info-finder/reactors/ip2.html, accessed 12 September 2023.

1370 - U.S. NRC, "NRC Approves Changes to Indian Point Energy Center Emergency Planning Requirements", Press Release, 26 October 2023, see https://www.nrc.gov/cdn/doc-collection-news/2023/23-067.pdf, accessed 20 August 2024.

1371 - Frank Spagnuolo and Patrick O'Brien, "Decommissioning Oversight Board - Holtec Decommissioning International (HDI)", Vice President, Indian Point Site, and Director, Government Affairs and Communications, Holtec Decommissioning International, April 2024, see https://holtecinternational.com/wp-content/uploads/2024/05/DOB-IPEC-4-25-2024-Final.pdf, accessed 27 May 2024.

1372 - Rich Burroni, Presentation, on Behalf of Holtec Decommissioning International, 27 April 2023; see Department of Public Service of New York, "In the Matter of the Indian Point Closure Task Force and Indian Point Decommissioning Oversight Board", Transcript, Joint Meeting and Public Statement Hearing, filed 25 May 2023, see https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BC0015388-0000-C613-A53D-39FF2699B7CF%7D, accessed 17 November 2023.

1373 - Post-treatment tritium concentration levels in water from spent fuel pools of Indian Point-1 measured in September 2008 show levels of 0.447 µCi/liter (microcurie per liter). The official maximum tritium concentration for safe drinking water lies at 20 µCi per liter. Water discharge into the Hudson had been ongoing for decades before, reportedly leading to no measurable increase in tritium concentration; see Dave Lochbaum, "Tritium Disposal Options and Their Risks", filed with the New York State Department of Public Service, May 2023, see https://dps.ny.gov/system/files/documents/2023/05/disposal-options-and-risks-may-2023.pdf; and U.S. NRC, "Backgrounder on Tritium, Radiation Protection Limits, and Drinking Water Standards", United States Nuclear Regulatory Commission, April 2019, see https://www.nrc.gov/docs/ML0620/ML062020079.pdf, both accessed 12 September 2023.

1374 - John Camera, "Company says state law could delay dismantling Indian Point by 8 years", *Spectrum News 1*, 1 December 2023, see https://spectrumlocalnews.com/nys/central-ny/news/2023/11/30/company-says-dismantling-indian-point-could-be-delayed-8-years, accessed 27 May 2024.

1375 - HDI, "Report on Status of Decommissioning Funding for Reactors and Independent Spent Fuel Storage Installations", Holtec Decommissioning International, March 2020, see https://www.nrc.gov/docs/ML2009/ML20091M858.pdf, accessed 27 May 2024.

the NRC has not updated its online information since August 2022,[1376] Holtec has announced an eight-year delay to 2035 for the partial termination,[1377] and potential regulatory and legal challenges might arise from wastewater release issues similar to the Indian Point site.[1378]

The closure of Palisades marks the latest reactor closure in the U.S. The plant was taken off the grid in May 2022 after 50 years of operation. In June 2022, Holtec became the owner of the plant and defueled it. After halting the decommissioning process, Holtec applied for federal funding to restart the plant. In April 2024, the U.S. Department of Energy announced a US$1.52 billion loan guarantee to restart the 805-MW PWR for operation until at least 2051 which would bring final operational age to 80 years. Additionally, Holtec plans to construct two 300-MW SMRs on site.[1379] Until the reactor is restarted, WNISR classifies the Palisades reactor as being in the warm-up stage. (See United States Focus for further details)

CONCLUSION ON REACTOR DECOMMISSIONING

Assuming a 40-year average lifetime—the current world fleet age is just over 32 years—a further 120 reactors will have been closed by 2030 (reactors connected to the grid between 1984 and 1990), and an additional 153 will be closed by 2064. This does not account for the 134 reactors that have already been operating for more than 40 years, an additional 34 reactors in Long-term Outage (LTO), and the 59 reactors under construction as of mid-2024. As was shown in previous issues of WNISR, the financial and technical challenges of reactor decommissioning are often underestimated. With more and more reactors reaching the end of their lifetimes, this underestimation will likely bring costly consequences.

Since WNISR2023 and until 1 July 2024, only one additional reactor has been closed: Kursk-1 in Russia.[1380]

Worldwide, as of mid-2024, 213 nuclear power reactors have been closed, corresponding to over 106 GW of permanently retired capacity. Only 23 have been fully decommissioned, although some are still awaiting release from regulatory control, and only 9 have been returned to greenfield conditions, meaning the sites are available for unrestricted use. An additional 145 reactors are in some state of decommissioning, while 45 reactors are in a long-term enclosure (LTE) state.

In Europe, the 131 closed reactors represent 62 percent of the world's total and decommissioning efforts are advancing sporadically. With Germany having closed its last three operating nuclear power plants in April 2023, the country faces unprecedented parallel decommissioning

1376 - U.S. NRC, "Pilgrim Nuclear Power Station", United States Nuclear Regulatory Commission, 23 August 2022, see https://www.nrc.gov/info-finder/reactors/pilg.html, accessed 27 May 2024.

1377 - HDI, "2024 Revised Environmental Site Assessment Work Plan - Pilgrim Station", February 2024, see https://holtecinternational.com/wp-content/uploads/2024/05/2024-Revised-Environmental-Site-Assessment-Work-Plan.pdf, accessed 27 May 2024.

1378 - Jennette Barnes, "Pilgrim's 1M gallons of radioactive water could evaporate in seven years", *New Hampshire Public Radio*, 28 November 2023, see https://www.nhpr.org/2023-11-28/eight-year-delay-in-pilgrim-decommissioning-could-change-disposal-of-radioactive-water, accessed 27 May 2024.

1379 - Holtec, "First Two SMR-300 Units Slated to be Built at Michigan's Palisades Site for Commissioning by Mid-2030",4 December 2023, see https://holtecinternational.com/2023/12/04/first-two-smr-300-units-slated-to-be-built-at-michigans-palisades-site-for-commissioning-by-mid-2030/, accessed 20 August 2024.

1380 - One additional reactor was closed in Taiwan on 27 July 2024.

of 31 reactors, with one additional reactor remaining in LTE. The U.K. is still implementing its new "lead-and-learn strategy" to its legacy fleet and is facing potential financial shortfalls for the decommissioning of its AGR fleet. In France, the regulator considers that, with the exception of GCRs, decommissioning is advancing satisfactorily, although completion dates for ongoing projects are gradually pushed back year on year, and cost projections rise continuously with their total volume remaining uncertain.

The only countries to have fully decommissioned any commercial power reactors are the U.S. (17), Germany (4), Japan (1), and Spain (1). The latest addition to the list is the 141-MW José Cabrera reactor, also known as Zorita, located in the Spanish province of Guadalajara. This reactor was connected to the grid in 1968 and closed in 2006. Technical decommissioning was completed in September 2023, and the site is awaiting its release from regulatory oversight following greenfield remediation.

Most of these decommissioned reactors are of low capacity, many of them are first-generation designs, with an average capacity of 350 MW. On average, decommissioning work lasted over 20 years, sometimes years longer than operation.

Due to statistical changes since WNISR2023 in which the post-operational phase was reintegrated into the warm-up stage, nine reactors have reentered the warm-up stage: one each in Pakistan, Russia, and the U.S., two in Taiwan, and four in Germany. Two reactors, i.e. one each in Russia and the U.S., have also moved into the warm-up stage either due to closure or status transfer from LTE. In the U.K., 21 reactors are currently in the warm-up stage, trumped only by 26 reactors in Japan; in total 93 reactors are in this stage.

Seven reactors moved from the warm-up to hot-zone stage, namely Ågesta in Sweden, EL-4 in France, Philippsburg-2 in Germany, Trino in Italy as well as Indian Point-2 and San Onofre-2 & -3, all three of which are located in the U.S. Thus, 36 reactors are currently in the hot-zone stage, located in Germany (11), the U.K. (9), the U.S. (6), Sweden (5), France (3), and Italy (2).

The only reactors to have advanced to the ease-off stage are U.S. reactors Crystal River-3 and Fort Calhoun-1. This places a total of 16 reactors in the ease-off stage. Germany leads in this category with a total of nine reactors, followed by the U.S. (4), Slovakia (2), and Belgium (1).

As no additional reactor has been placed into LTE since WNISR2023, the number of reactors in LTE has dropped from 46 in 2023 to 45 in 2024.

POTENTIAL NEWCOMER COUNTRIES

AFRICA FOCUS

In continental Africa, only South Africa has an operating nuclear power plant (see South Africa in Annex 1). This is despite repeated support from national governments and encouragement from international vendors, particularly China and Russia in recent times.

According to the World Nuclear Association (WNA), China has agreements with—but no plants under construction—Kenya and Sudan, while Russia has pursued a very aggressive strategy of securing any type of nuclear energy-linked agreements with about 20 African states.[1381] Egypt is the only country with active construction (see Egypt in Potential Newcomer Countries).

In September 2020, Russia's Rosatom signed a Memorandum of Understanding (MoU) with the African Commission on Nuclear Energy (AFCONE), intended to create "a basis pillar for cooperation" to render assistance to African countries in the "sphere of energy security, including diversifying energy sources, use of renewable sources of energy, and implementation of projects in the nuclear energy industry."[1382] In October 2023, this was followed by the approval of an "Action Plan for Cooperation in the field of the peaceful use of nuclear energy for 2023–2025."[1383] The vast majority of these projects appear to be little more than political statements of support designed to increase diplomatic links with key infrastructure providers and recipients.

In spite of the multitude of agreements, in the majority of instances involving Russia and its state nuclear company Rosatom, few developments on nuclear activities in Africa reflect some significant advances on the ground.

Table 13 provides a list of African countries that have in the past entered into some formal nuclear energy linked agreement with Russia or Rosatom. The list is not exhaustive: it does not feature Egypt, Nigeria and South Africa, as these countries are covered in more depth in separate sections (see Egypt and Nigeria in Potential Newcomer Countries and South Africa in Annex 1), and engagements between Rosatom and many more African countries have happened that may have resulted in further links. Only the most significant and/or recent identified agreements concluded by the listed countries are included.

1381 - WNA, "Emerging Nuclear Energy Countries", World Nuclear Association, Updated October 2022, see https://world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx, accessed 17 October 2022.

1382 - Rosatom, "The African Commission on Nuclear Energy and Rosatom will develop cooperation in nuclear field", Press Release, 22 September 2020, see https://rosatom-europe.com/en/press-centre/news/the-african-commission-on-nuclear-energy-and-rosatom-will-develop-cooperation-in-nuclear-field/, accessed 2 August 2024.

1383 - Rosatom, "Rosatom and African Commission on Nuclear Energy announce cooperative Action Plan for peaceful use of nuclear energy", Press Release, 19 October 2023, see https://rosatom.ru/en/press-centre/news/rosatom-and-african-commission-on-nuclear-energy-announce-cooperative-action-plan-for-peaceful-use-o/, accessed 18 August 2024.

Table 13 · Nuclear Power Agreements Concluded Between Russia/Rosatom and African Countries (excl. Egypt, Nigeria and South Africa)

Country	Agreement (latest and/or most significant)
Algeria	March 2024. Memorandum of Understanding (MoU) signed with Rosatom on nuclear cooperation.[a]
Burkina Faso	October 2023. MoU signed with Rosatom aiming to construct a nuclear plant.[b] June 2024. Follow-up agreement that includes training and publicity work.[c]
Burundi	July 2023. Agreement signed with Russia to cooperate in the "use of atomic energy for peaceful purposes."(d) This was preceded by the signing of related agreements with Rosatom in the two years prior to that.[e]
Congo (Republic of)	February 2018. MoU signed with Rosatom on general nuclear cooperation.[f]
Ethiopia	July 2023. Two-year roadmap signed with Rosatom, including to "explore the possibilities of building a nuclear power plant."[g] This follows an Agreement signed with Rosatom in October 2019, and similar accords in previous years.[h]
Ghana	June 2015. Memorandum of Agreement (MoA) signed with Rosatom that sought to lay out the framework for nuclear newbuild.[i]
Kenya	May 2016. MoU signed with Rosatom on general collaboration in nuclear technology, including "practical implementation of the key Kenyan project - the first ever nuclear power generating plant."[j]
Mali	October 2023. MoU with Rosatom to cooperate on nuclear energy.[k] July 2024. Three Memoranda of Understanding signed with Rosatom on nuclear energy feasibility assessment, "forming a positive public opinion" and personnel training.[l]
Morocco	October 2017. MoU signed with Rosatom on "cooperation in peaceful uses of atomic energy."[m]
Namibia	Talks of a nuclear cooperation agreement in 2018, appears this was never finalized. Mining company and Rosatom subsidiary Uranium One has been involved in uranium mining in the country for some time.[n]
Rwanda	February 2019. Memoranda of Cooperation signed with Rosatom for nuclear training and "the formation of the positive public opinion on nuclear energy in the country".[e] October 2019. Signed an agreement with Rosatom to construct a nuclear research center with a 10 MW reactor.[o]
Sudan	June 2017. MoU signed with Rosatom on "cooperation in peaceful uses of atomic energy", including a research center and a Russian-designed nuclear plant.(p) Since then Sudan has undergone a regime change and is currently in a state of civil war.
Tanzania	October 2016. Agreement signed with Rosatom—whose subsidiary Uranium One runs a uranium mining project in the country—to build a nuclear research reactor, with the aim to introduce larger scale nuclear power plants later.[q]
Uganda	September 2019. Signs an Intergovernmental Agreement on Cooperation in the Use of Nuclear Energy for Peaceful Purposes.[r] August 2023. Ugandan President announced the selection of Russia (and South Korea) to build a nuclear plant.[s]
Zambia	May 2018. Contract signed with Rosatom to construct a nuclear research facility.[t]
Zimbabwe	July 2023. Intergovernmental agreement signed with Russia for use of atomic energy for peaceful purposes.[u] Follows the signing of related Memoranda of Understanding with Rosatom in September 2021 and November 2022.[v]

Sources: Various, compiled by WNISR, 2024

Notes:

a - Chinedu Okafor, "Russia's nuclear influence expands further north of Africa", *Business Insider Africa*, 27 March 2024, and Ministry of Energy and Mines, "توقيع مذكرة تفاهم للتعاون في مجال الاستخدامات السلمية للطاقة النووية", Government of Algeria, 26 March 2024.

b - Bate Felix, "Burkina Faso and Russia's Rosatom sign agreement for nuclear power plant", *Reuters*, 13 October 2023; and Rosatom, "Russia and Burkina Faso signed a Memorandum of Understanding on cooperation in the field of peaceful uses of atomic energy", 13 October 2023.

c - Rosatom, "Rosatom and Burkina Faso Begin Cooperation on Preparation to Nuclear Technology Development", Press Release, 5 June 2024.

d - Ministry of Foreign Affairs and Development Cooperation, "The Republic of Burundi and the Federal Republic of Russia sign some cooperation agreements", Government of Burundi, 27 July 2023; and Rosatom, "Russia and Burundi sign Memorandum on peaceful atomic energy cooperation", Press Release, 27 July 2023.

e - Rosatom, "History of cooperation", 2024, see https://rosatomafrica.com/en/rosatom-in-country/history-of-cooperation/.

f - *WNN*, "Russia and Congo to cooperate in nuclear power", *World Nuclear News*, 14 February 2018.

g - Rosatom, "Russia and Ethiopia begin cooperation in the field of peaceful atom", 28 July 2023.

h - Rosatom, "Russia and Ethiopia map their cooperation in the field of peaceful uses of atomic energy", Press Release, 15 April 2019; and *Atom Media*, "Agreements on cooperation between Russia and Ethiopia", Rosatom, 25 July 2023.

i - M. V. Ramana and Priscilla Agyapong, "Thinking big? Ghana, small reactors, and nuclear power", *Energy Research & Social Science*, November 2016.

j - Rosatom, "ROSATOM and Kenyan Council for nuclear energy signed a Memorandum of understanding in the field of peaceful use of nuclear energy", 1 June 2016.

k - Rosatom, "Russia and Mali signed a Memorandum of Understanding on cooperation in peaceful use of nuclear energy", Press Release, 13 October 2023.

l - Goddy Ikeh, "Mali, Russia sign nuclear energy deal", *African Press Agency*, 3 July 2024, and Rosatom, "ROSATOM delegation visits the Republic of Mali", 3 July 2024.

m - Rosatom, "Rusatom International Network and the National Center of Nuclear Energy, Science and Techniques of the Kingdom of Morocco signed a memorandum of cooperation", 13 October 2017.

n - Rosatom, "Rosatom and Rwanda will cooperate to develop human capital and public acceptance for nuclear energy program in Rwanda", 28 February 2019.

o - Ministry of Infrastructure, "Rwanda and Russia agree to strengthen bilateral cooperation for the implementation of the Nuclear Centre for Science and Technology", Government of the Republic of Rwanda, 8 September 2020.

p - Rosatom, "Russia and Sudan sign a Memorandum of understanding on cooperation in peaceful uses of atomic energy", 19 June 2017.

q - *NEI Magazine*, "Russia signs deal with Tanzania and Uganda", *Nuclear Engineering International*, 9 November 2016.

r - Embassy of the Russian Federation in the Republic of Uganda, "On September 17, 2019, ROSATOM State Nuclear Energy Corporation and the Ministry of Energy and Mineral Resources of the Republic of Uganda signed an Intergovernmental Agreement on Cooperation in the Use of Nuclear Energy for Peaceful Purposes", 17 September 2019.

s - *bne IntelliNews*, "Uganda picks Russia, South Korea to build two nuclear plants with total 15,000MW capacity", 9 August 2023; and Infrastructure Uganda, "Uganda Nuclear Power Plants To Be Built By South Korea and Russia", Government of Uganda, 10 August 2023.

t - Rosatom, "Rosatom Newsletter #206— Nuclear Center for Zambia", June 2018.

u - Rosatom, "Russia and Zimbabwe signed an intergovernmental agreement on cooperation in the field of peaceful use of atomic energy", Press Release, 27 July 2023.

v - *Atom Media*, "Memorandum between Russia and Zimbabwe", Rosatom, 25 July 2023.

Table 14 provides the recent (2022) scale of electricity consumption in the countries recorded in Table 13 as well as Nigeria, their total installed capacity, and the average capacity used throughout the year (calculated through dividing the total annual consumption by the hours per annum). The results show that the typical capacity of a nuclear plant in most cases would vastly exceed current installed capacities and usage. The IAEA, for example, stipulates as rule of thumb: "A single power plant should represent no more than 10 per cent of the total installed grid capacity."[1384] Considering a typical large nuclear reactor is around 1,000 MW (1 GW), there are only four countries, Algeria, Libya, Morocco, and Nigeria that would meet the criteria. All others are far from it.

While all African countries foresee future large increases in electricity demand due to economic growth, industrialization, population growth, and electrification, the same countries are likely to meet much of this shortfall through their still largely untapped efficiency and generating options.[1385]

1384 - Joanne Liou, "What are Small Modular Reactors (SMRs)?", International Atomic Energy Agency, 14 September 2023, see https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs, accessed 28 July 2024.

1385 - IRENA, "Renewable Energy Market Analysis", International Renewable Energy Agency, 14 January 2022, see https://www.irena.org/Publications/2022/Jan/Renewable-Energy-Market-Analysis-Africa, accessed 17 July 2024.

Table 14 · Annual Electricity Consumption in Selected African Countries That Consider the Nuclear Power Option (Excluding Egypt and South Africa)

Country	Annual Electricity Consumption (2022) (in TWh)	Installed Capacity (2022) (in MW)	Average Capacity Drawn (2022) (in MW)
Algeria	78.0	25,400	8,900
Burkina Faso	2.1	510	240
Burundi	0.4	120	50
Congo (Republic of)	2.2	3,040	250
Ethiopia	11.0	5,680	1,300
Ghana	19.0	5,190	2,200
Kenya	9.6	3,310	1,100
Libya	25.0	12,770	2,900
Mali	3.5	1,110	400
Morocco	35.0	9,890	4,000
Namibia	3.4	720	390
Nigeria	32.0	13,840	3,700
Rwanda	0.9	300	100
Sudan	15.0	3,870	1,700
Tanzania	7.9	?	900
Uganda	4.0	1,320	460
Zambia	15.0	3,820	1,700
Zimbabwe	8.9	2,230	1,000

Sources: U.S. EIA[1386] and Ember[1387], 2024

East Africa

Despite little evidence of substantive progress, statements of intent from political figures to launch nuclear power projects, along with associated media activity, continue to be generated in the East African Region.

Uganda

An extraordinary example of this would be Uganda, whose government, in May 2024, expressed exceptionally ambitious ideas to build nuclear plants with a total capacity of 24 GW,[1388] i.e. more than 18 times the country's installed electricity generating capacity as of 2022 (see Table 14). Its initial plan is to construct a 1 GW nuclear plant,[1389] proposed to be located in the Buyende district.[1390] That projected plant's capacity alone amounts to more than

1386 - U.S. EIA, "International—Data—Electricity", U.S. Energy Information Administration, Undated, see https://www.eia.gov/international/data/world/electricity/electricity-consumption, accessed 5 July 2024.

1387 - Ember, "Yearly electricity data", 17 July 2024, see https://ember-climate.org/data-catalogue/yearly-electricity-data/, accessed 28 July 2024.

1388 - Phiona Nyamutoro, Minister for Energy and Mineral Development, Government of Uganda, on X (formerly Twitter), 14 May 2024, see https://x.com/PNyamutoro/status/1790329012494954498, accessed 3 August 2024.

1389 - IEA, "Uganda 2023—Energy Policy Review", International Energy Agency, 2023, see https://www.oecd-ilibrary.org/energy/uganda-2023_1b6b9a5a-en, accessed 18 August 2024.

1390 - *The Independent*, "Buyende leaders ask for sensitization on planned nuclear power plant", 1 December 2023, see https://www.independent.co.ug/buyende-leaders-ask-for-sensitization-on-planned-nuclear-power-plant/, accessed 17 July 2024.

the total national capacity.[1391] Highlighting the volatility of nuclear planning and its uncertain implementation, Uganda's president stated in August 2023 that "We have now agreed with the Russians and Koreans to build two nuclear power stations for electricity of 15,600mgws [MW] total"[1392], while another governmental portal specified "simply put, two power plants producing 7,300 and 3,400 megawatts each would yield 10,700 meg[a]watts."[1393] Details of the underlying agreement and information on potential design choices and financing packages are unknown. The statements frankly sound vastly overblown.

At the same time, an MoU with Korea's KHNP was signed in March 2023,[1394] while Uganda had also signed an agreement in 2018 with China to assist with nuclear plant construction.[1395]

Rwanda, Kenya, Tanzania, and Ethiopia

Much more modest—though still extremely optimistic—nuclear development plans are being considered by Rwanda, which signed an agreement with Canadian-German Company Dual Fluid in September 2023 to build and operate a smaller demonstration unit by 2026, with "subsequent testing" of the technology completed by 2028.[1396] While addressing the IAEA's General Conference the same month, the CEO of Rwanda Atomic Energy Board clarified "The Government of Rwanda is fully aware that these SMR technologies are new and mostly under development. Consequently, Rwanda is establishing strategic partnerships with interested SMR developing companies with the objective to have the whole or part of the development process taking place in Rwanda."[1397]

There are periodic efforts to get a nuclear build project started in Kenya, Tanzania and Ethiopia, but these still seem to be at the discussion stage. Kenya has established an official Nuclear Power and Energy Agency (NuPEA), but its current focus appears to be largely oriented on setting up a small research reactor, with no indications given in the past year of significant efforts to establish a utility scale reactor.[1398] In March 2024 however, NuPEA launched its Strategic Plan 2023–2027 containing plans to establish a nuclear plant in the longer term, with construction starting in ~2031.[1399] Tanzania has an established body to oversee nuclear energy

1391 - Grant Thornton, "FY 2023/24 Budget", 15 June 2023, see https://www.gtuganda.co.ug/globalassets/1.-member-firms/uganda/media/pdf-documents/grant-thornton_budget-booklet_-2023-24.pdf#page=10, accessed 17 July 2024.

1392 - The State House of Uganda, "President Museveni's Speech On Coffee Summit", Government of Uganda, 8 August 2023, see https://statehouse.go.ug/president-musevenis-speech-on-coffee-summit/, accessed 3 August 2024.

1393 - Infrastructure Uganda, "Uganda Nuclear Power Plants To Be Built By South Korea and Russia", 10 August 2023, op. cit.

1394 - Jung Min-Hee, "KHNP Gives Keynote at Africa Nuclear Conference in Uganda", Business Korea, 17 March 2023, see https://www.businesskorea.co.kr/news/articleView.html?idxno=111117, accessed 3 August 2024.

1395 - Elias Biryabarema, "China to help Uganda build nuclear power plants", 17 May 2018, see https://www.reuters.com/article/world/china-to-help-uganda-build-nuclear-power-plants-idUSKCN1II2HE/; and CAEA, "CNNC and Uganda move on nuclear technology cooperation", 11 May 2018, see https://www.caea.gov.cn/english/n6759361/n6759362/c6801719/content.html; both accessed 3 August 2024.

1396 - Rwanda Atomic Energy Board and Dual Fluid, "Dual Fluid signs agreement with Rwanda to build demonstration reactor", Press Release, 12 September 2023, see https://raeb.prod.risa.rw/index.php?eID=dumpFile&t=f&f=98506&token=8fe9a72c49b3cfc8d701e505c30082fbc1e226d9, accessed 3 August 2024.

1397 - Fidele Ndahayo, "Rwanda Statement at the 67th Regular Session of the General Conference of the International Atomic Energy Agency (IAEA)", Rwanda Atomic Energy Board, Republic of Rwanda, 27 September 2023, see https://raeb.prod.risa.rw/index.php?eID=dumpFile&t=f&f=98504&token=1c19f98b46a752f2b7370690da6666a1009c4ab1, accessed 3 August 2024.

1398 - NuPEA, "Homepage", Nuclear Power and Energy Agency, 2024, see https://www.nuclear.co.ke/, accessed 17 July 2024.

1399 - NuPEA, "Strategic Plan 2023–2027", Nuclear Power and Energy Agency, March 2024 see https://www.nuclear.co.ke/wp-content/uploads/2024/03/NuPEA-2023-2027-Strategic-Plan.pdf, accessed 18 August 2024.

matters, the Tanzania Atomic Energy Commission, which also failed to report any significant developments with respect to nuclear plants.[1400] While Ethiopia has signed nuclear cooperation agreements with Russia in 2017 and 2019 (see Table 13) and again in July 2023,[1401] significant expansion of generating capacity is rather expected from large hydroelectric projects under construction. Nuclear power developments are still at the "pre-feasibility study" stage. Per Ministerial officials, earlier plans to deploy two units of 1.2 GW capacity each by 2032–2034 are being revised to include SMRs and attain an estimated 6 percent share of total installed capacity from nuclear.[1402]

Sahel States

In recent years there have been military coups in Mali, Burkina Faso and Niger, and in all of these cases this has led to a significant growth in presence and influence of Russia in these countries. This influence includes shaping the energy sector of these nations. In particular, the new rulers of Mali and Burkina Faso are now very actively promoting nuclear builds as the means to end energy poverty in their countries. In March 2024, together with a Nigerian delegation, they attended Russia's ATOMEXPO for the first time.

As shown in Table 13, in October 2023, Mali and Burkina Faso signed further agreements with Rosatom.[1403] While statements calling for urgent nuclear newbuild abound, the scale of even a single large nuclear reactor would vastly exceed the capacity of the current electricity systems in the Sahel states (see Table 14). The economies of these states are also much too small to shoulder the level of supplementary local investments typically seen in current international Rosatom nuclear newbuilds. Indispensable major grid extension would further exacerbate local industrial capacities and investment needs.

The optimism generated towards potential nuclear newbuild and the associated assistance in these countries could therefore be interpreted as being a strategic intervention for securing political and economic allies especially for Russia (this includes involvement in mining, especially uranium, such as in Tanzania[1404], and now possibly also in Niger[1405]). Indeed, in Mali for example the involvement of Rosatom now even extends to new solar energy projects, which are much easier to initiate and complete.[1406] This suggests a new approach that seeks to cement Rosatom's involvement in a country's energy sector through quicker deliverables, especially in

1400 - TAEC, "Homepage", Tanzania Atomic Energy Commission, 2024, see https://www.taec.go.tz/, accessed 17 July 2024.

1401 - Rosatom, "Russia and Ethiopia begin cooperation in the field of peaceful atom", Press Release, 28 July 2023, see https://rosatom.ru/en/press-centre/news/russia-and-ethiopia-begin-cooperation-in-the-field-of-peaceful-atom/, accessed 18 August 2024.

1402 - Awel Abdela Husen, "National Nuclear Programme in Ethiopia and consideration for SMR", Ministry of Innovation and Technology, Government of Ethiopia, 6–10 May 2024, see https://nucleus.iaea.org/sites/INPRO/df22/Day%203/3.2.Ethiopia.pdf, accessed 27 July 2024.

1403 - *NEI Magazine*, "Burkina Faso and Mali sign nuclear agreements with Rosatom", *Nuclear Engineering International*, 17 October 2023, see https://www.neimagazine.com/news/burkina-faso-and-mali-sign-nuclear-agreements-with-rosatom-11224451/, accessed 5 July 2024.

1404 - Mantra Tanzania, "Ruvimbe—Newsletter", Issue #1, Rosatom, December 2023, see https://mantratanzania.co.tz/news/RUVIMBE2023ENG.pdf, accessed 25 August 2024.

1405 - *Al Jazeera*, "Niger revokes French nuclear group's licence at major uranium mine", 21 June 2024, see https://www.aljazeera.com/news/2024/6/21/niger-revokes-french-nuclear-groups-licence-at-major-uranium-mine, accessed 18 August 2024.

1406 - Rosatom, "Russia's Novawind starts construction on solar energy plant in Mali", 27 May 2024, see https://rosatomafrica.com/en/press-centre/industry-in-media/russia-s-novawind-starts-construction-on-solar-energy-plant-in-mali/, accessed 5 July 2024.

countries where the chances of initiating nuclear power plant construction would be extremely remote.

Nigeria

When in early 2023 Nigeria launched its Energy Transition Plan (ETP) with the goal of carbon neutrality by 2060, observers were surprised that nuclear power did not feature amongst the options outlined for electricity generation.[1407] The ETP sets very ambitious targets for centralized solar, going from virtually nothing currently to 8 GW in 2030, 81 GW in 2040 to 197 GW in 2050 then representing three quarters of the installed capacity. Centralized storage is to be boosted to 35 GW by 2040 and 90 GW in 2050 complemented by a 22 GW electrolizer capacity for hydrogen production. Decentralized systems are to be developed in parallel to progressively replace 5.3 GW of oil and gas fired generators. The main components are microgrids, solar home systems, and solar-plus-battery systems that are to contribute respectively 2.6 GW, 1.8 GW and 1.9 GW by 2030 and 7 GW, 5.2 GW, and 3.5 GW by 2050.[1408]

For years, the Nigerian administration and various national institutions have strongly supported the idea of the implementation of a national nuclear power program. Nigeria signed agreements on nuclear power development with South Korea, France, Russia, and India, and the Nigerian Nuclear Regulatory Authority (NNRA) signed cooperation agreements with nuclear regulators in the U.S., Pakistan, South Korea, and Russia.[1409]

A conference organized in July 2022 by the Heinrich Böll Foundation and the Electricity Hub in Abuja, Nigeria,[1410] saw the former Chairman of the Nigerian Electricity Regulatory Commission (NERC) pointing to the lack of adequate transmission infrastructure to manage even existing electricity capacity and posed the question "whether the government should be more concerned with expanding capacity or increasing investments to ensure that the current generated capacity gets reliably distributed". The Co-founder/CTO of the Clean Technology Hub Nigeria suggested that the country did not appear ready for nuclear power generation "given the challenges around the existing electricity generation and supply network".[1411]

Minister of Science, Technology and Innovation, Sen. Adeleke Mamora stated at a conference in Washington, D.C. in October 2022, that Nigeria had taken the decision to "fully explore and harness nuclear energy resources for the generation of electricity", further specifying that

> With the Small Modular Reactor (SMR) technology evolving, Nigeria sees this as a future game-changer in the nuclear industry and looks forward to a greater engagement with the

1407 - Ola Alokolaro, Uchechi Ibeku and Mary Oke, "Prospect for nuclear power development in Nigeria", *BusinessDay*, 23 March 2023, see https://businessday.ng/news/legal-business/article/prospect-for-nuclear-power-development-in-nigeria/, accessed 26 September 2023.

1408 - Nigerian Government, "Nigeria Energy Transition Plan—Power", 2023, see https://www.energytransition.gov.ng/power/, accessed 26 September 2023.

1409 - *WNN*, "Nigeria moving ahead on nuclear power plant plan", 18 March 2022, see https://www.world-nuclear-news.org/Articles/Nigeria-moving-ahead-on%C2%A0nuclear-power-plant-plan, accessed 18 March 2022.

1410 - The WNISR-Coordinator gave a presentation at the event.

1411 - *The Authority*, "Electricity Crisis: Experts at Nextier canvass for Nigeria's nuclear energy development", 3 August 2022, see https://authorityngr.com/2022/08/03/electricity-crisis-experts-at-nextier-canvass-for-nigerias-nuclear-energy-development/, accessed 4 August 2022.

> IAEA and other global partners in the coming months and years to discuss the possibility of deploying SMRs in the country.[1412]

At the General Conference of the IAEA in September 2023, the government through its Ministry of Foreign Affairs reiterated the country's interest for SMRs, stating "Nigeria looks forward to a greater engagement and collaboration with the IAEA and other global partners in the coming months and years to discuss the immense potentials of the SMRs."[1413]

In March 2024, local media featured some reports about a supposedly imminent new nuclear build in conjunction with Russia, but media monitor *Africa Check* found these stories to be incorrect.[1414] Furthermore, in the last year no significant developments have been noted on the website of the official Nigerian Nuclear Regulatory Authority suggesting progress towards a new nuclear build.[1415] It therefore appears that nuclear build initiatives promoted two years earlier have slowed. However, Chinese nuclear developers are now active in the country, having opened an office in Lagos[1416] and considering signing of an inter-governmental agreement on a nuclear program.[1417]

Ghana

Ghana has long explored a move to nuclear energy and has as a result already established associated governance structures, institutions, and processes. It has a Nuclear Regulatory Authority[1418], the Ghana Atomic Energy Commission with its Nuclear Power Institute, and a company, Nuclear Power Ghana[1419], set up in 2018 to develop and operate the country's proposed first nuclear plant. It also runs a small research reactor.

It was announced in August 2022 that Ghana has officially decided to include nuclear energy in the national electricity mix.[1420] The list of potential sites for a nuclear plant by 2030 was reportedly narrowed down in September 2023 to two locations, Nsuban and Obotan.[1421] In that same month, the U.S. announced a US$1.75 million grant to support nuclear power

1412 - Senator Adeleke Olorunnimbe Mamora, "National Statement of Nigeria", Minister of Science Technology and Innovation, Government of Nigeria, at the International Ministerial Conference on Nuclear Power in the 21st Century, 26–28 October 2022, see https://nigatom.gov.ng/wp-content/uploads/2022/10/NATIONAL-STATEMENT-OF-NIGERIA_IMC-on-NP_Washington-DC.pdf, accessed 4 August 2024.

1413 - Ambassador Adamu Ibrahim Lamuwa, "National Statement Delivered at the 67th Regular Session of the IAEA General Conference", Permanent Secretary, Ministry of Foreign Affairs, 26 September 2023, see https://www.iaea.org/sites/default/files/23/09/nigeria-gc67.pdf, accessed 4 August 2024.

1414 - Muktar Balogun, "Old reports of agreement for Russia to build nuclear power plants in Nigeria resurface online in 2024, presented as recent", *Africa Check*, 26 March 2024, see https://africacheck.org/fact-checks/meta-programme-fact-checks/old-reports-agreement-russia-build-nuclear-power-plants, accessed 17 July 2024.

1415 - NNRA, "Home", Nigerian Nuclear Regulatory Authority, see https://www.nnra.gov.ng/nnra/, accessed 17 July 2024.

1416 - NAEC, "NAEC and CNNC Seek Collaboration on Nuclear Science and Technology", Nigeria Atomic Energy Commission, October 2023, see https://nigatom.gov.ng/naec-and-cnnc-seek-collaboration/, accessed 18 August 2024.

1417 - NAEC, "NAEC and Foreign Affairs Ministry Meet to Strategize", 30 January 2024, see https://nigatom.gov.ng/naec-and-foreign-affairs-ministry-meet-to-strategies/, accessed 4 August 2024.

1418 - Nuclear Regulatory Authority of Ghana, "Ghana's Nuclear Power Programme", 2024, see https://nra.gov.gh/nuclear-power.php, accessed 5 July 2024.

1419 - NPG, "About Us", Nuclear Power Ghana, 2024, see https://nuclearpowergh.com/about-us/, accessed 5 July 2024.

1420 - *GNA*, "President Akufo-Addo approves nuclear technology in Ghana's energy mix", *Ghana News Agency*, 31 August 2022, see https://gna.org.gh/2022/08/president-akufo-addo-approves-nuclear-technology-in-ghanas-energy-mix/, accessed 4 August 2024.

1421 - *NEI Magazine*, "Ghana selects potential sites for first NPP", *Nuclear Engineering International*, 26 September 2023, see https://www.neimagazine.com/news/ghana-selects-potential-sites-for-first-npp-11174091/, accessed 5 July 2024.

training,[1422] a likely manifestation of its intention to counter Russian influence in the form of nuclear development in what the U.S. considers an important ally in the region. This followed a U.S.-Japanese initiative to establish Ghana as an African leader in SMR rollouts[1423], and may also have been the driver for a U.S.-Africa Nuclear Energy Summit held in Accra in November 2023.[1424] The U.S. is also specifically seeking to interest Ghana in purchasing SMR technology and signed a series of cooperation agreements.[1425] In May 2024, it was reported that "16 countries and companies" had sought interest in contributing to a 1 GW nuclear plant, and that the list had been narrowed down to bidders from five countries: China, France, Russia, South Korea, and the U.S., with a decision on the successful bidder to be made by December 2024, for the addition of 1 GW of nuclear power by 2034.[1426]

Nuclear Power Ghana indicated it is working to overcome 19 infrastructural issues it needs to resolve to obtain greenlighting from the IAEA to initiate a nuclear newbuild, but its report gave no indication of the level of complexity of these issues, the financial outlay required to remedy them, or the timeframes required.[1427] They have also yet to identify the preferred site for such a plant. It therefore appears that an actual construction start, if it ever materializes, is still some time away.

1422 - U. S. Embassy in Ghana, "U.S. Announces New Support for Ghana's Civil Nuclear Energy Program under the FIRST Capacity Building Program", 13 September 2023, see https://gh.usembassy.gov/u-s-announces-new-support-for-ghanas-civil-nuclear-energy-program-under-the-first-capacity-building-program/, accessed 5 July 2024.

1423 - U.S. Department of State, "United States and Japan Announce Partnership with Ghana to Support its Goal of Being the Mover in Africa for Small Modular Reactor Deployment", Press Release, United States Government, 26 October 2022, see https://www.state.gov/united-states-and-japan-announce-partnership-with-ghana-to-support-its-goal-of-being-the-mover-in-africa-for-small-modular-reactor-deployment/, accessed 1 July 2024.

1424 - Office of Nuclear Energy, "African Nations Gather to Discuss the Future of Nuclear Energy in the Region", U.S. Department of Energy, United States Government, 2 November 2023, see https://www.energy.gov/ne/articles/african-nations-gather-discuss-future-nuclear-energy-region, accessed 5 July 2024.

1425 - U.S. Embassy in Ghana, "United States and Ghana Advance Cooperation on Clean, Secure, Safe and Reliable Nuclear Energy", Press Release, as published by the Ghana Atomic Energy Commission, 29 May 2024, see http://gaec.gov.gh/united-states-and-ghana-advance-cooperation-on-clean-secure-safe-and-reliable-nuclear-energy/, accessed 4 August 2024.

1426 - Maxwell Akalaare Adombila, "French, Russia, Chinese firms vie to build Ghana's first nuclear power plant", *Reuters*, 21 May 2024, see https://www.reuters.com/business/energy/french-russia-chinese-firms-vie-build-ghanas-first-nuclear-power-plant-2024-05-21/, accessed 5 July 2024.

1427 - NPG, "NPG unveils more insights on Ghana's Nuclear Power Project at media workshop", Nuclear Power Ghana, 11 June 2024, see https://nuclearpowergh.com/npg-unveils-more-insights-on-ghanas-nuclear-power-project-at-media-workshop/, accessed 5 July 2024.

BANGLADESH

Bangladesh is building two Russian designed VVER-1200 nuclear reactors at Rooppur at a reported cost of US$12.65 billion (as of 2017).[1428] Construction of the two units began in November 2017 and July 2018, respectively.[1429] In July 2018, Rosatom announced that commercial operations were to commence in 2023 and 2024 respectively.[1430] But these have been delayed, in part due to Russia's attack on Ukraine and resulting sanctions (see WNISR2022).

In April 2024, one of Bangladesh's largest newspapers reported that "the deadline for the project's completion has been extended to 2027", while the first unit was to be commissioned in December 2024 provided "transmission lines are ready".[1431] Indeed, the delay is not just with the reactor but also the grid extensions needed to connect the reactors to places that will utilize the electricity.[1432] Nevertheless, in October 2023, Russia's President Vladimir Putin, Bangladesh's Prime Minister Sheikh Hasina and Rafael Grossi, head of IAEA, virtually attended an official ceremony to mark "the delivery of Russian-made nuclear fuel to the Rooppur Nuclear Power Plant's No 1 Unit".[1433] In July 2024, the first 48 future operators of the plant completed "pre-licensing training".[1434] According to a release issued by Rosatom in April 2024, upon meeting with Director General of Rosatom Alexey Likhachev, Prime Minister Sheikh Hasina[1435] indicated that there is interest in building further units at Rooppur.[1436]

Even in 2022, *The Daily Star*, a prominent Bangladeshi newspaper, reported that the Rooppur project's cost might "rise due to slow progress in power grid upgrade, possible changes in the loan repayment method amid the Russia-Ukraine war and the devaluation of the taka."[1437]

1428 - Rooppur Nuclear Power Plant, "A Dream Come True", Brochure, September 2017, see https://rooppurnpp.portal.gov.bd/sites/default/files/files/rooppurnpp.portal.gov.bd/page/323ceed5_dcaf_40b7_9518_bf407d9b928f/A%20Dream%20Comes%20True%20September%20%202017.pdf, accessed 1 August 2024.

1429 - Rosatom, "First concrete poured at the constructed Rooppur NPP site (Bangladesh)", 30 November 2017, see https://rosatomafrica.com/en/press-centre/news/first-concrete-poured-at-the-constructed-rooppur-npp-site-bangladesh/, accessed 29 July 2023; and Rosatom, "Main construction of the 2nd Unit of Rooppur NPP begins with the 'First Concrete' ceremony", Press Release, 14 July 2018, see https://rosatom-mena.com/press-centre/news/main-construction-of-the-2nd-unit-of-rooppur-nuclear-power-project-begins-with-the-first-concrete-ce/, accessed 1 August 2024.

1430 - Rosatom, "Main Construction of the 2nd Unit of Rooppur NPP Begins with the 'First Concrete' Ceremony", July 2018, op. cit.

1431 - Ahmed Humayun Kabir Topu, "Rooppur Nuclear Power Plant: First unit to start production in December", *The Daily Star*, 27 April 2024, see https://www.thedailystar.net/news/bangladesh/news/rooppur-nuclear-power-plant-first-unit-start-production-december-3596116, accessed 3 May 2024.

1432 - Rejaul Karim Byron and Asifur Rahman, "Rooppur will be ready on time", *The Daily Star*, 21 August 2023, see https://www.thedailystar.net/business/economy/news/rooppur-will-be-ready-time-3398991, accessed 5 March 2024.

1433 - President of Russia, "Ceremony marking the delivery of nuclear fuel to the Rooppur Nuclear Power Plant", 7 October 2023, see http://en.kremlin.ru/events/president/news/72438, accessed 24 July 2024; and Rosatom, "The first batch of nuclear fuel has been delivered to Rooppur NPP", 5 October 2023, see https://rosatom.ru/en/press-centre/news/the-first-batch-of-nuclear-fuel-has-been-delivered-to-rooppur-npp/?, accessed 1 August 2024.

1434 - Rosatom, "Pre-licensing training of the personnel for operation of Rooppur NPP (Bangladesh) was completed", 1 July 2024, see https://rosatom.ru/en/press-centre/news/pre-licensing-training-of-the-personnel-for-operation-of-rooppur-npp-bangladesh-was-completed/, accessed 6 July 2024.

1435 - Sheikh Hasina has fled the country on 5 August 2024 following a wave of student protests. Nobel Laureate Muhammad Yunus was sworn in as interim Prime Minister three days later. Accusations of massive corruption were part of Hasina's ouster. There are rumors that this might have involved the Rooppur project. The future energy policy is highly uncertain.

1436 - ASE, "Alexey Likhachev, Rosatom State Corporation Director General, held a working meeting with Sheikh Hasina, Prime Minister of the Republic of Bangladesh", 2 April 2024, see https://ase-ec.ru/en/for-journalists/news/2024/apr/alexey-likhachev-rosatom-state-corporation-director-general-held-a-working-meeting-with-sheikh-hasin/, accessed 1 August 2024.

1437 - Rejaul Karim Byron, "Rooppur nuclear power plant: Cost may rise for multiple factors", *The Daily Star*, 25 October 2022, see https://www.thedailystar.net/news/bangladesh/news/rooppur-nuclear-power-plant-cost-may-rise-multiple-factors-3151171, accessed 29 July 2023.

Repayment has become harder for Bangladesh because of its worsening economic outlook. The country's foreign exchange reserves have declined from over US$40 billion in early 2022 to US$20.8 billion in early 2024.[1438] The devaluation of the Bangladeshi taka has also made it more costly to import fossil fuels.[1439]

Earlier in 2023, the government sought a two-year extension on repayment of the loan from Russia for Rooppur.[1440] The agreement between the Bangladesh Atomic Energy Commission and the JSC Atomstroyexport of the Russian Federation, signed on 25 December 2015, reportedly "requires semiannual payments of the loan, due on 15 March and 15 September. Each year, [US]$379.33 million is to be paid towards the principal amount, with [US]$189.66 million per instalment."[1441] The first instalment is currently slated for "payment on 15 March 2027", but "the government now seeks to extend this deadline to 15 March 2029."

These large payments will come in the way of Bangladesh implementing what energy analysts recommend, namely to "invest more in renewable energy and energy efficiency to reduce fossil fuel imports."[1442] Bangladesh's installed capacity of renewables at the end of 2023 was only 1 GW. However, that figure represents a 32 percent increase over the figure of 762 MW at the end of 2022, and about 2.5 times the capacity of 405 MW a decade ago.[1443] The increase was entirely due to solar energy expanding by 46 percent, from 524 MW in 2022 to 767 MW in 2023.

EGYPT

Since early 2024, full-scale construction is underway at what is to be the country's first nuclear power plant, El Dabaa, located on the north-west coast of Egypt, by the Mediterranean Sea.

With the official construction start of the fourth VVER-1200 reactor on 23 January 2024, all Generation III+ 1,200 MWe-Pressurized-Water Reactors (PWRs) of Russian design (AES-2006) planned for the site are now under active construction.[1444]

1438 - ADB, "Asian Development Outlook: Bangladesh", Asian Development Bank, April 2024, see https://www.adb.org/sites/default/files/publication/957856/ban-ado-april-2024.pdf; and World Bank, "Strong Financial Sector, Fiscal and Monetary Policy Reforms will be Critical to Sustain Bangladesh's Growth Momentum", 5 April 2024, see https://www.worldbank.org/en/news/feature/2024/04/05/strong-financial-sector-fiscal-and-monetary-policy-reforms-will-be-critical-to-sustain-bangladesh-s-growth-momentum; both accessed 24 July 2024.

1439 - Shafiqul Alam, "Finance is key to Bangladesh's energy transition", Institute for Energy Economics and Financial Analysis, 25 June 2024, see https://ieefa.org/resources/finance-key-bangladeshs-energy-transition, accessed 27 June 2024.

1440 - Shaikh Abdullah, "Bangladesh seeks 2-year extension for Rooppur nuke plant loan repayments", *The Business Standard*, 26 April 2024, see https://www.tbsnews.net/bangladesh/energy/bangladesh-seeks-2-year-extension-rooppur-nuke-plant-loan-repayments-836701, accessed 24 July 2024.

1441 - Ibidem.

1442 - Shafiqul Alam, "Finance is key to Bangladesh's energy transition", IEEFA, June 2024, op. cit.

1443 - IRENA, "Renewable Capacity Statistics 2024", International Renewable Energy Agency, March 2024, see https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2024/Mar/IRENA_RE_Capacity_Statistics_2024.pdf?rev=a587503ac9a2435c8d13e40081d2ec34, accessed 17 April 2024.

1444 - NPPA, "In attendance of H.E. the President of the Arab Republic of Egypt and H.E. the President of the Russian Federation", Nuclear Power Plants Authority, 23 January 2024, see https://nppa.gov.eg/News/Details?id=2121, accessed 30 August 2024.

As discussed in previous WNISR editions, the long history of Egypt's nuclear ambitions stems back to the mid-1950, and the El Dabaa site was already selected in the early 1980s.[1445] The current US$30 billion-project is implemented by Russia's state-owned company Rosatom and its subsidiaries Atomstroyexport, TVEL, NFCL and Rusatom Service, as provided by contracts signed in 2015 and put into effect in late 2017.[1446] Rosatom will assist Egypt in training personnel and carrying out maintenance work during the facility's first 10 years of operation, supply fuel for the plant's planned 60-year operating life, and provide spent fuel management equipment and infrastructure.[1447] By 2028, "Rosatom State Corporation will train about 1700 specialists within the project," the company said.[1448] Furthermore, Russian entities are extensively involved in helping develop the regulatory framework and training of personnel for the Egyptian Nuclear and Radiological Regulatory Authority (ENRRA), established in 2010.[1449]

In 2016, it was also announced that Russia would provide a US$25-billion loan—covering about 85 percent of the estimated costs—which Egypt would repay over 22 years with a 3-percent interest rate, starting in October 2029.[1450]

The project has seen some delay in its past years—which gave rise to contradicting explanations from various involved parties as discussed in previous WNISR editions. In December 2017, when notices to proceed were signed, the first unit was to be commissioned in 2026.[1451] By May 2022, it was anticipated that the first two units would start operating in 2028 and 2029 respectively, and full operation of the plant would occur in 2030.[1452] Other reported earlier announcements have mentioned a 2031-completion date for the whole project.[1453]

Much has been done to accelerate the implementation of the project and make up for past delays, including through changes in the Egyptian legislation (see past WNISR editions), and the endeavor has regained momentum since 2022 leading-up to the full-scale construction of the plant in early 2024. The official kick-off marked by concrete pouring at Unit 1 took place on

1445 - Joy Nasr and Ali Ahmad, "Middle East Nuclear Energy Monitor: Country Perspectives 2018", Energy Policy and Security Program, Issam Fares Institute for Public Policy and International Affairs, American University of Beirut, January 2019, see https://www.aub.edu.lb/ifi/Documents/publications/research_reports/2018-2019/20190103_middle_east_nuclear_energy_monitor_country_perspectives_2018.pdf, accessed 30 July 2023.

1446 - Phil Chaffee, "Rosatom Locks in $30 Billion Nuclear Deal in Egypt", *Nuclear Intelligence Weekly*, 15 December 2017.

1447 - Rosatom, "Newsletter #200—Notice to proceed contracts signed for El Dabaa NPP", December 2017, see https://rosatomnewsletter.com/2017/12/15/notice-to-proceed-contracts-signed-for-el-dabaa-npp/, accessed 31 August 2024.

1448 - Rosatom Service, "Training of El-Dabaa NPP Personnel Started at Rosatom Technical Academy, news of the energy company Rosatom Service JSC", 13 September 2021, see https://rosatom-service.ru/en/news/v-tekhnicheskoy-akademii-rosatoma-startovalo-obuch/, accessed 31 August 2024.

1449 - IAEA, "Mission Report on the Integrated Nuclear Infrastructure Review (INIR) – Phase 2", 27 October–6 November 2019, see https://www.iaea.org/sites/default/files/documents/review-missions/inir2-egypt.pdf, accessed 23 July 2022.

1450 - Asma Alsharif, "Russia to lend Egypt $25 billion to build nuclear power plant", *Reuters*, 1 May 2016, see https://www.reuters.com/article/us-egypt-russia-nuclear/russia-to-lend-egypt-25-billion-to-build-nuclear-power-plant-idUSKCN0YA1G5, accessed 24 April 2018.

1451 - Rosatom, "Notices to proceed contracts for El Dabaa NPP construction signed in the presence of presidents of Russian Federation and Egypt", 11 December 2017, see https://rosatomafrica.com/en/press-centre/news/notices-to-proceed-contracts-for-el-dabaa-npp-construction-signed-in-the-presence-of-presidents-of-r/?sphrase_id=6414, accessed 1 September 2024.

1452 - *EgyptToday*, "Egypt's Nuclear Plants Authority, Rosatom committed to Dabaa plant construction schedule: Official", 9 May 2022, see https://www.egypttoday.com/Article/3/115597/Egypt's-Nuclear-Plants-Authority-Rosatom-committed-to-Dabaa-plant-construction, accessed 17 July 2022.

1453 - Ibrahim Ayyad, "Ukraine war could delay Egypt's first nuclear power plant", *Al-Monitor*, 27 March 2022, see https://www.al-monitor.com/originals/2022/03/ukraine-war-could-delay-egypts-first-nuclear-power-plant, accessed 28 March 2022.

20 July 2022, followed by that of Unit 2 in November 2022, Unit 3 in May 2023, and Unit 4 in January 2024.[1454]

In March 2024, it was reported that trial operations for the commissioning of Unit 1 would begin "by the second half of 2027", and its commercial operation in September 2028.[1455] Attaining commercial operation after just over six years since construction start would be a remarkable achievement, especially in a newcomer country, even more so considering the scope of ongoing construction projects Rosatom is leading in parallel as of mid-2024. These include four reactors each in India, China, and Türkiye (see Türkiye Focus), two in Bangladesh (see Bangladesh), and six at home. That is, despite the sanctions weighing on Russia over its illegal invasion of Ukraine and Rosatom's active role in the occupation of a nuclear power plant.

However, track records show that reality not always synchs with set ambitions and announced timeframes, allowing for some cautious skepticism on the forecasting. In August 2022 a program to "reduce the interval between the start of construction of each power unit from six to four months" was reported in *Nuclear Engineering International*.[1456] That did not pan out, as Unit 3 was put under construction in early May 2023, over five months after Unit 2, and the interval lasted twice the targeted time for Unit 4. Interestingly, of the four units, it was also the longest delay between the issuance of the construction permit (late August 2023) and construction start,[1457] for which there is no known explanation.

Nevertheless, the progress reports suggest a steady pace of implementation, and imply that contrary to expectations, the broader adversarial context has largely spared the project.

Energy Policy

Egypt relies heavily on natural gas for its power supply: it provided over 80 percent of the country's power in 2023, while non-hydro renewables contributed 11 TWh (gross), around 5 percent of the total electrical energy in Egypt's grid.[1458] Egypt's renewable energy capacity has grown slowly over the past decade, from 3.5 GW in 2013 to 6.3 GW in 2022 and 6.7 GW in 2023. Wind energy capacity has tripled over the decade to reach 1.9 GW in 2023, while solar energy capacity has surged from 35 MW in 2013 to 1.9 GW in 2023, an increase by a factor of 54.[1459]

1454 - Rosatom, "Main Construction Phase for El-Dabaa Nuclear Power Plant Project Begins in Egypt", Press Release, 20 July 2022, see https://rosatom-mena.com/press-centre/news/main-construction-phase-for-el-dabaa-nuclear-power-plant-project-begins-in-egypt/, accessed 20 July 2022; and Atomstroyexport, "Main construction phase for Unit 2 of the El-Dabaa Nuclear Power Plant commences in Egypt", 19 November 2022, see https://ase-ec.ru/en/for-journalists/news/2009/nov/main-construction-phase-for-unit-2-of-the-el-dabaa-nuclear-power-plant-commences-in-egypt/, accessed 21 November 2022; also Rosatom, "Main Construction Phase for Unit 3 of El-Dabaa Nuclear Power Plant Commences in Egypt", Press Release, 3 May 2023, see https://www.rosatom.ru/en/press-centre/news/main-construction-phase-for-unit-3-of-el-dabaa-nuclear-power-plant-commences-in-egypt/, accessed 7 May 2023, and NPPA, "In attendance of H.E. the President of the Arab Republic of Egypt and H.E. the President of the Russian Federation", Nuclear Power Plants Authority, 23 January 2024, op.cit.

1455 - *Asharq Al Awsat*, "Egypt Reveals Start Date for Trial Operation at Dabaa Nuclear Plant", 29 March 2024, see https://english.aawsat.com/node/4938331, accessed 14 August 2024.

1456 - *NEI Magazine*, "Work already underway at Egypt's El Dabaa NPP", 5 August 2022, see https://www.neimagazine.com/news/work-already-underway-at-egypts-el-dabaa-npp-9905385/, accessed 31 August 2024.

1457 - Construction started at Unit 1 and 2 less than one month after their constructions permits were secured, Unit 3 just over a month, and Unit 4 over four months later.

1458 - Energy Institute, "Statistical Review of World Energy 2024 - Data", June 2024, see https://www.energyinst.org/__data/assets/excel_doc/0020/1540550/EI-Stats-Review-All-Data.xlsx, accessed 29 June 2024.

1459 - IRENA, "Renewable Energy Statistics 2024", July 2024, see https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/Jul/IRENA_Renewable_Energy_Statistics_2024.pdf, accessed 31 August 2024.

Current policies envision for renewables to deliver 42 percent of generated power by 2035.[1460] In late June 2024, Ministry of Electricity Mohamed Shaker reportedly announced that the country's forthcoming updated strategy would feature an increased target for renewable sources, which are to provide 58 percent of electricity production by 2040.[1461] The role nuclear is to play in this future strategy has not been disclosed yet, but according to some press reports, Egypt is considering to build more reactors, for which it is already setting land aside.[1462]

JORDAN

Jordan has been interested in nuclear power since the Jordan Atomic Energy Commission (JAEC) was established through law in 2008.[1463] Since then, the JAEC has signed "more than 15 nuclear cooperation agreements" according to its webpage.[1464] In addition, JAEC has over the years announced plans to import two 1000-MW nuclear reactors from Russia,[1465] a High Temperature Reactor from the China National Nuclear Corporation,[1466] and talking about building Small Modular Reactor (SMR) designs including X-energy, NuScale,[1467] and floating reactors manufactured by Rosatom.[1468] Most recently, in December 2023, JAEC signed a Memorandum of Understanding with the Korean Hydro and Nuclear Power Company (KHNP) "to engage in extensive technical and information exchanges regarding i-SMR, which is currently in development, accompanied by a collaborative feasibility study".[1469] Jordan has also submitted reports to the IAEA about its plans to deploy SMRs and in October 2023 the IAEA

1460 - Ministry of Planning and Economic Development, "The National Agenda for Sustainable Development—Egypt's Updated Vision 2030", Government of Egypt, 2023, see https://mped.gov.eg/Files/Egypt_Vision_2030_EnglishDigitalUse.pdf, accessed 1 September 2024.

1461 - Aiden Lewis, "Egypt looking to raise target for renewable energy to 58% by 2040", Reuters, 29 June 2024, see https://www.reuters.com/business/energy/egypt-looking-raise-target-renewable-energy-58-by-2040-2024-06-29/, accessed 31 August 2024.

1462 - Nadim Kawach, "Egypt mulls building new nuclear reactor: report", *ZAWYA/LSEG*, see https://www.zawya.com/en/projects/utilities/egypt-mulls-building-new-nuclear-reactor-report-te2y4fqk, accessed 31 August 2024.

1463 - JAEC, "About Us", Jordan Atomic Energy Commission, 2021, see http://www.jaec.gov.jo/Pages/viewpage?pageID=1, accessed 1 May 2021.

1464 - JAEC, "International Cooperation", Jordan Atomic Energy Commission, 26 July 2024, see https://www.jaec.gov.jo/Pages/viewpage?pageID=41, accessed 25 July 2024.

1465 - Rosatom, "Russia and Jordan signed Project Development Agreement on Nuclear Power Plant Construction", Press Release, 22 September 2014, see https://rosatom-europe.com/press-centre/news/197-russia-and-jordan-signed-project-development-agreement-on-nuclear-power-plant-construction/; and *AP*, "Russia to build Jordan's first nuclear power plant", as published in *Al Jazeera*, 24 March 2015, see https://www.aljazeera.com/news/2015/3/24/russia-to-build-jordans-first-nuclear-power-plant; also Mohammad Ghazal, "Funding issues behind scrapping nuclear deal with Russia", *Jordan Times*, 12 June 2018, see http://www.jordantimes.com/news/local/funding-issues-behind-scrapping-nuclear-deal-russia-%E2%80%94-jaec, all accessed 30 July 2023.

1466 - Mohammad Ghazal, "Jordan, China in 'serious talks' to build gas-cooled $1b reactor", *Jordan Times*, 28 April 2018, see https://www.jordantimes.com/news/local/jordan-china-serious-talks%E2%80%99-build-gas-cooled-1b-reactor, accessed 8 May 2018.

1467 - Phil Chaffee, "Jordan: NuScale a Finalist in SMR Competition", *NIW*, 18 January 2019; and *WNN*, "NuScale SMR to be considered for use in Jordan", 15 January 2019, see http://www.world-nuclear-news.org/Articles/NuScale-SMR-to-be-considered-for-use-in-Jordan; also *NEI Magazine*, "Jordan and X-energy agree to accelerate work on SMR", *Nuclear Engineering International*, 22 November 2019, see https://www.neimagazine.com/news/newsjordan-and-x-energy-agree-to-accelerate-work-on-smr-7527332; and *WNN*, "Rolls-Royce to conduct SMR study for Jordan", 9 November 2017, see http://www.world-nuclear-news.org/NN-Rolls-Royce-to-conduct-SMR-study-for-Jordan-09111702.html; all accessed 30 July 2023.

1468 - *NEI Magazine*, "Jordan considers floating NPPs", 28 April 2023, see https://www.neimagazine.com/news/jordan-considers-floating-npps-10798331/, accessed 1 August 2024.

1469 - KHNP, Linkedin Post, December 2023, see https://www.linkedin.com/feed/update/urn:li:activity:7137366436892602368, accessed 1 August 2024.

expressed its satisfaction with these.[1470] However, none of these announcements and paper plans have resulted in actual construction so far.

In contrast to its nuclear plans, Jordan has been making great strides in expanding renewable energy: capacity has been growing quite rapidly, from 17 MW in 2014 to 2.6 GW in 2023, a 150-fold increase in a decade.[1471] Most of this consists of solar energy installations, with a total capacity of 2 GW as of 2023; until 2015, there was no solar PV capacity in the country. More importantly, renewable energy is already at 27 percent of electricity supply close to the targeted 30 percent by 2030, and hence the government plans to update the goal.[1472]

KAZAKHSTAN

Kazakhstan operated a small fast breeder reactor, the BN350 at Aktau, between 1973–1998 and is one of four countries in the world to have abandoned commercial nuclear power, the others being Germany, Italy, and Lithuania. But in contrast to the other countries Kazakhstan has considerable uranium reserves and, with Kazatomprom, has developed the world's largest producer. Kazakhstan has had discussions with countries and reactor suppliers over the years. In April 2019, during a meeting between President Putin of Russia and Kazakhstan's President Qasym-Zhomart Toqaev, it was suggested that Russia was to help in the construction of a nuclear power plant.[1473]

In February 2022, it was reported that the government was considering six suppliers for SMRs or large reactors: NuScale, GE Hitachi, China National Nuclear Corporation (CNNC), Rosatom and EDF. But in June 2022, NuScale and GE Hitachi were excluded from the process as their proposed technologies had not been implemented anywhere.[1474]

In April 2023, Almasadam Satkaliyev, Kazakhstan's Minister of Energy confirmed that "several applications are being considered. There is a French company, a Korean company, there are proposals from Chinese partners, there are proposals from Russian partners. When we consider construction experience and the number of units and efficient plants currently under construction in the world, then, with respect to the nuclear island Rosatom has a certain leadership." Kazakhstan has not decided whether to go ahead with the nuclear plan and, if yes, Satkaliyev indicated it might split the order into nuclear island, the electrical equipment, and grid system.[1475]

1470 - Lucy Ashton, "Jordan Advances Nuclear Power Programme with Support from IAEA SMR Platform", International Atomic Energy Agency, 4 October 2023, see https://www.iaea.org/newscenter/news/jordan-advances-nuclear-power-programme-with-support-from-iaea-smr-platform, accessed 1 August 2024.

1471 - IRENA, "Renewable Capacity Statistics 2024", International Renewable Energy Agency, March 2024, op. cit.

1472 - Yousef Saba, "Jordan plans to raise renewable targets by year-end or early 2024", *Reuters*, 3 October 2023, see https://www.reuters.com/business/energy/jordan-plans-raise-renewable-targets-by-year-end-or-early-2024-2023-10-03/, accessed 25 July 2024.

1473 - Bruce Pannier, "Putin Offers Russian Help To Build Kazakh Nuclear Plant", *RadioFreeEurope/RadioLiberty*, 6 April 2019, see https://www.rferl.org/a/kazakhstan-putin-offers-russian-nuclear-plant-help/29865177.html, accessed 1 May 2021.

1474 - *WNN*, "Kazakh, Korean companies to cooperate in nuclear power projects", 29 June 2022, see https://www.world-nuclear-news.org/Articles/Kazakh,-Korean-companies-to-cooperate-in-nuclear-p, accessed 29 August 2022.

1475 - *NEI Magazine*, "Kazakhstan continues to pursue NPP plans", as published on *World-Energy*, 14 April 2023, see https://www.world-energy.org/article/31317.html, 1 September 2024.

The International Atomic Energy Agency (IAEA) has completed an Integrated Nuclear Infrastructure Review (INIR) mission in March 2023, a follow-up to an initial 2016 mission. "Kazakhstan has made considerable effort to address the recommendations and suggestions made by the INIR team in 2016, which includes the preparatory work to inform the Government's decision on whether to introduce a nuclear power program," the mission's team leader stated.[1476]

In September 2023, Kazakh President Kassym-Jomart Tokayev suggested that a national referendum should be held in 2024 over the question whether to build two large nuclear power reactors. But according to media reports, in May 2024, a spokesperson of the Energy Ministry stated that the referendum had been delayed "over fears that the Kazakh population could vote against the plant's construction."[1477]

POLAND

See Focus Countries – Poland Focus.

SAUDI ARABIA

Saudi Arabia established The King Abdullah City for Atomic and Renewable Energy (KA-CARE) in 2010.[1478] Progress in the last decade and a half has been slow at best, and mostly involves officials reiterating plans to build nuclear plants. For example, at the International Atomic Energy Agency General Conference in September 2023, Saudi Arabia's Minister of Energy repeated the Kingdom's intention to develop "peaceful uses for nuclear energy across various fields (…) including the project of building the first nuclear energy power plant in the Kingdom."[1479] Later, in December 2023, Saudi Arabia hosted the IAEA Director General Rafael Mariano Grossi, who commented favorably on the Kingdom's preparations to embark on a nuclear energy program.[1480]

The slow rate of progress is also seen in choosing the builders of Saudi Arabia's first nuclear plant. In mid-2022, KA-CARE invited bids from South Korea, China, France, and Russia to construct two nuclear reactors.[1481] By the following year, the Kingdom confirmed that it had received bids, most likely from Korea Electric Power Company (KEPCO), China National

1476 - IAEA, "IAEA Reviews Progress of Kazakhstan's Nuclear Infrastructure Development", Press Release 32/2023, 11 April 2023, see https://www.iaea.org/newscenter/pressreleases/iaea-reviews-progress-of-kazakhstans-nuclear-infrastructure-development, accessed 7 October 2023.

1477 - *Nuclear Intelligence Weekly,* "Kazakhstan pushes back planned referendum on large-reactor nuclear plant", 15 May 2024.

1478 - Abdullah bin Abdul Aziz Al Saud, "Royal Decree establishing King Abdullah City for Atomic and Renewable Energy", Decree No A/35, 2010, see https://www.climate-laws.org/geographies/saudi-arabia/policies/royal-decree-establishing-king-abdullah-city-for-atomic-and-renewable-energy-2010, accessed 11 June 2021.

1479 - Abdulaziz Bin Salman Bin Abdulaziz Al Saud, "Statement of the Kingdom of Saudi Arabia", Minister of Energy, Government of Saudi Arabia, at "The 67th Session of the General Conference of the International Atomic Energy Agency (IAEA)", 25–29 September 2023, see https://www.iaea.org/sites/default/files/23/09/saudi-arabia-gc67_en.pdf, accessed 1 August 2024.

1480 - Wolfgang Picot, "IAEA Director General Visit Highlights Saudi Arabia's Dynamic Nuclear Power Preparations", IAEA, 13 December 2023, see https://www.iaea.org/newscenter/news/iaea-director-general-visit-highlights-saudi-arabias-dynamic-nuclear-power-preparations, accessed 4 August 2024.

1481 - Dan Yurman, "Saudi Arabia Kicks Off RFP for Twin 1400 MWe PWRs", *Neutron Bytes*, 2 June 2022, see https://neutronbytes.com/2022/06/02/saudi-arabia-kicks-off-rfp-for-twin-1400-mwe-pwrs/, accessed 25 July 2024.

Nuclear Corporation (CNNC), Russia's state-owned Rosatom, and France's EDF.[1482] KEPCO's ability to supply those reactors will depend on the results of a lawsuit filed by Westinghouse against Korea Hydro and Nuclear Power (KHNP) and KEPCO in October 2022.[1483]

Since then, Saudi Arabia has issued a call for "best and final offers" but the deadline for that submission has been extended from December 2023 to April 2024 and then to July 2024.[1484]

Although the United States did not make any offer, Saudi officials have expressed a preference for having the U.S. bid.[1485] But the U.S. Congress has "prohibited the use of appropriated funds for Export-Import Bank support for nuclear exports to Saudi Arabia until the kingdom has a 123 agreement 'in effect'; 'has committed to renounce uranium enrichment and reprocessing on its territory under that agreement'; and has 'signed and implemented' an Additional Protocol with the IAEA".[1486] Some U.S. interlocutors, such as Robert Einhorn of the Brookings Institute, have offered proposals to find a middle path between having Saudi Arabia acquire uranium enrichment technology and foreswear it completely.[1487] But others have argued against this possibility, highlighting how Saudi acquisition of the ability to enrich uranium would bring the Kingdom much closer to nuclear weapons capabilities.[1488]

In the meanwhile, total renewable energy capacity in Saudi Arabia has grown from 24 MW in 2014 and 843 MW in 2022 to 2.7 GW in 2023.[1489] Saudi Arabia's Vision 2030, released in 2016, set an initial target of 9.5 GW of renewables.[1490] A new, very ambitious, target of 130 GW by 2030 was reportedly announced by the Saudi Minister of Energy in December 2023.[1491] As of mid-2024, the Ministry mentions a target of "between 100 to 130 GW by 2030, depending on the growth of electricity demand."[1492]

The bulk of the current 2.7 GW capacity is solar energy—with 2.3 GW contributing 85 percent of the 2023-renewables capacity—more than quadrupling the 440 MW of 2022. Wind energy constituted 403 MW of the 2023 renewable capacity. The increase in solar capacity is likely to continue. In June 2024, for example, the Public Investment Fund, a state-owned investment fund of Saudi Arabia, announced it was investing in three new solar photovoltaic programs

1482 - Phil Chaffee and Jessica Sondgeroth, "Vendors Line Up for Saudi Nuclear Plant", *Nuclear Intelligence Weekly*, 31 March 2023.

1483 - *NIW*, "Westinghouse Sues Kepco/KHNP", *Nuclear Intelligence Weekly*, 4 November 2022.

1484 - Dan Yurman, "Saudi Arabia Kicks Request for Bids for Two Reactors to July", Neutron Bytes, 5 June 2024, see https://neutronbytes.com/2024/06/05/saudio-arabia-kicks-request-for-bids-for-two-reactors-to-july/, accessed 25 July 2024.

1485 - Aziz El Yaakoubi and Humeyra Pamuk, "Saudi foreign minister: wants U.S. to bid in domestic nuclear programme", *Reuters*, 8 June 2023, see https://www.reuters.com/world/saudi-foreign-minister-wants-us-bid-domestic-nuclear-programme-2023-06-08/, accessed 15 June 2023.

1486 - Paul K. Kerr and Christopher M. Blanchard, "Prospects for U.S.-Saudi Nuclear Energy Cooperation", Congressional Research Service, Updated 28 September 2023, see https://sgp.fas.org/crs/mideast/IF10799.pdf, accessed 1 August 2024.

1487 - Robert Einhorn, "A way forward on a US-Saudi civil nuclear agreement", Brookings, 12 April 2024, see https://www.brookings.edu/articles/a-way-forward-on-a-us-saudi-civil-nuclear-agreement/, accessed 27 May 2024.

1488 - Henry Sokolski and Sharon Squassoni, "The coming US-Saudi nuclear deal: Keep it honest", *The Bulletin of the Atomic Scientists*, 5 January 2024, see https://thebulletin.org/2024/01/the-coming-us-saudi-nuclear-deal-keep-it-honest/, accessed 25 July 2024.

1489 - IRENA, "Renewable Capacity Statistics 2024", International Renewable Energy Agency, March 2024, op. cit.

1490 - Andrew Roscoe, "Saudi Arabia sets 9.5GW renewable energy target", *MEED*, 26 April 2016, see https://www.meed.com/saudi-arabia-sets-9-5gw-renewable-energy-target/, accessed 4 August 2024; and Kingdom of Saudi Arabia, "Vision 2030, 2016.

1491 - Yara Abi Farraj, "Saudi Arabia to produce 130 GW of renewable energy by 2030", Economy Saudi Arabia, 20 December 2023, see https://economysaudiarabia.com/news/saudi-arabia-renewable-energy/, accessed 4 August 2024.

1492 - Ministry of Energy, "Saudi Power Procurement Company (SPPC) Signs Power Purchase Agreements for Three New Solar Energy Projects with a Total Capacity of 5,500 MW", 26 June 2024, see https://www.moenergy.gov.sa/en/MediaCenter/News/Pages/SPPC-Signs-PPA-for-Three-New-Solar-Energy-Projects-with-5500MW-Capacity.aspx, accessed 26 August 2024.

that are projected to start operating in 2027, with a combined capacity of 5.5 GW.[1493] Although the speed of expansion of renewables in the country is dramatically different from how nuclear energy plans are evolving, renewables still contributed a mere 5.8 TWh or 1.4 percent of the total gross electricity produced in the country in 2023, which are up from the corresponding figures from 2022 of 2.3 TWh and 0.57 percent.[1494]

TÜRKIYE

See Focus Countries – Türkiye Focus.

UZBEKISTAN

In 2017, Uzbekistan signed a framework nuclear cooperation agreement with Russia. In September 2018, a further agreement was signed for the construction by Rosatom of two VVER-1200 reactors with a combined capacity of 2.4 GW. As of 2020, they were expected to be commissioned in 2028 and 2030, respectively.[1495]

In an April-2019 interview with *Nuclear Engineering International* (*NEI*), Jurabek Mirzamakhmudov, Director General of Uzatom, announced site analysis work over the following 12–18 months at three locations. Mirzamakhmudov said that the investment would be partially financed through a soft loan from Russia. The reactors would provide power for domestic consumption, but some of it could also be exported to neighboring countries such as Afghanistan.[1496] It was later reported that the intention was to choose a site, and have it licensed by September 2020,[1497] which did not happen.

In May 2022, Mirzamakhmudov stated that a site had been chosen in the Farish district of the Jizzakh region, near Lake Tuzkan to host two Rosatom-supplied VVER-1200s. Mirzamakhmudov said in an interview that while the financing package were still under negotiation, recent Ukraine-related sanctions against Russia would have no impact on the process. He added that one of the reasons of delay were ongoing analysis whether to use "dry cooling" towers to save water uptake from Lake Tuzkan.[1498]

The IAEA carried out a Site and External Events Design Review Service (SEED) mission, which took place from 16 to 20 January 2023, and concluded that "Uzbekistan has carried out an objective and safety-oriented site characterization process". However, amongst the

1493 - Public Investment Fund, "Power purchase agreements signed for major renewables program in Saudi Arabia", 27 June 2024, see https://www.pif.gov.sa/en/news-and-insights/newswire/2024/power-purchase-agreements-signed-for-major-renewables-program-in-saudi-arabia, accessed 25 July 2024.

1494 - Energy Institute, "Statistical Review of World Energy 2024 - Data", June 2024, see https://www.energyinst.org/__data/assets/excel_doc/0020/1540550/EI-Stats-Review-All-Data.xlsx, accessed 29 June 2024.

1495 - *NEI Magazine*, "Uzbekistan's energy plans", 29 July 2020, see https://www.neimagazine.com/advanced-reactorsfusion/uzbekistans-energy-plans-8051183/, accessed 13 September 2024.

1496 - *NEI* Magazine, "Uzbekistan's nuclear aspirations", Interview with Jurabek Mirzamakhmudov, Director of Uzatom, 9 April 2019, see https://www.neimagazine.com/features/featureuzbekistans-nuclear-aspirations-7145738/, accessed 1 May 2021.

1497 - *WNN*, "Russia and Uzbekistan agree to start survey of new plant site", 17 May 2019, see https://www.world-nuclear-news.org/Articles/Russia-and-Uzbekistan-agree-to-start-survey-of-new, accessed 1 May 2021.

1498 - *Nuclear Intelligence Weekly*, "Uzbekistan – Site Selected for First Nuclear Plant", 1 July 2022.

recommendations, there are some issues that seem rather basic like the advice to "identify and select feasible engineering measures to provide plant cooling and site protection from external events, with reference to the specific plant technology selected by the owner and the number of units."[1499]

Uzbekistan moved away from the idea to build two large nuclear reactors and in May 2024 signed an agreement with Russia's Rosatom to build six 55 MW Small Modular Reactors (SMRs) in the eastern Jizzakh region, which marks the first export agreement for an SMR anywhere in the world.[1500] The design to be implemented is the RITM-200N, that has never been operating yet anywhere. The most advanced project received a construction license from the Russian regulator in April 2023, is to be built in the Ust-Yansky district of Yakutia in the arctic region and is supposed to start up in 2028.[1501]

The RITM-200 series is derived from a design originally developed for the Russian icebreaker fleet.

1499 - IAEA, "IAEA Team in Uzbekistan Concludes Site and External Events Design (SEED) Review for the Country's First Nuclear Power Plant", Press Release 8/2023, International Atomic Energy Agency, 27 January 2023, see https://www.iaea.org/newscenter/pressreleases/iaea-team-in-uzbekistan-concludes-site-and-external-events-design-seed-review-for-the-countrys-first-nuclear-power-plant, accessed 25 April 2023.

1500 - *Nuclear Intelligence Weekly,* "Newbuild: Uzbekistan Shifts Plans From Large Reactors to SMRs", 31 May 2024; and Rosatom, "The Russian Federation and Uzbekistan sign an agreement on the construction of a small nuclear power plant", Press Release, 27 May 2024, see https://www.rosatom.ru/en/press-centre/news/-the-russian-federation-and-uzbekistan-sign-an-agreement-on-the-construction-of-a-small-nuclear-powe/?sphrase_id=5860349, accessed 31 May 2024.

1501 - Rosatom, "Rosatom obtained a license for the first land-based SMR in Russia", Press Release, 24 April 2023, see https://rosatom-asia.com/press-centre/news/rosatom-obtained-a-license-for-the-first-land-based-smr-in-russia/, accessed 13 August 2024.

RUSSIA NUCLEAR DEPENDENCIES

Russia is a major global supplier of nuclear fuel services, including uranium mining, conversion, enrichment, and fuel assembly fabrication for Soviet-designed VVER pressurized water reactors, of which there are 19 in the E.U. and 15 in Ukraine. In particular, since Russia's full-scale invasion of Ukraine in February 2022, E.U. members and others in the region have discussed and taken measures to deprive Russia of the considerable revenue streams provided by such businesses and reduce the inherent risk of the region's dependence on Russia. But in contrast to Russian supplies of oil, natural gas, and coal, the nuclear sector has received little attention. While the U.S. introduced sanctions on some subsidiaries of Russian government-controlled company Rosatom in April 2023 and banned the import of uranium products from Russia in May 2024, the E.U. did not establish any sanctions in the nuclear sector—a strong indicator of dependency on Russia.

This chapter provides an overview of these dependencies, with a special focus on the supply of VVER fuel elements in the E.U. In some areas diversification is easier than in others. Switching suppliers of natural uranium and uranium conversion and enrichment services is costly while manufacturing fuel assemblies involves technical dependencies that are more challenging to overcome.

RUSSIA'S ROLE IN THE GLOBAL NUCLEAR FUEL SUPPLY CHAIN

According to the World Nuclear Association (WNA), as of 2020, Russia held about 20 percent of the estimated world primary uranium conversion capacities[1502] and 46 percent of enrichment capacities globally.[1503] In 2022, Russia contributed 5 percent to the world's natural uranium production with Kazakhstan providing 43 percent and Uzbekistan an estimated 6.7 percent (both countries have close ties to Russia).[1504]

According to an analysis published in March 2024 by U.K.-based defense and security studies think tank Royal United Services Institute (RUSI), "UN Comtrade data shows US$2.03 billion in global imports from Russia under HS code 284420 [normally overwhelmingly made up of enriched uranium] in 2022, up from US$1.29 billion in 2021," and "data compiled from a range of sources shows US$2.7 billion of enriched uranium imports from Russia in 2023." The RUSI authors warn, however, that the estimates are "likely to be inexact and are not necessarily representative of the revenue that Rosatom generates from this trade." [1505]

1502 - WNA, "Conversion and Deconversion", World Nuclear Association, 15 February 2022, see https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/conversion-and-deconversion, accessed 22 June 2024.

1503 - WNA, "Uranium Enrichment", World Nuclear Association, Updated 11 October 2022, see https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment, accessed 22 June 2024.

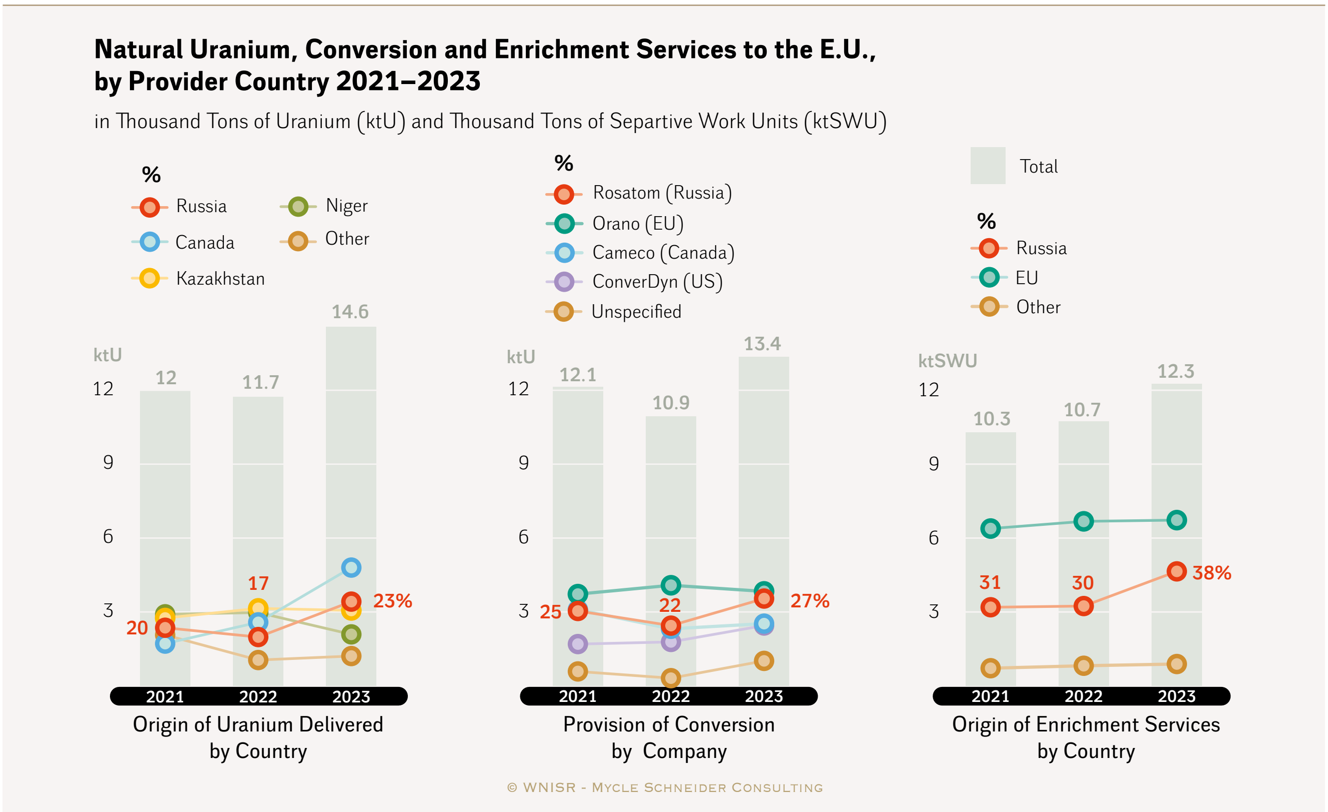
1504 - WNA, "World Uranium Mining Production", World Nuclear Association, Updated 16 May 2024, see https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production , accessed 22 June 2024.

1505 - Darya Dolzikova, "Power Plays: Developments in Russian Enriched Uranium Trade", The Royal United Services Institute, March 2024, see https://static.rusi.org/SR-power-plays-web-final.pdf, accessed 6 July 2024.

In particular, the U.S. imported enriched uranium from Russia for ~US$1.2 billion in 2023, up from ~US$0.8 billion in 2022.[1506] Rosatom provided 30 percent of uranium enrichment services to E.U. nuclear utilities in 2022, down from 31 percent in 2021.[1507] The company was also the largest foreign provider, at 27 percent of the total enrichment services, to U.S. nuclear operators in 2023, up from 24 percent in 2022, roughly equal to the amount provided by the U.S. itself.[1508]

Figure 53 shows the origin of natural uranium, conversion services, and enrichment services supplied to the E.U., based on data provided by the Euratom Supply Agency (ESA). In all three categories, Rosatom provided between 23.5 and 37.9 percent of the services in 2023, so that Russia/Rosatom was the second-largest supplier of the E.U., behind the E.U. itself, and Canada for Uranium. The significant increases of the share of Russia/Rosatom in 2023 may reflect the influence of the Ukraine war and may be temporary, which will be discussed below with respect to the import of VVER fuel assemblies.

Figure 53 • Russian Nuclear Fuel Services to the E.U. on the Rise



Source: ESA, 2022 and 2024

Notes: Total of uranium delivered to E.U. utilities in 2021 also includes 196 tU (1.6 percent) of re-enriched uranium, not represented.

1506 - Ibidem.

1507 - ESA, "Annual Report 2022", Euratom Supply Agency, January 2024, see https://euratom-supply.ec.europa.eu/document/download/416f638d-1928-44b6-a9d9-d9180b6eb2ad_en?filename=ESA%20Annual%20Report%202022%20-%20Final%20%28website%29_2.pdf, accessed 6 July 2024.

1508 - U.S. EIA, "Uranium Marketing Annual Report—Table 16. Purchases of enrichment services by owners and operators of U.S. civilian nuclear power reactors by origin country and year, 2019–23", United States Energy Information Administration, 2023, see https://www.eia.gov//uranium/marketing/table16.php, accessed 23 June 2024.

According to ESA, the nameplate capacity of uranium conversion and enrichment plants in the E.U. would be "sufficient for the E.U. to be self-dependent," but the "Global West" would be missing enrichment capacity of 3,500–8,000 tSWU (thousand Separative Work Units) without Russia. The Agency warns that constructing "additional conversion and enrichment capacity will take several years."[1509] E.U. and U.S. nuclear utilities alone had an enrichment service-need of about 25,000 tSWU in 2022.[1510] In France, imports of enriched uranium product (EUP) from Russia jumped from 75 tons in 2021 to 210 tons in 2022, according to UN trade data. Russian imports accounted for 67 percent of France's enriched uranium imports in 2022 and were equivalent to approximately one-fifth of EDF's annual demand.[1511]

The enrichment of reprocessed uranium represents a case of singular dependency on Russia. Framatome has a contract to supply Enriched Reprocessed Uranium (ERU) fuel assemblies to EDF from 2023 to 2032.[1512] This relies entirely on deliveries from Russia, which "has the only conversion plant in the world capable of converting reprocessed uranium." [1513] However, EDF stresses that it always has the option to replace ERU with low-enriched natural uranium.

Regarding fuel for the 19 Soviet-designed VVERs in the E.U., Norwegian environmental think tank Bellona's analysis of cross-border trade operations shows a 1.8-fold increase in imports of VVER fuel elements to E.U. countries in 2023 as compared to 2022 (see Figure 54), a more than two-fold increase in financial terms. It further notes:

> If EU countries paid a total of €280 million [US$$_{2022}$295 million] for Russian nuclear fuel in 2022, that more than doubled to €686 million [US$$_{2023}$742 million] in 2023. In physical terms, this represents an increase from 314 tons of nuclear fuel to 573 tons.[1514]

However, this is likely a temporary increase because utilities have been stockpiling fuel since 2022 in anticipation of tightening sanctions on the nuclear industry or other aggravation of relations between Russia and the E.U.,[1515] and also because alternative fuel supplies can be expected in the future. According to the *Wall Street Journal*, "EU imports of Russian nuclear fuel shot up in 2023 as utilities stockpiled supplies, trade data shows, but that could be short-lived."[1516]

1509 - Euratom Supply Agency, Slides from PPT Presentation at Hearing in German Federal Parliament, 6 February 2023.

1510 - ESA, "Annual Report 2022", January 2024, op. cit.; and U.S. EIA, "Uranium Marketing Annual Report—Table 16. Purchases of Enrichment Services by Owners and Operators of U.S. Civilian Nuclear Power Reactors by Origin Country and Year, 2019–23", op. cit.

1511 - Grace Symes, "France: Nuclear Industry Retains Ties With Rosatom", *Energy Intelligence*, 1 March 2024, see https://www.energyintel.com/0000018d-f041-d9ab-adff-f26da88c0000, accessed 31 May 2024.

1512 - Framatome, "France: Framatome to supply EDF with Enriched Reprocessed Uranium fuel assemblies", Press Release, 23 May 2018, see https://www.framatome.com/medias/framatome-to-supply-edf-enriched-reprocessed-uranium-fuel-assemblies/, accessed 7 July 2024.

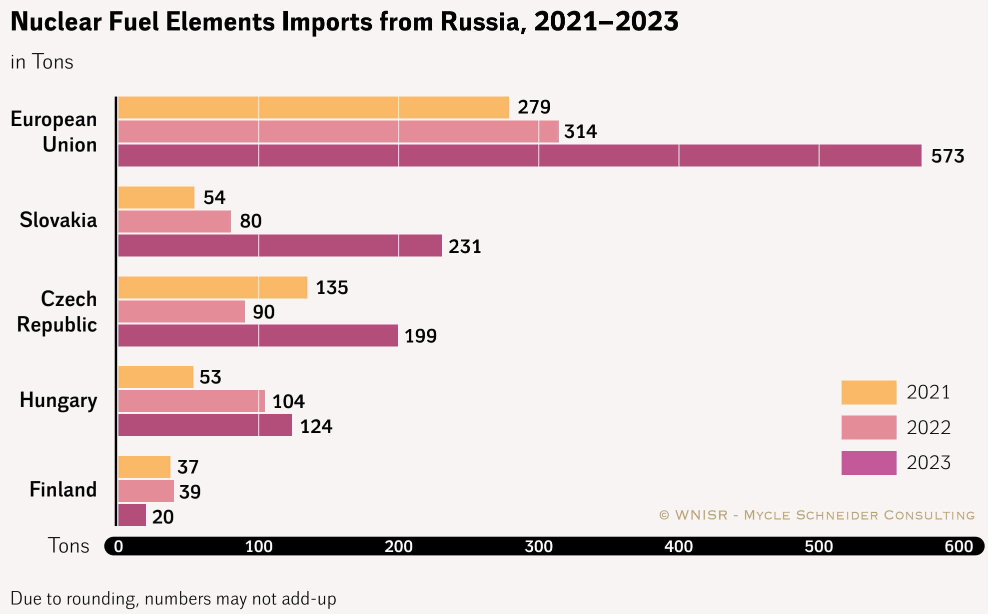
1513 - Grace Symes, "France: Nuclear Industry Retains Ties With Rosatom", *Energy Intelligence*, 1 March 2024, op. cit.

1514 - Charles Digges, "Europe doubled its import of Russian nuclear fuel for 2023, data say", Bellona, 15 March 2024, see https://bellona.org/news/nuclear-issues/2024-03-europe-russian-nuclear-fuel, accessed 15 April 2024.

1515 - Ibidem.

1516 - Kim Mackrael, James Marson, Nikita Nikolaienko and Jennifer Hiller, "The American Company Trying to Keep Ukraine's Nuclear Reactors Online", *The Wall Street Journal*, 7 June 2024, see https://www.wsj.com/world/the-american-company-trying-to-keep-ukraines-nuclear-reactors-online-e636917a, accessed 7 June 2024.

Figure 54 • E.U. Imports of Russian Nuclear Fuel Elements



Source: Comtrade Database, 2024[1517]

Note: Data for Bulgaria not available. For more detail, see investigation by Bellona.[1518]

SANCTIONS

In July 2022, the U.K. introduced a 35 percent tariff on imports of radioactive chemical elements and isotopes from Russia, which includes enriched uranium.[1519]

In April 2023, the U.S. Government expanded its 'Russia sanctions' to Rosatom subsidiary Rusatom Overseas,[1520] which was in charge of implementing the construction projects of nuclear power plants in other countries until a reshuffle of activities between various subsidiaries in recent years.

In May 2024, President Biden signed the "Prohibiting Russian Uranium Imports Act" which bans the import of Russian uranium products into the U.S. as of 12 August 2024, but includes a waiver process through 1 January 2028.[1521] The U.S. Office of Nuclear Energy notes that "Russia has roughly 44% of the world's uranium enrichment capacity and supplies approximately 35% of our imports for nuclear fuel," and that "a transition away from Russian-sourced fuel

1517 - Research by products "840130 -- Fuel elements (cartridges), non-irradiated" on United Nations, "Comtrade Database", see https://comtradeplus.un.org/, and World Bank, "World Integrated Trade Solution", see https://wits.worldbank.org/; both accessed August 2024

1518 - Charles Digges, "Europe doubled its import of Russian nuclear fuel for 2023, data say", Bellona, op. cit.

1519 - Darya Dolzikova, "Power Plays: Developments in Russian Enriched Uranium Trade", RUSI, March 2024, op. cit.

1520 - U.S. Department of State, "Further Curbing Russia's Efforts to Evade Sanctions and Perpetuate its War against Ukraine", 12 April 2023, see https://www.state.gov/further-curbing-russias-efforts-to-evade-sanctions-and-perpetuate-its-war-against-ukraine-2/, accessed 7 July 2024.

1521 - U.S. Department of State, "Prohibiting Imports of Uranium Products from the Russian Federation", Press Release, United States Government, 14 May 2024, see https://www.state.gov/prohibiting-imports-of-uranium-products-from-the-russian-federation/, accessed 23 May 2024.

will not happen overnight."[1522] While "U.S. utilities have roughly three years of LEU [Low-Enriched Uranium] available through existing inventory or pre-existing contracts," to avoid any disruptions, "we're creating a waiver process to allow some imports of LEU from Russia to continue for a limited time."[1523]

The E.U. has introduced fourteen different rounds of sanctions against Russia, the latest approved in June 2024. Despite many of these addressing energy industries, they have not included measures involving nuclear. In fact, while the E.U. has closed its ports to most of Russia's merchant fleet, "nuclear fuel and other goods necessary for the functioning of civil nuclear capabilities" are amongst the explicit exceptions.[1524]

In February 2023, the European Parliament passed a resolution calling for further expansion of sanctions to include individuals and entities present on the E.U. market, including Rosatom.[1525] However, despite initially suggesting it would propose sanctions against the Russian commercial nuclear sector, the European Commission reportedly abandoned such plans a couple of weeks later, and none have subsequently been introduced.[1526] The exception to this are the sanctions decided in February 2023 against Atomflot, a Russian company that "maintains Russia's nuclear icebreaker fleet", also sanctioned by other countries including the U.S., U.K., and Canada.[1527]

Meanwhile, the E.U. is considering duties instead of sanctions. On 30 May 2024, the E.U. trade ministers reportedly "asked the European Commission to draw up a plan to place duties on products that are exempt from the measures, such as food, nuclear fuel and medicines, with the revenues likely to go to Ukraine."[1528] Applying duties does not require a unanimous decision of the E.U. and may therefore bypass the largely stalled efforts for new sanctions. On the other hand, duties will not solve the E.U.'s underlying dependency on Russian fuel-element supply for VVER reactors. Duties are meant to deter buyers from purchasing a given product by increasing its price. However, VVER operators that currently have no alternative to TVEL fuel supply for most of their reactors (see Table 15) will likely fight the duties but are unlikely to stop buying Russian fuel.

1522 - It is unclear here what is meant by "nuclear fuel" and thus what exactly the 35 percent figure refers to.

1523 - Office of Nuclear Energy, "Russian Uranium Ban Will Speed up Development of U.S. Nuclear Fuel Supply Chain", Department of Energy, United States Government,14 May 2024, see https://www.energy.gov/ne/articles/russian-uranium-ban-will-speed-development-us-nuclear-fuel-supply-chain, accessed 14 May 2024.

1524 - European Council, "EU sanctions against Russia explained—What are the sanctions on transport?", Council of the European Union, 27 June 2024, see https://www.consilium.europa.eu/en/policies/sanctions-against-russia/sanctions-against-russia-explained/, accessed 7 July 2024.

1525 - European Parliament, "European Parliament resolution of 2 February 2023 on the preparation of the EU-Ukraine Summit (2023/2509(RSP))", 2 February 2023, see https://www.europarl.europa.eu/doceo/document/TA-9-2023-0029_EN.html, accessed 8 February 2023.

1526 - Leonie Kijewski and Jacopo Barigazzi, "EU Commission scratches Russia nuclear sanctions plans", *Politico*, 16 February 2023, see https://www.politico.eu/article/rosatom-russia-ukraine-volodymyr-zelenskyy-vladimir-putin-eu-executive-scratches-russia-nuclear-sanctions-plans/, accessed 16 July 2023.

1527 - Council of the European Union, "Council Decision (CFSP) 2023/432 of 25 February 2023 amending Decision 2014/145/CFSP concerning restrictive measures in respect of actions undermining or threatening the territorial integrity, sovereignty and independence of Ukraine", *Official Journal of the European Union*, L 59 I/437, 25 February 2023, see http://data.europa.eu/eli/dec/2023/432/oj/eng, accessed 16 August 2023.

1528 - Andy Bounds, "EU prepares tariffs on Russian goods exempt from sanctions", *The Financial Times*, 30 May 2024, see https://www.ft.com/content/b79a1c1a-5923-4b19-bf34-9cd9cce892a3, accessed 21 June 2024.

SUPPLY OF FUEL ASSEMBLIES FOR RUSSIAN VVERs

Five E.U. countries—Bulgaria, Czech Republic, Finland, Hungary, and Slovakia—operate 19 Soviet-designed VVER reactors, 15 of which are 440s and four are 1000s. Diversifying fuel supply for these reactors is complex. In 1998, Westinghouse started manufacturing VVER fuel assemblies in three E.U. projects with mixed results (see below). Westinghouse has now become a supplier in Ukraine, but Framatome is expected to join the ranks of VVER fuel manufacturers. Westinghouse has been focused on manufacturing VVER-1000 fuel. But this might change, as in September 2023 Westinghouse delivered a first load of VVER-440 fuel assemblies to the Ukrainian Rivne plant.[1529]

Table 15 · Fuel Supply for Soviet-designed Reactors in the E.U. and Ukraine (as of mid-2024)

<table>
<tr><th>Country</th><th>Nuclear Share 2023</th><th>Unit</th><th>Type</th><th>TVEL (Russia)</th><th>Westinghouse (USA/Canada)</th><th>Framatome (France)</th></tr>
<tr><td rowspan="2">Bulgaria</td><td rowspan="2">40.5%</td><td>Kozloduy-5</td><td>VVER-1000</td><td rowspan="2">Contract until 2025, terminated early, last fuel load for Unit 6 in autumn 2024</td><td>- 10-year supply contract (December 2022)
- First load: May 2024</td><td>-</td></tr>
<tr><td>Kozloduy-6</td><td>VVER-1000</td><td>-</td><td>10-year supply contract 2025–2034 (December 2022)</td></tr>
<tr><td rowspan="2">Czech Republic</td><td rowspan="2">40%</td><td>Dukovany-1–4</td><td>VVER-440</td><td>- Fuel reload in October 2023 at Dukovany-4
- Fuel reserve until approx. 2026</td><td>7-year supply contract starting 2024 (April 2023)</td><td>Ongoing negotiations as of January 2024; No contract as of July 2024</td></tr>
<tr><td>Temelín-1 & -2</td><td>VVER-1000</td><td>- Supply since 2010
- Contract until 2023
- Fuel reload completed in June 2024</td><td>- Supply 2000–2010
- 6 lead test assemblies loaded in 2019
- 10+-year contract, supply starting 2024 (June 2022)</td><td>10+-year contract, supply starting 2024 (June 2022)</td></tr>
<tr><td rowspan="2">Finland</td><td rowspan="2">42%</td><td>Loviisa-1</td><td>VVER-440</td><td>Contract until end 2027</td><td rowspan="2">- Supply 2001–2007
- Supply contract (November 2022)
- Lead test assembly loaded: 2023</td><td rowspan="2"></td></tr>
<tr><td>Loviisa-2</td><td>VVER-440</td><td>Contract until end 2030</td></tr>
<tr><td>Hungary</td><td>48.8%</td><td>Paks-1–4</td><td>VVER-440</td><td>- “Lifetime” supply contract
- Fuel reserve until 2026</td><td></td><td>MoU, incl. fuel supply (September 2023)</td></tr>
<tr><td rowspan="2">Slovakia</td><td rowspan="2">61.3%</td><td>Bohunice-3 & -4</td><td>VVER-440</td><td rowspan="2">- Supply contract 2022–2026, with option until 2030 (June 2019)
- Fuel reserve until 2026–2027</td><td rowspan="2">Supply contract (August 2023)</td><td rowspan="2">MoU, incl. fuel supply (May 2023)</td></tr>
<tr><td>Mochovce-1–3</td><td>VVER-440</td></tr>
<tr><td rowspan="5">Ukraine</td><td rowspan="5">55% (2021)</td><td>Rivne-1 & -2</td><td>VVER-440</td><td rowspan="5">Supply contract for 8 reactors 2021–2025 (December 2018)</td><td rowspan="5">- Since 2010, fuel supplied to 6 VVER-1000
- Full load to South Ukraine-3 in July 2018
- Supply contract for all Ukrainian reactors (June 2022)
- First load Rivne: September 2023
- First load Khmelnistkyi: March 2024</td><td rowspan="5"></td></tr>
<tr><td>Khmelnytskyi-1 & -2</td><td>VVER-1000</td></tr>
<tr><td>Rivne-3 & -4</td><td>VVER-1000</td></tr>
<tr><td>South Ukraine-1–3</td><td>VVER-1000</td></tr>
<tr><td>Zaporizhzhia-1–6</td><td>VVER-1000</td></tr>
</table>

Sources: Various, compiled by WNISR, all available in Annex 2

1529 - Westinghouse, “Westinghouse Delivers First VVER-440 Fuel Assemblies to Energoatom”, Press Release, Westinghouse Electric Company, 12 September 2023, see https://info.westinghousenuclear.com/news/westinghouse-delivers-first-vver-440-fuel-assemblies-to-energoatom, accessed 17 November 2023.

All of the countries dependent on VVER fuel also have particularly high shares of nuclear power in their respective electricity mixes, ranging from 40 percent to over 60 percent (see Table 15). From the start of their reactors' operations, these countries have almost exclusively received fuel assemblies from TVEL, a 100-percent subsidiary of Rosatom. Table 15 provides an overview of publicly available information on fuel supply agreements for the VVERs in the E.U. The reinforced attempts to diversify fuel supply and phase out deliveries from Russia, following its February 2022 invasion of Ukraine, are described in more detail in the respective sections covering these countries.

WESTINGHOUSE

Under a contract signed in 1993, Westinghouse started manufacturing VVER-1000 fuel assemblies in 1998 and supplied Czech reactors at Temelín in their first decade of operations, starting in 2000.[1530] But in 2010 the operators switched to Russian supplier TVEL,[1531] which was already supplying the four VVER reactors at Dukovany. There had been significant technical difficulties with Westinghouse's VVER-1000 fuel that, although reportedly solved by the end of the contract period, might have influenced the decision to turn to TVEL.[1532] It was also claimed that "Westinghouse was effectively priced out of the market via aggressive enriched uranium product and fuel assembly offerings from TVEL, first in Finland and then in Slovakia."[1533] Westinghouse remained in the field and in 2019 supplied six Lead Test Assemblies (LTA) that were loaded into Temelín-1.[1534]

In 2001, Westinghouse initiated a different VVER-1000 fuel design for delivery to Ukraine. In contrast to the fuel for Temelín, mixed core conditions had to be considered where fuel assemblies from different suppliers were involved. This represented additional challenges since "compatibility data on the resident fuel was not easily accessible to Westinghouse."[1535] LTAs were loaded in 2005 at South Ukraine-3 and discharged in 2010 after completing four cycles of operation. Subsequently, fuel assemblies were loaded into South Ukraine-2 and -3 which, however, showed mechanical problems.[1536]

Westinghouse progressively improved the design of the VVER-1000 fuel assemblies and, since 2015, their use was gradually extended in Ukraine. As of July 2021, six of Ukraine's fifteen reactors were operating using Westinghouse fuel: South Ukraine-2 and -3 and four units at

1530 - Jan Höglund and Ulf Benjaminsson, "New fuel for Temelín 1", Technical Lead for Fuel Engineering, and Fuel Marketing Manager, Westinghouse, published in *NEI Magazine*, 3 October 2019, see https://www.neimagazine.com/analysis/new-fuel-temelin-1-7436970/, accessed 29 June 2024.

1531 - *NEI Magazine*, "TVEL to supply fuel for Temelin", 22 July 2010, see https://www.neimagazine.com/news/newstvel-to-supply-fuel-for-temelin, accessed 2 August 2023.

1532 - Ernst and Lukáš Milisdörfer, "10 years of experience with Westinghouse fuel at NPP Temelín", ČEZ, November 2010, op. cit.

1533 - Grace Symes, "Fuel Fabrication: Westinghouse's Inroads Into EU VVER-440 Fuel Supply", *Energy Intelligence*, 27 January 2023, see https://www.energyintel.com/00000185-e477-dd05-a5b5-ef7f33700000, accessed 3 June 2024.

1534 - Jan Höglund and Ulf Benjaminsson, "New fuel for Temelín 1", Westinghouse, *NEI Magazine*, 3 October 2019, op. cit.; and *WNN*, "ČEZ set to test Westinghouse fuel at Temelín", 5 April 2019, see https://world-nuclear-news.org/Articles/CEZ-set-to-test-Westinghouse-fuel-at-Temelin, accessed 2 August 2023.

1535 - Mark Dye, Jan Höglund, and Ulf Benjaminsson, "Diversification of the VVER fuel market", Westinghouse, published by *Nuclear Engineering International*, 30 September 2015, see https://www.neimagazine.com/analysis/diversification-of-the-vver-fuel-market-4682502/, accessed 29 June 2024.

1536 - Ibidem.

Zaporizhzhia.[1537] In March 2024, a first batch of VVER-1000 fuel assemblies were delivered to the Khmelnytskyi plant (see Annex 2).

Regarding fuel assemblies for VVER-440 reactors, in 1998, British Nuclear Fuels Limited (BNFL) delivered LTAs to Unit 2 at Finland's Loviisa plant. In December 1999, BNFL—which acquired Westinghouse the same year—was awarded a contract to supply reload deliveries to Loviisa, and a total of seven reload batches were delivered between 2001 and 2007. These batches were manufactured by ENUSA in Spain. Since no new contract was awarded after 2007, reportedly due to "much better" offerings from TVEL,[1538] Westinghouse decided to exit the business of VVER-440 fuel assemblies.[1539]

However, after Russia's annexation of Crimea and a renewed interest in fuel supply diversification, Euratom supported a project from 2015 to 2017 in which Westinghouse Electric Sweden AB, eight partners from the E.U. (including then-member U.K.), and Ukraine worked on methods required to license a VVER-440 fuel design and to improve the Loviisa design.[1540] In September 2020, Westinghouse signed a contract to deliver VVER-440 fuel assemblies to the Rivne plant and delivered the first load in September 2023.[1541] This was achieved with strong support from Ukraine which "sent a big group of [their] engineers to work with Westinghouse in Sweden."[1542] In June 2022, Westinghouse was contracted to supply fuel to all Ukrainian reactors.[1543]

In January 2023, a further Euratom funded project named APIS (Accelerated Program for Implementation of secure VVER fuel Supply) started. It is coordinated by Westinghouse and involves partners mainly from all E.U. countries operating VVER-reactors and Ukraine (see Table 15). The project runs until 2025, and its targets include completion of the VVER-440 fuel design for short term delivery, development of improved and advanced VVER-440 and VVER-1000 fuel designs, standardization of fuel licensing, and re-instatement of fuel manufacturing capabilities.[1544]

1537 - WNA, "Nuclear Power in Ukraine", Updated 25 March 2024, op. cit.

1538 - Grace Symes, "Fuel Fabrication: Westinghouse's Inroads Into EU VVER-440 Fuel Supply", *Energy Intelligence*, 27 January 2023, op. cit.

1539 - *NEI Magazine*, "Diversification of the VVER fuel market", 30 September 2015, see https://www.neimagazine.com/analysis/diversification-of-the-vver-fuel-market-4682502/, accessed 29 June 2024.

1540 - European Commission, "ESSANUF—European Supply of SAfe NUclear Fuel", Updated 8 August 2022, see https://cordis.europa.eu/project/id/671546?isPreviewer=1; and Westinghouse, "Westinghouse-led Consortium Prepared to Supply Fuel to VVER-440 Reactors in Europe", Press Release, 12 March 2018, see https://info.westinghousenuclear.com/news/westinghouse-led-consortium-prepared-to-supply-fuel-to-vver-440-reactors-in-europe; both accessed 9 July 2024.

1541 - Westinghouse, "Westinghouse Delivers First VVER-440 Fuel Assemblies to Energoatom", Press Release, 12 September 2023, op. cit.; and Westinghouse, "Westinghouse-Energoatom Contract Signals Full Diversification for Ukraine's Nuclear Fuel Supply", Press Release, 30 September 2020, op. cit.

1542 - Jonathan Tirone and Petra Sorge, "Putin's French Venture Shows Russian Atomic Power Still Growing", *Bloomberg*, 16 March 2024, see https://www.bloomberg.com/news/articles/2024-03-16/putin-s-french-venture-shows-russian-atomic-power-still-growing, accessed 20 July 2024.

1543 - Westinghouse, "Energoatom and Westinghouse Reaffirm Clean Energy Partnership, Announce Expanded Cooperation on Westinghouse-supplied VVER Fuel and AP1000® Plants to be Built in Ukraine", Press Release, 3 June 2022, see https://info.westinghousenuclear.com/news/energoatom-and-westinghouse-reaffirm-clean-energy-partnership, accessed 9 July 2024.

1544 - APIS, "Accelerated Program for Implementation of secure VVER fuel Supply—Home", Accelerated Program for Implementation of secure VVER fuel Supply, 2024, see https://apis-project.eu/, accessed 31 May 2024.

FRAMATOME AND THE LINGEN VVER FUEL MANUFACTURING PLANT PROJECT

In contrast to Westinghouse which has developed and manufactured fuel assemblies for VVER-type reactors at least since 1998, Framatome has been completely absent from this market. However, on 2 December 2021, twelve weeks before Russia invaded Ukraine, Framatome announced that it had signed a long-term strategic agreement with Rosatom aimed at "further expanding the companies' efforts to develop fuel fabrication and instrumentation and control (I&C) technologies."[1545] At that time, little was known about the joint "efforts to develop fuel fabrication" referred to. But on 24 February 2022, the day Russia attacked Ukraine, the German Federal Minister of Economics, Robert Habeck, announced that a request for an "investment approval" had been withdrawn, concerning a joint venture between Advanced Nuclear Fuels (ANF), a Framatome subsidiary in Lingen, Germany, and TVEL, a Rosatom subsidiary.[1546]

This cooperation had been long in the making. At the end of 2019, the company "Framatome Newco SASU" was registered in Lyon (France) and later renamed "European Hexagonal Fuel SAS" in 2023.[1547] According to documents in the commercial register of Lyon, the only shareholders are Framatome and JSC TVEL, with TVEL holding a 25 percent share in the €8 million (US$8.7 million) capital investment. The company's first stated purpose is the "supply of nuclear fuel elements and nuclear fuel element manufacturing services for use in Russian-made VVER reactors." These documents also refer to the "Joint Venture Agreement dated August 24, 2022".[1548] Meanwhile, in Germany, Framatome and TVEL requested approval for a joint venture from the German Federal Cartel Office in February 2021,[1549] and subsequently the 100-percent Framatome subsidiary "European Hexagonal Fuel Vermögensverwaltungs GmbH", originally founded at the end of 2020, was registered in April 2021 at the same address as ANF in Lingen.[1550]

On 10 March 2022, ANF sent a new approval request to the Lower Saxony Government, the local licensing authority. Instead of a joint venture, the license application requested modifications of the present facilities to enable the manufacturing of VVER fuel assemblies under license, and it refers to the role of the French "European Hexagonal Fuel SAS" as

1545 - Framatome, "Framatome and Rosatom sign long-term cooperation agreement", Press Release, 2 December 2021, see https://www.framatome.com/medias/download/?id=6545&n=Framatome-Rosatom-sign-cooperation-agreement-pdf, accessed 9 July 2024.

1546 - Stefan Schultz, "Lingen: Einstieg von Rosatom in deutsche Atomfabrik vorerst geplatzt", *Der Spiegel*, 24 February 2022 (in German), see https://www.spiegel.de/wirtschaft/unternehmen/lingen-einstieg-von-rosatom-in-deutsche-atomfabrik-vorerst-geplatzt-a-f355e411-7635-4a44-8d4f-c9c9061888fb, accessed 3 May 2024.

1547 - Le Figaro Emploi, "European Hexagonal Fuel SAS (69007) : siret, siren, TVA, bilan gratuit…", Registered 11 December 2019, Updated 9 May 2023 (in French), see https://entreprises.lefigaro.fr/framatome-newco-92/entreprise-880033311, accessed 30 June 2024.

1548 - Registre du Commerce et des Sociétés, "European Hexagonal Fuel SAS", A2023/016206, filed 27 April 2023, Tribunal de commerce de Lyon.

1549 - *dpa*, "Atomfabrik: Französisch-russisches Gemeinschaftsunternehmen", as published in *Süddeutsche Zeitung*, 26 February 2021 (in German), see https://www.sueddeutsche.de/wirtschaft/berlin-atomfabrik-franzoesisch-russisches-gemeinschaftsunternehmen-dpa.urn-newsml-dpa-com-20090101-210226-99-604609, accessed 30 June 2024.

1550 - Northdata, "European Hexagonal Fuel Vermögensverwaltungs GmbH, Lingen", Undated, see https://www.northdata.de/European+Hexagonal+Fuel+Verm%C3%B6gensverwaltungs+GmbH,+Lingen/Amtsgericht+Osnabr%C3%BCck+HRB+216003, accessed 30 June 2024.

"processing of the manufacturing under license" (Abwicklung der Lizenzfertigung).[1551] The Lower Saxony Environment Ministry in charge, headed by a Green Party Minister, is opposed to the project,[1552] but can only examine the application based on his mandate under Federal Atomic Law and does not have a veto right. It is up to the federal government to approve or block the initiative. Furthermore, according to knowledgeable sources, the Chancellery does not wish to put what neighboring France would see as a stumbling block in an area of low strategic significance.

Following the Atomic Law, ANF's application was subject to a public inquiry from 4 January to 3 March 2024[1553] resulting in more than 11,000 comments to be considered by the Lower Saxony Government.[1554] In June 2023, a legal expertise commissioned by the Federal Ministry of the Environment concluded, amongst other things, that clarification was needed on whether TVEL employees will have access to the ANF factory in Lingen, what their role would be, and whether security and reliability checks of such persons can be an effective means "to exclude an endangerment of the inner and outer security of the Federal Republic of Germany."[1555] A counter-expertise commissioned by ANF, however, denies the veto right of the federal government ("Versagungsermessen")[1556] that had been confirmed in the legal expertise. As of mid-2024, no decision had been issued by the Lower Saxony Government.

ANF nevertheless started preparations for manufacturing VVER fuel assemblies in Lingen. In May 2024, ANF confirmed that production machinery had been set up at a separate facility outside the Lingen factory, and that it had been tested in April 2024. While preparations inside the factory would have been illegal due to the still outstanding approval, the legality of preparations outside the factory has also been questioned.[1557] ANF did not confirm the presence of TVEL experts—most certainly required for such activities—which had been reported by local anti-nuclear activists. In late June 2024, they revealed the location, a former furniture storage facility outside the Lingen factory, where the production machinery had been set up.[1558]

1551 - Ministry for the Environment, Energy and Climate Protection, "Sachstandsinformation Brennelementfertigungsanlage (BFL), Lingen/Ems", Government of Lower Saxony, Updated 3 January 2024, see https://www.umwelt.niedersachsen.de/brennelementfertigungsanlage_lingen/sachstandsinformation-bfl-8451.html, accessed 27 April 2024.

1552 - Andrea Rehmsmeier, "Im Kern russisch - So abhängig ist Europas Nuklearindustrie von Russland", Radio show (in German), *Deutschlandfunk*, 17 March 2023, see https://www.deutschlandfunk.de/im-kern-russisch-europas-nuklearindustrie-und-die-abhaengigkeit-von-russland-dlf-1855dd23-100.htmlhttps://www.deutschlandfunk.de/im-kern-russisch-europas-nuklearindustrie-und-die-abhaengigkeit-von-russland-dlf-1855dd23-100.html, accessed 12 August 2023.

1553 - Ministry for the Environment, Energy and Climate Protection of Lower Saxony, "Sachstandsinformation Brennelementfertigungsanlage (BFL), Lingen/Ems", Updated 3 January 2024, op. cit.

1554 - Reimar Paul, "Einstieg bei Nuklearfabrik im Emsland: Russen könnten „Fakten schaffen"", *Die Tageszeitung: taz*, 2 May 2024 (in German), see https://taz.de/!6004558/, accessed 4 May 2024.

1555 - Gerhard Roller, "Berücksichtigung der Belange der inneren und äußeren Sicherheit der Bundesrepublik Deutschland im Rahmen des Versagungsermessens nach § 7 Abs. 2 AtG—Untersuchung anlässlich des Änderungsgenehmigungsverfahrens der Brennelementefertigungsanlage Lingen", commissioned by Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutzfiled/Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, Federal Government of Germany, 23 March 2023, filed June 2023 (in German), see https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/gutachten_brennelemente_lingen_bf.pdf, accessed 1 July 2024.

1556 - *dts-Nachrichtenagentur*, "Ein neues Gutachten kommt zu dem Schluss, dass das niedersächsische Umweltministerium die geplante", as published by *Ad Hoc News* (in German), 29 June 2024, see https://www.ad-hoc-news.de/politik/ein-neues-gutachten-kommt-zu-dem-schluss-dass-das-niedersaechsische/65388540, accessed 29 June 2024.

1557 - Claus Hecking, "Russische Atomtechniker bereiten Testanlage im Emsland vor", *Der Spiegel*, 9 May 2024 (in German), see https://www.spiegel.de/wissenschaft/rosatom-russische-atomtechniker-bereiten-testanlage-im-emsland-vor-a-b0742276-a5a3-4da2-9130-434cbcbefc1c, accessed 10 May 2024.

1558 - Reimar Paul, "Russische Atomkraft in Niedersachsen: Atom-Anlage in Möbelhaus versteckt?" *taz*, 27 June 2024 (in German), see https://taz.de/!6020171/, accessed 27 June 2024.

On the other hand, apparently in response to the legal expertise mentioned above, ANF stated that after governmental approval and installation of the production machinery in the Lingen factory, "there will be no employees of TVEL/Rosatom on our premises in Lingen."[1559] However, TVEL shall not only provide production machinery but also be involved in quality control. This seems inevitable given the high standards and regulations to be fulfilled for any nuclear fuel production. ANF will therefore have to explain how VVER manufacturing would be possible without the presence of TVEL experts on the premises in Lingen.

Even before the August 2022 joint venture agreement with TVEL, Framatome was awarded a supply contract for the Temelín reactors by Czech operator ČEZ in April 2022, which was signed in June 2022.[1560] However, in January 2024, the Czech economic daily *Ekonomický deník* described the fact that fuel assemblies will be manufactured by Framatome under license from TVEL as "surprising information" and called the replacement of Russian nuclear fuel in the Czech reactors "somewhat half-hearted."[1561] Subsequently to the Temelín case, Framatome signed a contract to supply fuel for Bulgaria's Kozloduy-6 reactor and preliminary agreements pertaining to several nuclear plants in Hungary and Slovakia. Negotiations on a potential contract with the Czech clients were apparently still underway as of mid-2024.

The Czech journal's assessment of Czech fuel supply diversification as "somewhat half-hearted" is shared by the U.K. think tank RUSI which comes to the conclusion that, "should fuel fabrication for VVER reactors take place at the Lingen facility with the use of Rosatom-supplied enriched uranium and in collaboration with Rosatom, this could hardly be considered successful diversification away from Russia for Framatome's VVER fuel customers."[1562]

This apparent lack or delay of 'real' diversification away from Russia raises the broader question why Framatome chose TVEL as a partner for its entry into the VVER fuel market, and why it stuck to this decision even after February 2022, particularly given Rosatom's proactive role in the Ukraine war.[1563] Alternatively, Framatome could have licensed technology from Westinghouse which has developed and delivered VVER fuel assemblies for two decades. Framatome argues that its (future) fuel production in Lingen "does not require any modification to the reactor or licensing processes and contributes to a stock of European components from the licensed and qualified design."[1564] But this argument appears weak as Westinghouse is already delivering fuel assemblies or is in the process of licensing them through the APIS project mentioned above. It is unknown if Framatome had attempted obtaining a license for the Westinghouse technology

1559 - Claus Hecking, "Russische Atomtechniker bereiten Testanlage im Emsland vor", *Der Spiegel*, 9 May 2024, op. cit.

1560 - CEZ Group, "Americans and French will supply nuclear fuel to Temelín", 12 April 2022, see https://www.cez.cz/en/media/press-releases/americans-and-french-will-supply-nuclear-fuel-to-temelin-157447; and CEZ Group, "We are strengthening the energy security of the Czech Republic: we have signed contracts for the supply of fuel assemblies with Westinghouse and Framatome", 28 June 2022, op. cit.

1561 - *Ekonomický deník*, "Polovičatá náhrada ruského paliva v Temelíně. Framatome dodá palivové soubory v ruské licenci", 4 January 2024, op. cit.

1562 - Darya Dolzikova, "Power Plays: Developments in Russian Enriched Uranium Trade", RUSI, March 2024, op. cit.

1563 - Ibidem; and Charles Digges, "Rosatom's role in the war in Ukraine", 2023, see https://network.bellona.org/content/uploads/sites/3/2023/06/Rosatom-working-paper-cover-727x1024.png; also Shaun Burnie and Jan Vande Putte, "Russia's Atomic Partners: Framatome, Siemens Energy and Rosatom", Greenpeace, July 2023, see https://www.greenpeace.de/publikationen/Rosatom_Report_G.pdf, accessed 16 April 2024.

1564 - Framatome, "Framatome signs Memorandum of Understanding with Slovenské elektrárne to extend long-term partnership", Press Release, 31 May 2023, see https://www.framatome.com/medias/framatome-signs-memorandum-of-understanding-with-slovenske-elektrarne-to-extend-long-term-partnership/, accessed 9 July 2024.

and whether this had been declined by Westinghouse, and neither company responded to corresponding requests by WNISR.[1565]

Assuming that cooperation with Westinghouse was not an option, Framatome needed Rosatom to enter the market for VVER fuel in a timely manner. In particular since the Ukraine war started, Framatome, without a short-term solution, would have been overtaken by Westinghouse until having developed its own fuel, which is likely to only be after 2030.

A further question arises why TVEL entered into the joint venture even *before* the Ukraine war because it effectively meant losing market share and revenues. Some hints might be contained in the overall strategic cooperation agreement signed between Framatome and Rosatom in December 2021 which aims, amongst others, "to develop fuel fabrication and instrumentation and control (I&C) technologies."[1566] Thus, the cooperation between Rosatom and Framatome covers far more than fuel manufacturing. Possibly in return for sacrificing market shares in VVER fuel manufacturing, Rosatom gained further access to Framatome's I&C technology, while Framatome could enter the VVER fuel market and extend its business with I&C technology. This may also partially answer the earlier question as to why Framatome stood by its decision to undertake a joint venture with TVEL even after February 2022: strong mutual business interests between Framatome and Rosatom.

In parallel, Framatome has been progressing on its own VVER fuel design since 2018. Framatome hopes to begin fabricating the first lead test assemblies in 2026 and load those assemblies in 2028, likely in one of the Czech Temelín reactors. Following three test irradiation cycles, the technology could be available in the early 2030s, according to the head of Fuel Business at Framatome.[1567]

In addition, in June 2024, the European Commission announced the start of a Euratom project SAVE (Safe and Alternative VVER European Project). Led by Framatome, it gathers seventeen partners from seven E.U. Member States as well as Ukraine. Finland and Ukraine, both involved in the project, do not currently have supply agreements with Framatome. The goal of the project is to "strengthen VVER fuel security of supply in Europe and Ukraine by qualifying a reliable and safer sovereign VVER-440 fuel design, by developing a fast-track licensing path and improving European capabilities for VVER-440 fuel design qualification".[1568]

1565 - Westinghouse's Laurent Vansoen, Head of Government Affairs & Public Policies Europe, responded to a series of questions in a single sentence, "we will not follow up" ("nous ne donnerons pas suite") in a personal message on LinkedIn, dated 10 June 2024. Framatome did not reply at all to a similar list of questions.

1566 - Framatome, "Framatome and Rosatom sign long-term cooperation agreement", Press Release, 2 December 2021, op. cit.

1567 - Grace Symes, "Fuel Fabrication: Framatome Awaiting German Authorization to Produce VVER Fuel", *Energy Intelligence*, 1 March 2024, see https://www.energyintel.com/0000018d-f0dd-d9ab-adff-f2fd0d950000, accessed 31 May 2024.

1568 - European Commission, "A new Euratom project will help diversify nuclear fuel supply", 20 June 2024, see https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/new-euratom-project-will-help-diversify-nuclear-fuel-supply-2024-06-20_en, accessed 22 June 2024. European Commission, "Safe and Alternative VVER European Fuel", Updated 21 June 2024, see https://cordis.europa.eu/project/id/101114771, accessed 9 July 2024.

RUSSIA'S DEPENDENCIES AND POTENTIAL FURTHER SANCTIONS

The business relations between Framatome and Rosatom concerning fuel fabrication and Instrumentation & Control (I&C) technology create a mutual dependency, including a significant dependence of Russia on the West which may be relevant when further sanctions are considered. I&C technology is "the brain and central nervous system" of a power plant,[1569] and for a decade Russia has received from Framatome, and its partner Siemens, I&C technology involving the different phases of construction, modernization, and servicing which last long into the future even without new contracts. The most recent one is a reactor protection system due to be fully installed at the Kursk II nuclear power plant by the end of 2025.[1570] Siemens, in cooperation with Framatome, has contracted I&C equipment to Rosatom for the four reactors at the Akkuyu site in Türkiye (under construction) and for the Paks II project in Hungary (in advanced planning) as well as a range of other Russian reactor projects around the world, including in Russia itself.[1571] Siemens Energy—which was spun off from Siemens in April 2020—denied "lucrative contracts" and claimed their turnover with Rosatom in 2022 would have been "in the one-digit million range".[1572]

Framatome's business relations with Rosatom are not restricted to nuclear fuel and I&C technology. They also comprise Arabelle turbines which have a "heavy order book with Rosatom" through a joint venture with Rosatom to supply turbine islands for ten Rosatom VVER-1200 exports—four at Akkuyu in Türkiye, two at Paks II in Hungary, and four at El-Dabaa in Egypt.[1573] The Arabelle turbine business was recently acquired by EDF from General Electric.

In summary, the operations of Russian nuclear power plants which have been built with Western I&C technology are heavily dependent on modernization and servicing by the companies which supplied them, Framatome and Siemens. The same applies to nuclear power plants under construction by Rosatom for which Arabelle turbines and I&C technology are to be supplied. In theory, this situation would provide a significant leverage for sanctions. On the other hand, such a dependency not only concerns France, Germany, and Russia but also Hungary and Türkiye regarding nuclear newbuild as well as current operators of VVER reactors in the E.U. that depend on services, including modernization, from Russia.[1574]

The present operation of Russian-designed reactors in Ukraine seems to demonstrate that it is nevertheless possible to do without Russia because it is unlikely that Russia has provided any support to Ukraine's reactors since February 2022.

1569 - Framatome, "Instrumentation & Control: the brain and central nervous system of the plant", Undated, see https://www.framatome.com/en/expertise/instrumentation-and-control/, accessed 6 July 2024.

1570 - Greenpeace, "Russia's Atomic Partners: Framatome, Siemens Energy and Rosatom", July 2023, op. cit.

1571 - *NEI Magazine*, "Hungary expects France and Germany to supply I&C equipment for Paks II", 14 October 2022, see https://www.neimagazine.com/news/newshungary-expects-france-and-germany-to-supply-ic-equipment-for-paks-ii-10086599; and Greenpeace, "Russia's Atomic Partners: Framatome, Siemens Energy and Rosatom", July 2023, op. cit.

1572 - Marc Dimpfel, "Siemens Energy bleibt Russlands Atomkonzern treu", *n-tv.de*, 22 July 2023 (in German), see https://www.n-tv.de/wirtschaft/Siemens-Energy-bleibt-Russlands-Atomkonzern-treu-article24277291.html, accessed 7 July 2024.

1573 - Grace Symes, "France: Nuclear Industry Retains Ties With Rosatom", *Energy Intelligence*, 1 March 2024, op. cit.

1574 - *NEI Magazine*, "Bulgaria to continue imports from Russia for Kozloduy NPP", 24 March 2023, see https://www.neimagazine.com/news/newsbulgaria-to-continue-imports-from-russia-for-kozloduy-npp-10701347, accessed 27 March 2023.

Russia has also developed into a major hub for nuclear education. In a recent official statement, Russia's Ministry of Foreign Affairs claimed: "We actively participate in the training and retraining of personnel for the nuclear power industry. Over 2,000 students from 65 countries study at Russian universities specializing in nuclear and related disciplines."[1575]

Russia turned into the dominant supplier of reactor technology in the world. In fact, except for projects in China, Russian industry implemented all 13 construction starts in the world since 2019, when construction officially began at the U.K.'s Hinkley Point C Unit 2, and up to mid-2024 (see Overview of Current Newbuild). These included newbuilds in newcomer countries like Egypt and Türkiye with a large demand in training and skills acquisition.

As there are few other clients, component suppliers also largely depend on Russian projects. Examples of this co-dependency include the Arabelle turbine manufacturer in France. The company, formerly known as GEAST (for GE-Alstom), was acquired by EDF from GE,[1576] after a lengthy process of over two years.[1577] Renamed as Arabelle Solutions, it produces turbines for nuclear power plants and is highly dependent on the niche market virtually entirely controlled by the Russian nuclear industry over the past four and a half years. Reportedly, Rosatom represented about half of the Arabelle manufacturer's turnover as of 2022.[1578] It was therefore no surprise that, just prior to Russia's invasion of Ukraine, the French Government had offered to sell Rosatom a 20-percent share in the company.[1579]

As previously mentioned, the German electronics giant Siemens, in cooperation with Framatome, has contracted I&C equipment to Rosatom for projects in Türkiye and Hungary as well as a range of other Russian reactor projects around the world, including in Russia itself.[1580] In the case of the Turkish project, apparently, the German authorities have not yet issued any export license for the items in question and it remains unclear whether Rosatom will need to do entirely without Siemens.

1575 - Ministry of Foreign Affairs, "Statement by the Head of the Delegation of the Russian Federation at the First Session of the Preparatory Committee for the 11th Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (General debate)", Government of the Russian Federation, 1 August 2023, see https://mid.ru/en/foreign_policy/news/1899782/, accessed 11 August 2023.

1576 - EDF, "EDF acquires GE Steam Power's nuclear activities from GE Vernova", Press Release, 31 May 2024, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/edf-acquires-ge-steam-powers-nuclear-activities-from-ge-vernova, accessed 9 July 2024.

1577 - EDF, "EDF Signs an Exclusive Agreement to Acquire Part of GE Steam Power's Nuclear Activities", Press Release, 10 February 2022, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/edf-signs-an-exclusive-agreement-to-acquire-part-of-ge-steam-power-s-nuclear-activities; and Marc Endeweld, "EXCLUSIF. EDF s'apprête à racheter les activités nucléaires de GE", *La Tribune*, 27 August 2021, see https://www.latribune.fr/entreprises-finance/industrie/energie-environnement/exclusif-edf-s-apprete-a-racheter-les-activites-nucleaires-de-ge-891258.html; both accessed 9 July 2024.

1578 - *La Tribune*, "Nucléaire : pourquoi le géant russe Rosatom pourrait prendre 20% des turbines Arabelle", 9 March 2022 (in French), see https://www.latribune.fr/entreprises-finance/industrie/energie-environnement/nucleaire-pourquoi-le-geant-russe-rosatom-pourrait-prendre-20-des-turbines-arabelle-905779.html, accessed 9 July 2024.

1579 - Guillaume Guichard, "Nucléaire: l'État prêt à céder 20% d'Arabelle au russe Rosatom", *Le Figaro*, 8 March 2022.

1580 - *NEI Magazine*, "Hungary expects France and Germany to supply I&C equipment for Paks II", 14 October 2022, see https://www.neimagazine.com/news/newshungary-expects-france-and-germany-to-supply-ic-equipment-for-paks-ii-10086599, accessed 2 September 2023; and Rosatom, "RASU JSC and Framatome-Siemens consortium sign contract to supply automated process control systems for Paks-2 NPP (Hungary)", 22 October 2019, see https://www.rusatom-energy.ru/en/media/rosatom-news/rasu-jsc-and-framatome-siemens-consortium-sign-contract-to-supply-automated-process-control-systems-/https://www.rusatom-energy.ru/en/media/rosatom-news/rasu-jsc-and-framatome-siemens-consortium-sign-contract-to-supply-automated-process-control-systems-/, accessed 9 July 2024; also Greenpeace, "Russia's Atomic Partners: Framatome, Siemens Energy and Rosatom", July 2023, op. cit.

CIVIL-MILITARY CROSS-FINANCING IN THE U.K. NUCLEAR SECTOR[1581]

This chapter follows up directly on work discussed in WNISR2018 that examined interdependencies between civil and military nuclear infrastructures around the world. As countries withdraw from nuclear power, abstain from renewing their fleets or scale back earlier plans, a striking worldwide pattern of association is emerging between the scales of national commitments to civil nuclear power and intensities of parallel attachments to military nuclear capabilities.

The WNISR2018 chapter explored these circumstantial associations with in-depth analysis of growing evidence from particular countries. It appears clear that across all major nuclear-armed states, 'civil' nuclear policies are increasingly driven by pressures to maintain military nuclear infrastructures. Connections involving shared dependence on fissile materials have long been known and are quite exhaustively explored. The relatively new factor revealed in Stirling and Johnstone's report "Illuminating the 'UK Nuclear Complex': Implications of Hidden Links between Military and Civil Nuclear Activities for Replacing Negative with Positive Irreversibilities around Nuclear Technologies"[1582] is the importance for the civil nuclear industry of pressures to maintain a nuclear industrial base for military purposes. What civil activities help provide for military interests, is a way to subsidize distinctive national nuclear skills, supply chains, design capabilities, manufacturing capacities, educational provision, research facilities, regulatory infrastructures, and career incentives, which would not otherwise be affordable under the supposedly responsible budgets.

Key here is that all military activities, including the development of nuclear weapons and their platforms, fundamentally rely on national industrial ecosystems around nuclear-specific capabilities that are, crucially, maintained by consumer and taxpayer revenues ostensibly dedicated to supporting civil nuclear power. An especially strong dependency of this kind is evident around the production and operation of nuclear propelled submarines. Without massive flows of 'civil' expenditure into this wider 'nuclear complex', it would be impossible to sustain the industry necessary to design, build, maintain, staff, operate, regulate, and decommission these extraordinarily expensive strategic military platforms.

The Stirling and Johnstone report was written for a wider U.K. Government project that openly examined the reversibility of the U.K.'s commitments to questionable security strategies based around nuclear weapons. The government project also explored the more general irreversibility of broader steps towards nuclear disarmament. The Stirling and Johnstone report was discussed, alongside other aspects of the project, at a workshop including senior figures involved

1581 - This chapter summarizes a report for a U.K. Foreign, Commonwealth and Development Office (FCDO) project undertaken by Andy Stirling and Phil Johnstone of the Science Policy Research Unit at the University of Sussex; see Andy Stirling and Phil Johnstone, "Illuminating the 'UK Nuclear Complex': Implications of Hidden Links between Military and Civil Nuclear Activities for Replacing Negative with Positive Irreversibilities around Nuclear Technologies", York IND Research Report #2, University of York, March 2024, see https://www.york.ac.uk/media/politics/documents/yorkindproject/2024%20Report2%20Stirling%20&%20Johnstone%20Civil%20and%20military%20link%20in%20the%20UK%20nuclear%20weapons%20complexx.pdf, accessed 2 July 2024.

1582 - See previous reference.

in steering the U.K. Government policy on military and civil nuclear technologies. The report's basic analysis that large volumes of public resources are being diverted from supposedly civil to what are actually military purposes was neither refuted, nor even substantively disputed at the workshop.

The Stirling and Johnstone report undertook three main tasks. First, it analyzed (as requested by the government project) a range of different theoretical approaches in political science, the history of technology, innovation studies, and sociology concerning how technologies routinely obsolesce and so can become 'reversed' and effectively 'uninvented'. Second, it summarized the history of the development of military and civil nuclear technologies in the U.K. against the backdrop of world events—attending equally to issues unfolding around nuclear weapons, submarine propulsion, and civil nuclear power. Third, it undertook an initial pioneering study of an important feature of the U.K.'s economy that had hitherto been remarkably neglected: the overall flows of money, justification, and other resources that deeply interlink supposedly separate civilian and military nuclear activities.

It is on the basis of these three elements that Stirling and Johnstone's report for the U.K. Government project draws conclusions about questions of reversibility in both civil and military nuclear technologies—as well as on implications for current energy, climate, and security strategies and the U.K.'s economy.

First, the report shows how reversals in commitments to military/civil nuclear technologies have taken place in the past and can be possible in the future.

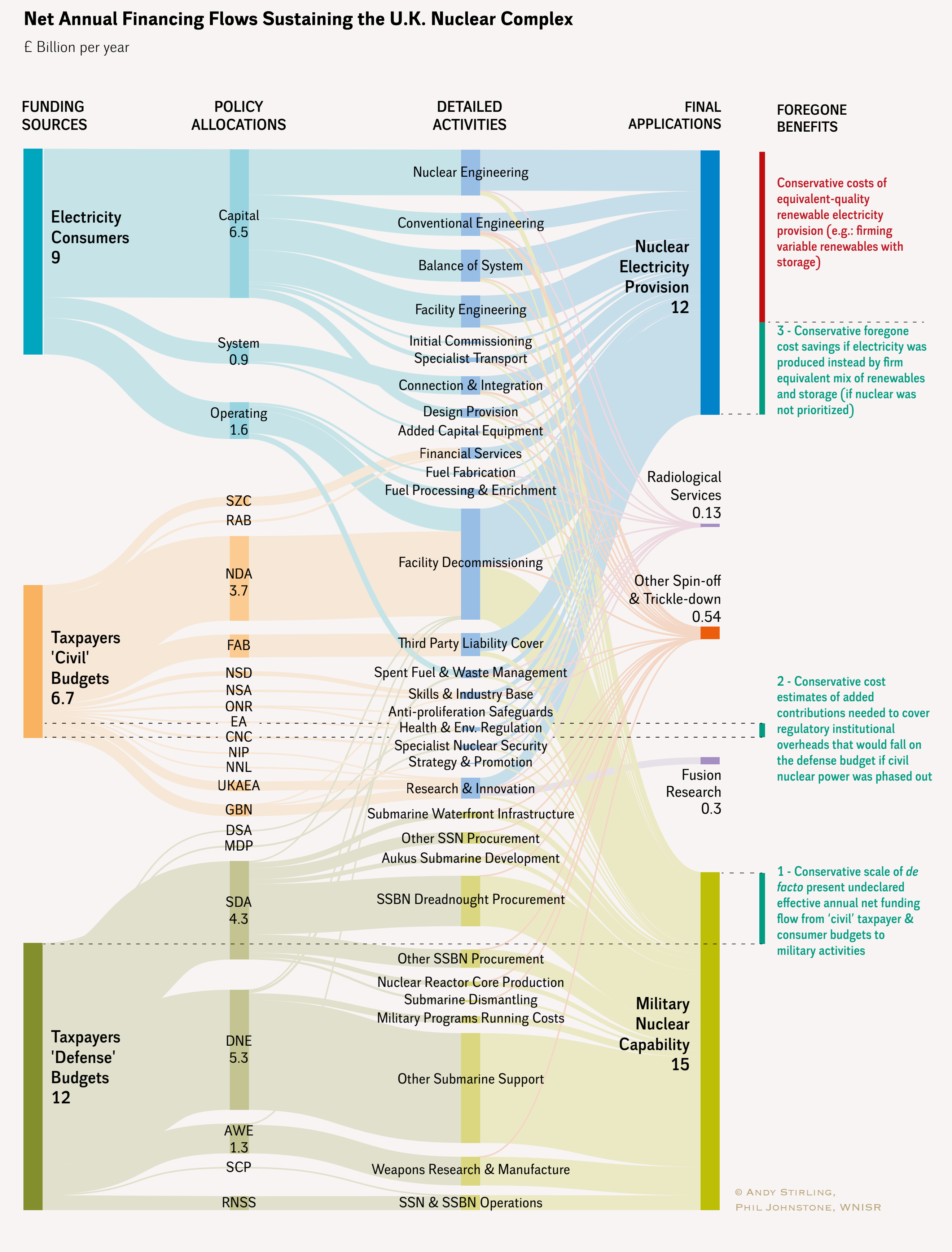
Second, the report documents the deep and intimate interlinkages between civil and military nuclear infrastructures in the U.K., illuminating how these technologies form in this country (and around the world) a single 'nuclear complex'. Dependencies between the two are not just limited to flows of special nuclear materials, but also include the sharing of distinctive skills, supply chains, industrial capabilities, educational provision, research facilities, regulatory capacities, and career incentives. Commitments to supporting these nuclear-specific capabilities hold significant implications—and pose important but under-explored opportunity costs—for the pursuit of alternative energy and security strategies in the U.K.

Third, the report seeks to navigate remarkable levels of official secrecy, obfuscation, and obstruction to provide an initial comprehensive analysis of the flows of money, justification, and cultural attachment that keep the combined civil-military 'U.K. nuclear complex' in operation. In short, even under highly conservative assumptions, hitherto uncounted additional costs to the national economy of maintaining this nuclear complex (rather than adopting alternative security and energy strategies) amount to at least—likely well in excess of—£5 billion (US$6.4 billion) per year. This is well over the annual cost of building the Hinkley Point C nuclear power station over the decade of its construction.

This latter provisional picture of additional costs is summarized in Figure 55. Extra nuclear burdens falling on U.K. electricity consumers and taxpayers arise from:

- requiring electricity consumers to purchase nuclear power rather than pursuing fully alternative zero carbon energy services which offer superior levels of quality at lower costs;
- transferring revenues from supposedly 'civil' taxpayer and consumer budgets to cover costs of military nuclear activities that fall outside existing levels of defense spending;

Figure 55 • Consumer and Taxpayer Financial Flows Towards the U.K. Nuclear Complex



Notes

Indicated funding flows are based where possible on U.K. Government data on expenses that are officially linked to civil and military nuclear activities. Figures are indicative and relate to the ranges and sources given in Annex 3; uncertainty ranges in background data and presentation with two significant figures may lead to rounding errors.

Scales of annual flows assume nuclear contributions to electricity supply at 15 percent (12.5 percent in 2023). Higher contributions would raise annual flows.

Values are expressed in billions of U.K. pounds at 2024 prices.

Notes on Foregone Benefits

The bar between the dotted lines:

- indicates the approximate scale of the difference between revenue flows from taxpayer budgets explicitly labeled as related to 'defense' and the actual real-world overall magnitude of the flow of value from taxpayers and consumers as a whole in support of these military activities.

- shows the rough indicative proportions of taxpayer-funded budgets for combined civil-military nuclear agencies and programs that comprise managerial overheads for these organizations. These also underwrite organizational functions necessary on the military nuclear side, including those dedicated to education, research, regulation, skills, decommissioning, and waste management. It is these costs that would have to fall to national 'defense' budgets if the U.K. civil nuclear program were phased out in favor of alternative low carbon energy options.

- shows how costs of providing renewable electricity at equivalent quality to nuclear output compare with overall costs of nuclear electricity provision in the U.K. using the latest available official data on 'enhanced levelized costs of electricity' from renewables (i.e., including energy storage).[1583]

The red vertical line under 'foregone benefits' shows the costs, according to official sources, of producing as much firm-equivalent power through renewables as is anticipated to be produced in 2024 from nuclear power.

Abbreviations

AWE: Atomic Weapons Establishment
CNC: Civil Nuclear Constabulary
DNE: Other Defence Nuclear Enterprise
DSA: Defence Safety Authority
EA: Environmental Agency
FAB: Nuclear Liabilities Financing Assurance Board
GBN: Great British Nuclear
MDP: Ministry of Defence Police (nuclear)
NDA: Nuclear Decommissioning Authority
NIP: Nuclear Innovation Programme
NNL: National Nuclear Laboratory
NSA: Nuclear Skills Allocations
NSD: Nuclear Sector Deal Policy
ONR: Office of Nuclear Regulation
RAB: Regulated Asset Base policy
RNSS: Royal Navy Submarine Service
SCP: Strategic Command Programmes
SDA: Submarine Delivery Agency
SZC: Sizewell C Ltd.
SSBN: Ballistic Missile Submarine (Ship Submersible Ballistic Nuclear)
SSN: Attack Submarine (Ship Submersible Nuclear)
UKAEA: UK Atomic Energy Authority

→ committing the U.K. to support an expensive array of nuclear-specific policy, regulatory, research and industrial bodies that are unnecessary for non-nuclear strategies, and which can contribute to crowd out more productive jobs and investments in other sectors.

The report concludes that a reversal of commitments to nuclear technologies in the U.K. might be seen as a routine—indeed inevitable—consequence of the jointly emerging obsolescence of nuclear technologies on both the civil and military sides. In both areas, alternative options and emerging challenges are increasingly eclipsing traditional forms of justification for nuclear-based strategies.

While the WNISR2018 chapter demonstrated interdependencies and the presence of a subsidy from civil to military nuclear, the magnitude and details of these revenue flows were unclear. The data and approach utilized to calculate the revenue flows as shown in Figure 55, followed by a summary and explanation of these flows. The overarching question concerns: What is the overall structure and magnitude of the total flow of value—including both state and market resources—across the full range of interlinked activities that sustain the U.K. nuclear complex taken as a whole?

1583 - BEIS, "Contracts for Difference Second Allocation Round Results", Department of Business Energy and Industrial Strategy, 2017; and Lazard, "Lazard's Levelized Cost of Storage Analysis—Version 7.0", 2021; also Lazard, "LCOE+—Lazard's Levelized Cost of Energy Analysis—Version 17.0", 2024.

SUMMARY OF REVENUE FLOWS IN THE U.K. NUCLEAR COMPLEX

Despite the caution built into this analysis, Figure 55 suggests that an initial estimate of the presently concealed *de facto* flow of value from civil allocations to military purposes is, conservatively, at least £2 billion (US$2.5 billion) per year.

In other words—as a separate matter to specific program budgets shown in the flows of Figure 55—this suggests the approximate scale of the administrative overheads for associated organizations and initiatives presently labeled primarily as 'civil' in their responsibilities that would attach to military costs if there were no civil nuclear power. Again, taking a cautious view, the magnitude of this item is estimated here to be roughly of the order of some £0.5 billion (US$0.6 billion) per year.

As the diagram shows, a conservative estimate of foregone benefits of a non-nuclear U.K. energy strategy is more than £3 billion (US$3.8 billion) per year. With the gap growing rapidly between nuclear power costs on the one hand and costs of renewables and short- and long-term energy storage on the other, this estimate becomes increasingly likely to be on the low side as the time horizon extends into the future.

Subject to all the complexities and caveats detailed above, and more as a prompt to further research than definitive findings at this stage, this analysis substantiates a *prima facie* case that the overall excess costs to the U.K. economy, of keeping the national nuclear complex in operation, may be estimated conservatively to be significantly greater than £5 billion (US$6.3 billion) per year.

MILITARIZATION OF CIVIL NUCLEAR REACTORS: TRITIUM FOR NUCLEAR WEAPONS

INTRODUCTION

Modern thermonuclear weapons utilize tritium, a radioactive isotope of hydrogen, to "boost" the nuclear yield of the fission explosive pit, or "primary", that generates the intense energy directed to ignite the fusion "secondary". The radioactive half-life of tritium is 12.3 years, and each year a given quantity of tritium will decrease by 5.5 percent. Thus, to maintain a given stockpile of tritium for weapons, the isotope must be continuously produced to replace the material lost to radioactive decay. Historically, this was done by the United States, France, and other nuclear weapon states by irradiating lithium targets in dedicated military production reactors and chemically processing the targets to extract the tritium.

In the United States, tritium was produced in the government-owned reactors at the Savannah River Site in South Carolina until the last operating reactor was closed in 1988 for safety reasons. Since 2003, the U.S. has been producing tritium for weapons by utilizing the neutrons generated by civil nuclear power plants—specifically, the two Watts Bar reactors in the state of Tennessee.[1584]

In March 2024, the French Government announced that, after the closure of its own tritium production reactors, it was partnering with the utility EDF to produce tritium for its nuclear weapons program at the Civaux dual-reactor nuclear station.[1585]

The program has not been approved yet by the French nuclear safety authorities. EDF is expected to submit a technical dossier in the fall of 2024 with a first test planned for 2025.[1586]

As there is hardly any information available on the French program, this chapter reviews the history of similar U.S. efforts, as well as the optics of using civil nuclear plants for military purposes.

1584 - The U.S. presumably also produced tritium for the United Kingdom's thermonuclear weapon stockpile under the Mutual Defense Agreement between the two countries. However, the U.K. stockpile, and tritium demand, are only a few percent of those of the U.S.

1585 - Ministère des Armées, "Déplacement du ministre des Armées à la centrale EDF de Civaux, le 18 mars 2024", Press Release (in French), Armed Forces Ministry, French Government, 18 March 2024, see https://www.defense.gouv.fr/sites/default/files/ministere-armees/18.03.2024%20D%C3%A9placement%20du%20ministre%20des%20Arm%C3%A9es%20%C3%A0%20la%20centrale%20EDF%20de%20Civaux%2C%20le%2018%20mars%202024.pdf, accessed 27 July 2024.

1586 - *Le Monde*, "L'armée française et EDF vont collaborer pour produire du tritium, indispensable aux armes de dissuasion nucléaire", with *AFP*, 19 March 2024 (in French), see https://www.lemonde.fr/planete/article/2024/03/19/nucleaire-l-armee-francaise-et-edf-vont-collaborer-pour-produire-du-tritium-indispensable-aux-armes-de-dissuasion_6222845_3244.html, accessed 22 August 2024.

TRITIUM DEMAND FOR NUCLEAR WEAPONS

Boosting occurs when a mixture of tritium and deuterium gas injected into the pit is compressed and undergoes fusion reactions, releasing high-energy neutrons that augment the rate of neutron generation within the pit compared to the rate due to fission neutrons alone. This process greatly enhances the efficiency, or fraction of the primary fuel (plutonium and/or highly enriched uranium) that undergoes fission. This allows for a reduction in the mass of the fuel and other primary components (reflector, high explosive) needed to generate a yield high enough (on the order of ten kilotons) to ignite the secondary. Tritium also renders nuclear fission weapons "predetonation-proof," allowing the utilization of fissile materials with higher spontaneous background neutron rates (such as reactor-grade plutonium[1587]) without any reduction in expected yield. Independent estimates of historical tritium requirements for thermonuclear weapons range from two to four grams per warhead on average.[1588] Some weapons (known as "dial-a-yield") can use variable amounts of tritium to adjust their explosive power. However, overall, the tritium demand has increased in recent years for the U.S. stockpile, presumably to increase performance margins.

Following the closure of its last dedicated tritium production reactor in 1988, the U.S. Department of Energy (DOE) sought to reinstate its production capacity by pursuing the development of a dedicated New Production Reactor (NPR). At the time, the option for the DOE to utilize commercial nuclear power reactors to produce tritium, either through leasing irradiation services or buying reactors outright, was thought to possibly violate the prohibition, under the 1954 Atomic Energy Act, on the use of special nuclear material produced in commercial reactors for "nuclear explosive purposes."[1589] In this case, the issue was tritium generation by neutrons released by the fission of plutonium that had been produced in the reactor core. However, the need for an expensive new tritium production reactor soon came into question when, in 1991, the U.S. decided to unilaterally dismantle most of its short-range (non-strategic) nuclear weapons, and then ratified the subsequent 1991 START I treaty, requiring the U.S. and Russia to reduce the number of long-range nuclear weapons in their stockpiles. This diminished the total tritium demand and allowed the need to be met by recycling tritium from dismantled warheads. Moving forward, the U.S. began to favor the option of utilizing existing power reactors, which would be quicker and cheaper to implement. All it took was a policy decision to go ahead.

The DOE estimated that it would need to produce 3 kilograms of tritium per year (an unclassified maximum level) to support a START I level stockpile (approximately 11,000 warheads, including reserves), which would have required tritium production to resume by 2005.[1590] For example, at 3 grams per warhead, the production requirement to make up an annual 5.5 percent loss of the START I stockpile of 33 kilograms would be 1.8 kilograms per year, after accounting

1587 - No country is known to currently use reactor-grade plutonium in its warheads.

1588 - See, for example, the derivation in Gregory S. Jones, "U.S. Increased Tritium Production Driven by Plan to Increase the Quantity of Tritium per Nuclear Weapon", 2 June 2016, see https://nebula.wsimg.com/08a60104185a91e6db9008fb929a0873?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1.

1589 - C. Lau and R.E. Rowberg, "The Department of Energy's Tritium Production Program", Congressional Research Service, 23 January 1997.

1590 - U.S. Department of Energy, "Final Environmental Impact Statement for the Production of Tritium in a Commercial Light-Water Reactor", DOE/EIS-0288, March 1999.

for process losses and other production-related factors. The additional makeup requirement to maintain a five-year reserve of about 12 kilograms would be about 0.65 kg per year, bringing the total production requirement to 2.5 kg per year. At the time, it was also anticipated that the follow-on START II agreement would reduce the number of warheads on each side by nearly 50 percent from the START I level and result in a proportional reduction in the annual tritium production requirement, pushing out the date for resumption to 2011. Although START II never went into force, the U.S stockpile continued to decline after 2001, and the Strategic Offensive Reductions Treaty (SORT), which did enter into force in 2003, eventually resulted in warhead levels decreasing to well below the START II level.

Nevertheless, the DOE was directed by the President in the 1996 Nuclear Weapons Stockpile Plan to support a START I stockpile level until the START II treaty was implemented, and the entry into force of SORT did not alter this requirement. Consequently, the DOE proceeded with plans to restart tritium production by 2005 by enlisting commercial light-water reactors for the task. It also continued to retain a backup option for years—the construction of a subcritical accelerator for tritium production—that was favored by powerful New Mexico senator Pete Domenici, but was never implemented.

TRITIUM PRODUCTION AT THE WATTS BAR NUCLEAR PLANT

In 1999, the DOE contracted with the Tennessee Valley Authority (TVA)—the only utility wholly owned by the federal government—to produce tritium in its Watts Bar-1 and Sequoyah-1 and -2 nuclear reactors. (Watts Bar-2 was unfinished at the time.) The approach involves replacing some of the boron-based burnable absorber rods that are used for reactivity control in light-water reactors with Tritium-Producing Burnable Absorber Rods (TPBARs) which contain lithium enriched in the isotope Li-6. As the reactor operates, neutrons are absorbed by the Li-6 nuclei, which then produce tritium and an alpha particle (helium nucleus). The tritium occurs as a gas that then reacts with metallic "getters," which trap the tritium in the form of a hydride. After one 18-month irradiation cycle, the TPBARs are shipped to a Tritium Extraction Facility at the Savannah River Site, where the recovered tritium is loaded into stainless-steel reservoirs for eventual insertion in weapons.

The substitution of TPBARs for burnable absorbers raises numerous safety concerns and imposes constraints on reactor operation. Some issues only emerged after the Watts Bar campaign began.[1591] In addition to increasing the radiological source term resulting from the in-core tritium inventory that could be released to the environment in the event of a core melt accident, the TPBARs reduce shutdown margins, necessitating core modifications such as a higher enrichment levels of the low enriched fuel.

After irradiation for one 18-month cycle, each TPBAR, on average, was estimated to produce just under 1 gram of tritium (but the average yield was originally expected to be as low as 0.75 gram per TPBAR, factoring in process loss). To meet the original tritium production goal

1591 - Dave Senor, "Recommendations for Tritium Science and Technology Research and Development in Support of the Tritium Readiness Campaign, TTP-7-084", PNNL-22873, Pacific Northwest National Laboratory, commissioned by the U.S. Department of Energy, October 2013, see https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22873.pdf.

of 3 kilograms per year, the DOE anticipated that it might have to load up to 6,000 TPBARs each cycle. This would require multiple reactors because at the time it believed that the safety limit was 3,400 TPBARs for a single unit. However, during the first production cycle at Watts Bar-1 in 2003, when only 240 TPBARs were loaded, it was discovered that the permeation rate of tritium into the reactor coolant was nearly ten times higher than predicted.[1592] Although the amount released was only a small fraction of the total inventory in the TPBARs, it exceeded the NRC's regulatory limit for annual tritium release in wastewater. This caused the NRC to impose a limit of no more than 704 TPBARs in a single reactor and triggered additional research and development work to improve tritium retention in the TPBARs (which has been unsuccessful).

Thus, for several subsequent cycles, the number of TPBARs loaded into Watts Bar-1 was well below the original number that DOE said was needed to maintain a START I-sized stockpile. Although the DOE could have also used the two Sequoyah reactors, there apparently was no need to do so. Due to the stockpile reductions that were taking place at the same time,[1593] the reduced level of tritium production apparently was tolerable, presumably with some drawdown of the 5-year reserve. However, by 2015, the DOE had raised the production requirement to 1,700 grams of tritium per 18-month cycle, or 1,130 grams per year, which required a ramp-up. At the declared level in 2015 of 4,571 warheads, assuming 3 grams per warhead, the annual makeup requirement would be about 1 kilogram per year including replenishment of the reserve, requiring about 1,500–2,000 TPBARs per 18-month cycle, or more than twice the 704 that were loaded in Watts Bar-1 that year.

Also in 2015, the public version of the Stockpile Stewardship and Management Plan that the DOE provides to Congress stated that the stockpile demand for tritium would further increase to 2,800 grams per cycle by 2025. Although the reasons for this were not disclosed, it has been posited that increasing the amount of tritium supplied to each warhead would allow the tritium reservoirs to be replaced less frequently and would increase weapon performance margins.[1594] Another possibility is that the DOE may want to retain additional tritium as a hedge in the event that it wants to increase the size of the stockpile. Accordingly, the TVA applied to the NRC for license amendments to increase the maximum number of TPBARs in Watts Bar-1, as well as to expand tritium production to Watts Bar-2. In 2023 TVA loaded 1,792 TPBARs in Watts Bar-1, the maximum licensed limit, and 1,104 in Watts Bar-2.

However, while the licensed limit of 1,792 TPBARs in both Watts Bar units would appear to be more than sufficient to meet the DOE's 2,800 gram per cycle objective, the DOE requested another increase in the TPBAR limit. In April 2024, the NRC granted a license amendment to TVA authorizing an increase in the TPBAR loading in each core to 2,496, for a total of nearly 5,000 TPBARs per cycle. If fully utilized, this quantity would represent a tritium production rate 70 percent greater than the stated DOE objective, and three times the original rate per warhead needed to support a START I stockpile. This oversupply may be needed to compensate

1592 - Dave Senor, "Commercial Light Water Production of Tritium: Update and Path Forward", PNNL-SA-94431, Tritium Focus Group, Pacific Northwest National Laboratory, 23 April 2013, see https://www.energy.gov/sites/prod/files/2015/08/f26/Comml%20Light%20Water%20Prod%20of%20Tritium.pdf.

1593 - National Nuclear Security Administration, "Transparency in the U.S. Nuclear Weapons Stockpile", U.S. Department of Energy, 2024 see https://www.energy.gov/nnsa/transparency-us-nuclear-weapons-stockpile.

1594 - Gregory S. Jones, "U.S. Increased Tritium Production Driven by Plan to Increase the Quantity of Tritium per Nuclear Weapon", 2016, op. cit.

for potential uncertainties in the production chain that significantly reduce the nominal likelihood of DOE, as the end user, actually receiving the tritium it requires.[1595]

Despite years of attention to the issue, DOE does not seem to have been able to reduce the tritium permeation problem from TPBARs. To meet the NRC's wastewater tritium discharge limit with a significantly greater number of TPBARs in the core, TVA needs to employ a mobile demineralizer to further treat the effluent or dilute it prior to discharge.[1596]

NONPROLIFERATION CONCERNS

The isotope tritium occupies a gray area in nuclear nonproliferation law and policy. Because it is not itself a fissionable material that can sustain a chain reaction (despite some who claim that it is possible to build a pure fusion bomb), nor can it be used as a source of nuclear explosive material, it is not subject to international safeguards. Moreover, it is not classified as "special nuclear material" in domestic laws such as the U.S. Atomic Energy Act (AEA). On the other hand, it defies common sense to argue that the production of tritium for nuclear weapons can be classified as "peaceful use," regardless of whether it can be used directly to fuel a nuclear weapon. And the production of tritium for weapons using commercial facilities violates the principle that civilian and military nuclear activities should remain fully separate.

In 1998, a U.S. Government interagency review concluded that the production of tritium in commercial light-water reactors was not prohibited by the AEA and was acceptable from a nonproliferation perspective because the U.S. had never fully separated civil and military nuclear activities.[1597] The review also argued that the use of reactors owned by the Tennessee Valley Authority, which is a U.S. Government agency, mitigated the dual-use nature of the program. It did take the position though that tritium production could not be carried out using imported materials, equipment, or technologies that had "peaceful use" obligations. U.S. policy also excludes the production of tritium using "encumbered" nuclear materials that were declared excess for weapons use after the end of the Cold War, specifically: stockpiles of around 47 metric tons of excess plutonium and 374 metric tons of highly enriched uranium (HEU). This means, in particular, that low-enriched uranium produced from blending down HEU from excess Cold War weapons that had been declared for peaceful use could not be used as fuel for a commercial reactor that was concurrently producing tritium.

These constraints have proven to be problematic given the limited amount of unobligated and unencumbered enriched uranium available in the United States. The U.S. stopped enriching uranium in government-owned facilities using U.S. technologies in 2013, and the sole domestic industrial-scale enrichment facility is owned by URENCO, an international consortium that is under peaceful use obligations. Consequently, TVA has been only able to utilize Low Enriched Uranium (LEU) fuel derived from blended-down unencumbered HEU from a dwindling

1595 - E.F. Love, M.L. Stewart et al., "Tritium Production Assurance", Tritium Focus Group, Pacific Northwest National Laboratory, 11 May 2017, 5 June 2017, see https://www.energy.gov/sites/prod/files/2017/06/f34/May%2011%20-%20Stewart%20-%20Tritium%20Production%20Assurance.pdf.

1596 - U.S. Nuclear Regulatory Commission, "Tennessee Valley Authority; Watts Bar Nuclear Plant, Units 1 and 2; Environmental Assessment and Finding of No Significant Impact", 16 February 2024, see https://www.nrc.gov/docs/ML2400/ML24009A172.pdf, accessed 22 August 2024.

1597 - Department of Energy, "Interagency Review of the Nonproliferation Implications of Alternative Tritium Production Technologies Under Consideration by the Department of Energy", United States Government, report to the U.S. Congress, July 1998.

stockpile that the U.S. has retained for military purposes, including production of fuel for naval reactors. After scouring the nuclear weapons complex for HEU scrap that no one else wanted, the DOE now says it can provide sufficient fuel to the TVA reactors to produce tritium until 2044.[1598] However, after that date, it will have to find another source. The DOE is currently sponsoring work on two different U.S.-origin centrifuge technologies with the ultimate goal of producing unobligated enriched uranium for a range of military purposes, including tritium production.

IMPLICATIONS FOR FRANCE

There is little public information at this time regarding the weapons tritium production program that has been proposed for the Civaux reactors in France. However, the scale of the effort is likely to be much smaller than the U.S. program at the Watts Bar plant. The active French nuclear stockpile is estimated at around 300 warheads, or less than one tenth of the active U.S. stockpile. Assuming France employs similar TPBAR technology to the U.S. and that its weapons use similar quantities of tritium, the core TPBAR inventory at Civaux would be far lower than the inventory planned for the Watts Bar reactors and would likely be below the maximum that the U.S. NRC approved to control tritium permeation into the coolant. The impact of the TPBARs on reactor operation would also be lower and may not necessitate the same types of adjustments that were made at Watts Bar.

France may also need to confront the policy question of whether uranium imported into France under "peaceful use" obligations, e.g. from Australia or Canada, can be used for co-production of tritium for weapons. If France concludes that it cannot be used, that would impose constraints on the source of the uranium fuel used at Civaux.

1598 - U.S. Department of Energy, "Fiscal Year 2024 Stockpile Stewardship and Management Plan: Report to Congress", November 2023.

SMALL MODULAR REACTORS (SMRs)

The gap between hype about Small Modular Reactors (SMRs) and reality continues to grow. The nuclear industry and multiple governments are doubling down on their investments into SMRs, both in monetary and political terms. In addition to individual governments, there are also multilateral efforts being launched, including the European Industrial Alliance on Small Modular Reactors set up by the European Commission with the aim of accelerating "the development, demonstration and deployment of Small Modular Reactors (SMRs) in Europe by the early 2030s."[1599] The Alliance's stated ambition is to "have at least 150 GW of nuclear capacity installed by 2050."[1600] Nuclear regulatory agencies in the United States, the United Kingdom, and Canada are trying to "facilitate resolution of common technical questions to facilitate regulatory reviews" of advanced reactors and SMRs.[1601]

At the same time, the reality is far more somber. As documented below, SMR projects continue to be delayed or canceled. Some mainstream news outlets are warning that costs for nuclear projects in general and SMRs in particular are surging.[1602] This is apparent in the few available cost estimates, especially when weighted by the electrical power generation capacities of SMRs.

This chapter provides updates on programs in all those countries developing their own SMR designs. In addition, there are countries that have expressed verbal interest in importing SMRs. These are discussed only in the context of agreements or contracts with the countries interested in exporting SMRs.

ARGENTINA

Argentina's CAREM (Central Argentina de Elementos Modulares) is currently the oldest pursued SMR design, passing the milestone of being under construction for a decade in February 2024. Under development by the National Atomic Energy Commission (CNEA) since the 1980s,[1603] the 25 MW CAREM was "scheduled to begin cold testing in 2016 and receive

1599 - Alfie Shaw, "European Commission launches industrial alliance for SMRs", *Power Technology*, 8 February 2024, see https://www.power-technology.com/news/eu-launches-smr-industrial-alliance/, accessed 13 February 2024; and Directorate-General for Energy, "Commission to ally with industry on Small Modular Reactors", European Commission, 9 February 2024, see https://energy.ec.europa.eu/news/commission-ally-industry-small-modular-reactors-2024-02-09_en, accessed 15 February 2024.

1600 - Thierry Breton, "Driving decarbonisation and resilience with nuclear energy", Internal Market Commissioner, European Commission, 28 November 2023, see https://ec.europa.eu/commission/presscorner/detail/en/speech_23_6156, accessed 12 August 2024.

1601 - U.S. NRC, CNSC and ONR, "Memorandum of Cooperation on Advanced Reactor and Small Modular Reactor Technologies Among the United States Nuclear Regulatory Commission, the Canadian Nuclear Safety Commission and the United Kingdom Office for Nuclear Regulation", 12 March 2024, see https://www.nrc.gov/docs/ML2406/ML24066A026.pdf, accessed 12 August 2024.

1602 - Jonathan Tirone, "Mini Reactor Cost Surge Threatens Nuclear's Next Big Thing", *Bloomberg*, 30 June 2023, see https://www.bloomberg.com/news/articles/2023-06-30/mini-reactor-cost-surge-threatens-nuclear-s-next-big-thing, accessed 2 July 2023.

1603 - Dario F. Delmastro, "Small modular reactors (SMRs): The case of Argentina", National Atomic Energy Commission and Universidad Nacional de Cuyo, in "Handbook of Small Modular Nuclear Reactors", ed. by Daniel T. Ingersoll and Mario D. Carelli, *Woodhead Publishing*, November 2020, see https://www.sciencedirect.com/science/article/pii/B978012823916200014X, accessed 7 August 2023; and U.S. House of Representatives, "Oversight review of South American science, space, and technology: report to the Committee on Science, Space, and Technology, U.S. House of Representatives, One Hundredth Congress, second session", U.S. Government Printing Office, 1988.

its first fuel load in the second half of 2017" at construction start.[1604] Since then, there have been a series of delays (see previous WNISR editions). The latest update comes from May 2024 when CNEA's head told *Reuters* that because of budget cuts, construction of the reactor has been halted.[1605] CNEA has subsequently announced a 60-day "critical design review" focused on engineering systems "that go inside the reactor which are not yet manufactured."[1606] CNEA now expects the reactor to start functioning in 2028.[1607] But there are good reasons to expect that the project will miss that deadline, including the fact that CNEA has other priorities, such as finishing the RA-10 multipurpose reactor that can produce radioisotopes like molybdenum-99.[1608] RA-10 has been described as "practically finished" and thus more likely to receive funding.[1609] Media reports also suggest that the investment in the CAREM project is approximately US$600 million, and needs another US$200 to 300 million.[1610] Assuming a total cost of US$800 million, CAREM's unit cost amounts to around US$32,000/kW, higher than recently built large nuclear reactors. (See Argentina in Annex 1)

CANADA

Canadian government entities have been promoting small modular reactors for many years, especially after the publication of the 2018 SMR Roadmap.[1611] As detailed in previous WNISR editions, the government has been offering considerable funding for SMRs and that trend has been continuing. In August 2023, the Federal Government approved CAD74 million (US$$_{2023}$55 million) for SMR development in the province of Saskatchewan, which derived 79 percent of its power from fossil fuels as of 2022.[1612] The provincial utility, SaskPower, announced in late May 2024 that it had "made significant progress in its search for a potential host site" for the first SMR, and expected a definitive selection in 2025, with a final investment decision in 2029.[1613] In July 2024, the Federal Government announced CAD2.5 million

1604 - *WNN*, "Construction of CAREM underway", *World Nuclear News*, 10 February 2014, see http://www.world-nuclear-news.org/NN-Construction-of-CAREM-underway-1002144.html, accessed 7 May 2021.

1605 - Candelaria Grimberg and Horacio Soria, "Argentina budget cuts hitting nuclear energy ambitions, atomic body says", *Reuters*, 2 May 2024, see https://www.reuters.com/business/energy/argentina-budget-cuts-hitting-nuclear-energy-ambitions-atomic-body-says-2024-05-02/, accessed 3 May 2024.

1606 - *WNN*, "Argentina's CAREM SMR project to have Critical Design Review", 31 May 2024, see https://www.world-nuclear-news.org/Articles/Critical-Design-Review-for-Argentina-s-CAREM-small, accessed 31 May 2024.

1607 - *Reuters*, "Argentina budget cuts hitting nuclear energy ambitions, atomic body says", May 2024, op. cit.

1608 - *WNN*, "Argentina's CAREM SMR project to have Critical Design Review", 31 May 2024, op. cit.

1609 - Nicolás Deza, "CAREM: las claves detrás del cruce de versiones sobre la paralización de la construcción del reactor", *Econo Journal*, 4 April 2024 (in Spanish), see https://econojournal.com.ar/2024/04/las-claves-detras-del-cruce-de-versiones-sobre-la-paralizacion-de-la-construccion-del-reactor-carem/, accessed 31 May 2024.

1610 - Ibidem.

1611 - Canadian Small Modular Reactor Roadmap Steering Committee, "A Call to Action: A Canadian Roadmap for Small Modular Reactors", November 2018, see https://smrroadmap.ca/wp-content/uploads/2018/11/SMRroadmap_EN_nov6_Web-1.pdf, accessed 14 June 2019.

1612 - Natural Resources Canada, "Government of Canada Announces Federal Support for Small Modular Reactor (SMR) Development in Saskatchewan", Government of Canada, August 2023, see https://www.canada.ca/en/natural-resources-canada/news/2023/08/government-of-canada-announces-federal-support-for-small-modular-reactor-smr-development-in-saskatchewan.html, accessed 12 August 2024; and Canada Electricity Advisory Council, "Powering Canada: A blueprint for success—Canada Electricity Advisory Council: Final report", Government of Canada, May 2024, see https://natural-resources.canada.ca/our-natural-resources/energy-sources-distribution/electricity-infrastructure/the-canada-electricity-advisory-council/powering-canada-blueprint-for-success/25863, accessed 1 August 2024.

1613 - SaskPower, "SaskPower Update on SMR Site Selection Near Estevan", Press Release, 31 May 2024, see https://www.saskpower.com/about-us/media-information/news-releases/2024/SaskPower-update-on-SMR-site-selection-near-Estevan, accessed 4 June 2024.

(US$1.8 million) for research into SMRs at the University of Regina (in Saskatchewan) and the University of Alberta.[1614]

At the provincial level, in September 2023, Alberta announced CAD7 million (US$$_{2023}$5.2 million) in funding to oil and gas producer Cenovus Energy to study the possible use of SMRs in operations at the oil sands.[1615] This was followed in April 2024 by an announcement of CAD600,000 (US$438,000) to X-Energy, a vendor of high-temperature gas-cooled reactors, for a study to "assess the suitability of repurposing a TransAlta fossil-fuelled electricity generation site with an Xe-100 SMR nuclear plant from an economics, technology, and nuclear regulatory perspective – work necessary to understand the implications of a first-of-a-kind nuclear project in Alberta."[1616] Alberta, too, is heavily dependent on fossil fuels, deriving 81 percent of its electricity in 2022 from these,[1617] yet deployment of an SMR is not expected before the "early 2030s",[1618] leading to suggestions that the talk about potential nuclear reactor deployment is a way to deflect and delay climate action.[1619]

the talk about potential nuclear reactor deployment is a way to deflect and delay climate action.

The Canadian Nuclear Safety Commission (CNSC) continues to promote small modular reactors, in line with its earlier actions, such as lobbying for excluding SMRs from the Impact Assessment process, that suggest institutional bias.[1620] It has continued to offer an optional service for nuclear vendors called "pre-licensing vendor design review" that is meant to enable CNSC staff "to provide feedback early in the design process" but "does not certify a reactor design or involve the issuance of a licence under the Nuclear Safety and Control Act", and it "is not required as part of the licensing process for a new nuclear power plant", in fact "the conclusions of any design review do not bind or otherwise influence future decisions made by the Commission."[1621]

1614 - Natural Resources Canada, "Government of Canada Announces $11 Million to Advance Small Modular Reactor Research and Hydrogen Technologies to Support Clean Energy Development", Press Release, Government of Canada, 3 July 2024, see https://www.canada.ca/en/natural-resources-canada/news/2024/07/government-of-canada-announces-11-million-to-advance-small-modular-reactor-research-and-hydrogen-technologies-to-support-clean-energy-development.html, accessed 31 July 2024.

1615 - Joel Dryden, "Alberta investing $7M into Cenovus Energy study on small modular reactors", *CBC News*, 19 September 2023, see https://www.cbc.ca/news/canada/calgary/world-petroleum-congress-rebecca-schulz-alberta-smrs-1.6971701, accessed 1 August 2024.

1616 - Phil Wood, "Alberta to fund research of small modular nuclear reactors", *Calgary City News*, 3 April 2024, see https://calgary.citynews.ca/2024/04/03/alberta-nuclear-research-funding/, accessed 1 August 2024; and Emission Reduction Alberta, "Assessing Site and Distribution Infrastructure from Transitioning a Thermal Power Plant to an SMR—X-energy Canada", Undated, see https://www.eralberta.ca/projects/details/assessing-site-and-distribution-infrastructure-from-transitioning-a-thermal-power-plant-to-an-smr/, accessed 12 August 2024.

1617 - Canada Electricity Advisory Council, "Powering Canada: A blueprint for success—Canada Electricity Advisory Council: Final report", Government of Canada, May 2024, op. cit.

1618 - Emission Reduction Alberta, "Assessing Site and Distribution Infrastructure from Transitioning a Thermal Power Plant to an SMR—X-energy Canada", op. cit.

1619 - Timothy Rauf, "Exploding Alberta's Myths about Small Nuclear Reactors", *The Tyee*, 15 February 2024, see https://thetyee.ca/Analysis/2024/02/15/Exploding-Alberta-Myths-Small-Nuclear-Reactors/, accessed 1 August 2024.

1620 - Kerrie Blaise and M. V. Ramana, "Regulation vs Promotion: Small Modular Nuclear Reactors in Canada", *Energy Policy*, 2024, see https://doi.org/10.1016/j.enpol.2024.114228, accessed 15 June 2024.

1621 - CNSC, "Pre-Licensing Vendor Design Review", Canadian Nuclear Safety Commission, Updated 20 April 2023, see https://nuclearsafety.gc.ca/eng/reactors/power-plants/pre-licensing-vendor-design-review/index.cfm, accessed 7 August 2023.

During the last year, CNSC completed the pre-licensing review of X-energy's 80 MW high-temperature gas cooled reactor design.[1622] Although CNSC said that its "staff did not identify any fundamental barriers to licensing", the executive summary released by CNSC did mention that there were "some technical areas that need further development in order for X-energy to better demonstrate adherence to CNSC requirements."[1623] Among the areas identified is information to demonstrate that all regulatory requirements "for means of reactor shutdown are fully met". The CNSC's executive summary further said, "The negative reactivity characteristics are a fundamental safety feature of Xe-100 design and play an important role in the control and shutdown of the reactor. Demonstration of this feature shall include operating experience (OPEX) and experimental data to the extent practicable." Since there is very limited experience with high-temperature gas cooled reactors, and that experience has not inspired much confidence (see discussion about Fort St. Vrain in section about China), finding reliable data might be a challenge.

Among the current SMR designs being reviewed by CNSC are Westinghouse's eVinci (since June 2023) and ARC-100 (since February 2022). The third design in that list, the 5 MW Micro Modular Reactor (MMR) design, which is proposed for construction at Chalk River, Ontario, is listed as being "on hold" as of mid-2024.[1624] Although CNSC does not give any reasons, Ultra Safe Nuclear Corporation (USNC), the MMR's designer, is changing the design. USNC attributed the "design updates" to "the inability in the short term to procure HALEU fuel [High Assay Low Enriched Uranium] (i.e. uranium enriched to 19.75 percent)" and "ongoing market assessments and research".[1625] The latter has led USNC to increase the design output of the MMR up to threefold—another piece of evidence suggesting that SMRs will be at a commercial disadvantage because they lack economies of scale. The potential markets for which the MMR is being designed—remote mines and communities—are unlikely to materialize because of the high cost of electricity from such small reactors.[1626]

In the meanwhile, Ultra Safe Nuclear Corporation announced in February 2024 that it was involved in "a reduction of USNC staff and the concentration of efforts on selected markets and customers" because "only a subset" of potential customers for the reactor design "have shown the resolve to incorporate advanced reactors in the near term."[1627] In other words, the market for its products is limited at best and non-existent at worst.

1622 - X-energy, "Canadian Pre-Licensing Milestone | Xe-100 Advanced Small Modular Reactor", 17 January 2024, see https://x-energy.com/media/news-releases/canadian-pre-licensing-xe-100-advanced-small-modular-reactor, accessed 4 April 2024.

1623 - CNSC, "Vendor Design Review—Executive summary: Combined phases 1 and 2 pre-licensing vendor design review - X-energy", Canadian Nuclear Safety Commission, Updated 17 January 2024, see https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/pre-licensing-vendor-design-review/x-energy-executive-summary/, accessed 31 July 2024.

1624 - CNSC, "Vendor Design Review", Updated 21 May 2024, see https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/pre-licensing-vendor-design-review/, accessed 12 August 2024.

1625 - Global First Power, "Letter from Global First Power to the Canadian Nuclear Safety Commission—Update to the Project Description in Support of Global First Power's Application for a Licence to Prepare Site for the Micro Modular ReactorTM Nuclear Facility at the Chalk River Site", addressed to the Environmental Assessment Division, Canadian Nuclear Safety Commission, Canadian Impact Assessment Registry, 4 August 2023, see https://iaac-aeic.gc.ca/050/evaluations/document/155611, accessed 31 July 2024.

1626 - Sarah Froese, Nadja C. Kunz and M.V. Ramana, "Too Small to be Viable? The Potential Market for Small Modular Reactors in Mining and Remote Communities in Canada", *Energy Policy*, Vol. 144, September 2020, see https://www.sciencedirect.com/science/article/abs/pii/S030142152030327X, accessed 3 July 2020.

1627 - Ultra Safe Nuclear, "USNC Focuses Its Operations to Accelerate Development and Delivery of its Nuclear Systems", 28 February 2024, see https://www.usnc.com/usnc-focuses-its-operations-to-accelerate/, accessed 31 July 2024.

Meanwhile, at the Darlington site, Ontario Power Generation (OPG) continues with its plans to build up to four 300 MW BWRX-300 reactors designed by GE-Hitachi (see Canada in Annex 1). In October 2022, OPG submitted an application for a license to construct a single unit.[1628] Instead of producing an impact assessment for this reactor, OPG argued that the environmental assessment approved by CNSC in 2009 to construct four large reactors would cover the potential impacts of the BWRX-300 reactor too. Highlighting a number of "weaknesses and gaps" inherent in using the older environmental assessment to evaluate the new project proposal, civil society groups objected to allowing OPG to proceed in this fashion and called for a new assessment.[1629] But in April 2024 CNSC decided that the existing environmental assessment was applicable to the BWRX-300 reactor. CNSC emphasized however that its "decision does not authorize the construction of a BWRX-300 reactor" and that the "Commission will hold a future public hearing to consider OPG's application for a license to construct one BWRX-300 reactor at the Darlington nuclear site."[1630]

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The other province that has been at the center of SMR activity in Canada is New Brunswick. On 30 June 2023, the province's electricity company, NB Power, applied to CNSC for a license to start preparing the Point Lepreau site—where one unit has been operating since the early 1980s—as part of its plans to construct and operate an ARC-100 sodium-cooled fast reactor by the early 2030s.[1631] But these plans have become unrealistic because of financial problems for ARC Clean Technology, the promoter of the ARC-100 concept. In June 2024, the company confirmed that Bill Labbe, its President and CEO, was leaving the company and layoff notices had been issued to a number of employees.[1632]

The company has raised only a very small fraction of the CAD500 million (US$$_{2023}$370 million) that Labbe had estimated in 2023 as being necessary for fully developing the ARC-100 reactor design.[1633] For comparison, in March 2024 during the fourth quarter 2023 earnings call,

1628 - CNSC, "Darlington New Nuclear Project", Canadian Nuclear Safety Commission, 11 January 2023, see http://www.nuclearsafety.gc.ca/eng/resources/status-of-new-nuclear-projects/darlington/index.cfm, accessed 11 January 2023.

1629 - Sara Libman, "Submission: Darlington New Nuclear Project's Environmental Assessment and Plant Parameter—Comments on the applicability of the Darlington New Nuclear Project's environmental assessment and plant parameter envelope to Ontario Power Generation's selected BWRX-300 reactor technology", Durham Nuclear Awareness, Slovenian Home Association and the Canadian Environmental Law Association, November 2023, see https://cela.ca/submission-darlington-new-nuclear-projects-environmental-assessment-and-plant-parameter/, accessed 31 July 2024.

1630 - CNSC, "Independent Commission determines environmental assessment for Ontario Power Generation's Darlington New Nuclear Project is applicable to the selected reactor technology", Press Release, Canadian Nuclear Safety Commission, 22 April 2024, see https://www.canada.ca/en/nuclear-safety-commission/news/2024/04/independent-commission-determines-environmental-assessment-for-ontario-power-generations-darlington-new-nuclear-project-is-applicable-to-the-select.html, accessed 12 August 2024.

1631 - NB Power, "NB Power Submits Environmental Impact Assessment Registration and Licence to Prepare Site Application for Advanced Small Modular Reactor Project", Press Release, 30 June 2023, see http://www.nbpower.com/en/about-us/news-media-centre/news/2023/nb-power-submits-environmental-impact-assessment-registration-and-licence-to-prepare-site-application-for-advanced-small-modular-reactor-project/; and NB Power, "License to Prepare Site Application— 930-00581-0001-001-LPA-A-00", 30 June 2023, see https://www.nbpower.com/media/1492441/licensetopreparesiteapplication.pdf, accessed 7 August 2023.

1632 - Adam Huras, "N.B. small modular CEO leaves, company cuts staff", *Telegraph-Journal*, 25 June 2024, see https://tj.news/new-brunswick/breaking-n-b-small-modular-ceo-leaves-company-cuts-staff, accessed 31 July 2024.

1633 - Matthew McClearn, "CEO, staff suddenly depart New Brunswick reactor developer ARC Clean Technology", *The Globe and Mail*, 26 June 2024, see https://www.theglobeandmail.com/business/article-ceo-staff-depart-new-brunswick-reactor-developer-arc-clean-technology/, accessed 31 July 2024.

NuScale's CEO announced that the company had "invested more than [US]$1.8 billion" so far,[1634] and that a NuScale reactor is still far from any commencement of construction.

The need for large amounts of government funding is also borne out by assessments from the provincial utility, NB Power. According to documents that Susan O'Donnell, an academic researcher, obtained using New Brunswick's freedom of information legislation, the former CEO of NB Power had warned the Federal Government in 2020 that "one or both companies [ARC and Moltex, the other SMR developer based in New Brunswick] are expected to close their offices in the next year" unless they received "federal support" amounting to hundreds of millions of dollars, which is necessary to "keep the SMR development option in New Brunswick viable."[1635] Despite the stated interest in SMRs, the Canadian Government has not offered that kind of federal support.

CHINA

In comparison with other countries discussed in this chapter, China places much less emphasis on SMRs, focusing primarily on large reactors. This difference in emphasis is especially evident when viewed in relation to China's status as host to the world's largest nuclear newbuild program. Its SMR program includes a high-temperature gas-cooled reactor design called the HTR-PM and an integral pressurized water reactor design, the ACP100.

HTR-PM Design

The HTR-PM, which consists of two 100 MW reactors connected to a single turbine, is constructed on the basis of experience with a pilot scale reactor, the HTR-10, which in turn can be traced back to the 80 MW HTR-MODUL design developed by a joint venture of Siemens and Asea Brown Boveri (ABB) in the late 1980s.[1636] The HTR-PM's fuel also derives from German technology. As *Nuclear Engineering International* reports

> In the 1970s and 1980s, a TRISO fuel production plant was operated in Hanau, Germany and as part of a later cooperation agreement parts of the original fuel fabrication plant were shipped to Beijing, China, in 1995 and rebuilt at Tsinghua University. The laboratory production line at the Institute of Nuclear and New Energy Technology (INET) went into operation in 1998. Based on the experience gained from the INET plant, CNNC designed the fuel production plant of the HTR-PM.[1637]

1634 - NuScale Power Corporation, "FQ4 2023 Earnings Call", 14 March 2024, see https://www.nuscalepower.com/-/media/nuscale/pdf/investors/2023/smr-4q23-transcript.pdf, accessed 12 August 2024.

1635 - Matthew McClearn, "Unable to effectively operate its lone existing nuclear reactor, New Brunswick is betting on advanced options", *The Globe and Mail*, 2 July 2024, see https://www.theglobeandmail.com/business/article-new-brunswick-nuclear-reactor-technology-arc-clean-moltex-energy/, accessed 31 July 2024.

1636 - M.V. Ramana, Laura Berzak Hopkins and Alexander Glaser, "Licensing small modular reactors", *Energy*, Vol. 61, November 2013, see http://www.sciencedirect.com/science/article/pii/S0360544213007615, accessed 6 November 2013.

1637 - *NEI Magazine*, "HALEU UF6 and SMR fuel fabrication", *Nuclear Engineering International*, 20 June 2024, see https://www.neimagazine.com/analysis/haleu-uf6-and-smr-fuel-fabrication/, accessed 21 July 2024.

The HTR-PM was declared as grid-connected in December 2021 and operating commercially in December 2023.[1638] Since then, the reactors have been re-rated to a combined capacity of 150 MW. There is no public announcement about why the power output has been reduced by 25 percent of the design power capacity. According to the IAEA's PRIS database, the HTR-PM reactors produced only 112.09 GWh of electrical energy in 2023. The IAEA also reports that the units were 744 h online, which corresponds to one month of full-power operations at the reduced capacity of 150 MW, or just one month of the year. The IAEA's 2024 edition on operating experience covering the year 2023 identifies the month as December 2023.[1639] This is puzzling. It is virtually impossible for two reactors to deliver 100 percent of nominal capacity precisely for one calendar month. What is more likely is that these reactors were connected to the grid at a fraction of full nominal capacity. If the 112.09 GWh were considered as the annual production of two reactors with a combined capacity of 150 MW, this translates to a load factor of just 8.5 percent.

Even though there is no official information, the reported energy generation clearly suggests that the reactor is experiencing operational problems. The HTR-PM's load factor for 2023 is the same as the load factor for the Fort St. Vrain (U.S.) high-temperature gas-cooled reactor in 1979, the first year the latter reactor announced a load factor. Fort St. Vrain, which became critical in 1974 took five years—versus two years for the Chinese HTR-PM—before being declared commercial. But a decade later, in August 1989, it was declared closed due to a series of operational problems.[1640] Its lifetime load factor was just 15.2 percent.

The apparent operational problems—no details have been communicated as to the nature of the issues—of the HTR-PM reactors add to a history of construction delays and cost escalations. When construction started in 2012, the construction time was estimated at "50 months",[1641] which was already more than the earlier estimates of around 3 years.[1642] The twin reactors reached full power operations only after 10 years (see HTR-PM Design in WNISR2023), with a further year before the units were declared as commercially operating, only to have their output derated subsequently. Likewise, in 2009, the developers of the HTR-PM estimated "the necessary budget excluding R&D [Research & Development] and infrastructure costs for the first HTR-PM demonstration plant to be about 2,000USD/kWe."[1643] By 2017, even well before it was completed, its cost estimate had jumped to RMB40,000/kWe,[1644] which converted to

1638 - *WNN*, "China's demonstration HTR-PM enters commercial operation", 6 December 2023, see https://www.world-nuclear-news.org/Articles/Chinese-HTR-PM-Demo-begins-commercial-operation, accessed 8 December 2023.

1639 - IAEA, "Operating Experience with Nuclear Power Stations in Member States—2024 Edition", International Atomic Energy Agency, August 2024, see https://www-pub.iaea.org/MTCD/Publications/PDF/OPEX_2024_web.pdf, accessed 21 July 2024.

1640 - M. V. Ramana, "The checkered operational history of high-temperature gas-cooled reactors", *Bulletin of the Atomic Scientists*, April 2016, see https://doi.org/10.1080%2F00963402.2016.1170395, accessed 12 August 2024.

1641 - David Dalton, "China Begins Construction Of First Generation IV HTR-PM Unit", *NucNet*, 7 January 2013, see http://www.nucnet.org/all-the-news/2013/01/07/china-begins-construction-of-first-generation-iv-htr-pm-unit, accessed 10 January 2013.

1642 - Zuoyi Zhang et al., "Design of Chinese Modular High-Temperature Gas-Cooled Reactor HTR-PM", in 2nd International Topical Meeting on High Temperature Reactor Technology, 22 September 2004; and Spencer Reiss, "Let a Thousand Reactors Bloom", *Wired*, 1 September 2004, see https://www.wired.com/2004/09/china-5/, accessed 16 July 2022.

1643 - Zuoyi Zhang, Zongxin Wu et al., "Current status and technical description of Chinese 2 × 250 MWth HTR-PM demonstration plant", Tsinghua University, *Nuclear Engineering and Design*, Vol. 239, July 2009.

1644 - Zuoyi Zhang, "The Status of HTR-PM, a 200 MWe High Temperature Gas-cooled Reactor demonstration plant constructed in China", Chief Scientists of HTR-PM Project and Director of INET, Tsinghua University, presented at the International Ministerial Conference on Nuclear Power in the 21st Century, 30 November 2017, see https://www.iaea.org/sites/default/files/17/11/cn-247-zhang.pdf, accessed 20 July 2024.

around US$6,000/kWe at the prevailing currency conversion rates, or more than double the initial cost estimate even after accounting for inflation. If evaluated with the lowered power rating of just 150 MW, the unit cost should be US$8,000/kWe.

ACP100 Design

The ACP100 integrated Pressurized Water Reactor (PWR), also referred to as Linglong One, has been in the developmental phase since 2010, and its initial design was finalized in 2014.[1645] Construction of the 100-MW Linglong One started in July 2021 at the Changjiang site in Hainan province, where two CNP600 PWRs are operating and two Hualong One units are being built.[1646] As detailed in WNISR2022, the start of construction was delayed by at least six years. The planned construction period is 58 months, which would mean that the reactor is to become operational by May 2026.[1647] The projected construction period is typical for Chinese nuclear reactors, which does not suggest any advantage resulting from building an SMR.

FRANCE

In July 2024, France's Électricité de France (EDF) announced that it was making significant changes to the Nuward design by moving the project "to a design based on proven technological building blocks", because many of the new elements it had proposed, such as a different type of steam generator, were not ready.[1648] The Nuward project was first revealed in September 2019.[1649] In February 2022, President Emmanuel Macron announced that through the "France 2030" re-industrialization plan, €500 million (US$$_{2022}$526.5 million) would be made available for SMR projects "carried by EDF NUWARD" and the same sum for other "innovative reactors which allow to close the fuel cycle", with the "ambitious goal" of starting to build a first prototype in

1645 - *WNN*, "Rapid construction of Chinese SMR containment shell continues", 7 July 2022, see https://www.world-nuclear-news.org/Articles/Rapid-construction-of-Chinese-SMR-containment-shel, accessed 17 July 2022; and Bin Xu, "CNNC's ACP100 SMR: Technique Features and Progress in China", China National Nuclear Corporation, Nuclear Power Institute of China, presented at "13th INPRO Dialogue Forum on Legal and Institutional Issues in the Global Deployment of Small Modular Reactors", IAEA, 18–21 October 2016, see https://nucleus.iaea.org/sites/INPRO/df13/Presentations/011_CNNC%27s%20ACP100%20SMR-Technique%20Features%20and%20Progress%20in%20China.pdf, accessed 8 August 2023.

1646 - CNNC, "World's first commercial Linglong One onshore small reactor starts construction", Press Release, China National Nuclear Corporation, 14 July 2021, see https://en.cnnc.com.cn/2021-07/14/c_642603.htm; and WNA, "Changjiang SMR-1, China", Undated, World Nuclear Association, see https://www.world-nuclear.org/reactor/default.aspx/CHANGJIANG%20SMR; also *NS Energy*, "Hainan Changjiang Nuclear Power Plant Phase Two", Undated, see https://www.nsenergybusiness.com/projects/hainan-changjiang-nuclear-power-plant/; all accessed 8 August 2023.

1647 - National Energy Administration, "小身躯、大用途 玲龙一号不只是核能 '充电宝'", Government of China, 18 September 2021 (in Chinese), see https://www.nea.gov.cn/2021-09/18/c_1310196316.htm, accessed 12 August 2024; and *WNN*, "Outer dome installed on Chinese small modular nuclear reactor", *World Nuclear News*, 7 February 2024, see https://world-nuclear-news.org/Articles/Outer-dome-installed-on-Chinese-small-modular-nucl, accessed 14 July 2024.

1648 - Sharon Wajsbrot, "Mini-réacteur nucléaire : EDF change ses plans pour son projet Nuward", *Les Echos*, 1 July 2024 (in French), see https://www.lesechos.fr/industrie-services/energie-environnement/mini-reacteur-nucleaire-edf-change-ses-plans-pour-son-projet-nuward-2105042, accessed 1 July 2024; and EDF, "2024 Half-Year Results Continued progress in operational performance Market prices decreasing Higher nuclear power output in France, expected at upper end of the range Lowest ever carbon intensity Success of commercial offers Net financial debt stabilized", Press Release, 26 July 2024, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/2024-half-year-results-continued-progress-in-operational-performance-market-prices-decreasing-higher-nuclear-power-output-in-france-expected-at-upper-end-of-the-range-lowest-ever-carbon; also NUWARD, "The EDF Group pivots its SMR product strategy", Linkedin Post, July 2024, see https://www.linkedin.com/feed/update/urn:li:activity:721598792477168435; both accessed 12 August 2024; also

1649 - CEA, "CEA, EDF, Naval Group and TechnicAtome unveil NUWARD: jointly developed Small Modular Reactor (SMR) project", Press Release, Commissariat à l'énergie atomique et aux énergies alternatives/French Alternative Energies and Atomic Energy Commission, 17 September 2019, see https://www.cea.fr/english/Pages/News/Nuward-SMR-CEA.aspx, accessed 8 August 2023.

France by 2030.[1650] In March 2023, EDF announced that it was creating a subsidiary to develop Nuward and the program was "now entering the basic design phase".[1651]

According to *Reuters*, the design changes announced in 2024 were a result of feedback from "prospective clients such as Vattenfall, CEZ and Fortum" who wanted to be confident about cost projections and delivery deadlines so that the "levelised cost of electricity for the SMRs would be in the range of 70 to 100 euros per megawatt-hour [US$76–108]."[1652] In June 2024, two years after announcing that it was beginning a feasibility study on building SMRs at the Ringhals site, Vattenfall revealed the two companies (out of six potential SMR suppliers) it had shortlisted to further explore the project with. Nuward had been ruled out.[1653]

It is not clear how the significant changes to the Nuward design would affect the earlier announced timeline of having a detailed design ready by 2029, and starting construction the following year.[1654] Also unclear at this time is whether these changes will affect the safety application submitted to the French Nuclear Safety Authority (ASN) in July 2023.[1655]

France has earlier abandoned three SMR designs, the Flexblue, Antares, and NP-300 (see WNISR2022). Although not described as an SMR, the final option that was considered for the subsequently abandoned ASTRID reactor was a design that would produce 100-200 MW, down from 600 MW.[1656] The French Government had reportedly budgeted up to €900 million (US$$_{2019}$1 billion) through 2019 for the ASTRID project.

1650 - President Emmanuel Macron, "Déclaration de M. Emmanuel Macron, président de la République, sur la politique de l'énergie, à Belfort le 10 février 2022.", Government of France, 10 February 2022 (in French), see https://www.vie-publique.fr/discours/283773-emmanuel-macron-10022022-politique-de-lenergie, accessed 8 August 2023.

1651 - EDF, "EDF announces the creation of its subsidiary NUWARD to boost the development of its SMR now entering the basic design phase", Press Release, Électricité de France, 30 March 2023, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/edf-announces-the-creation-of-its-subsidiary-nuward-to-boost-the-development-of-its-smr-now-entering-the-basic-design-phase, accessed 12 August 2024.

1652 - America Hernandez, "France's EDF to redraft small modular reactor design amid cost, technology concerns", *Reuters*, 1 July 2024, see https://www.reuters.com/business/energy/frances-edf-drops-plans-develop-its-own-small-nuclear-reactor-technology-2024-07-01/, accessed 1 July 2024.

1653 - Vattenfall, "Vattenfall begins feasibility study on construction of small modular reactors at Ringhals" Press Release, 28 June 2022, see https://group.vattenfall.com/press-and-media/pressreleases/2022/vattenfall-begins-pilot-study-on-construction-of-small-modular-reactors-at-ringhals, accessed 28 June 2022; and Vattenfall, "Vattenfall takes the next step for new nuclear power at Ringhals in Sweden", Press Release, 12 June 2024, see https://group.vattenfall.com/press-and-media/pressreleases/2024/vattenfall-takes-the-next-step-for-new-nuclear-power-at-ringhals-in-sweden, accessed 12 June 2024.

1654 - NUWARD, "NUWARD SMR – Leading the way to a low-carbon world", Hearing, Committee for Energy, Environment and Climate, Chamber of Representatives of Belgium, 30 May 2023, see https://www.lachambre.be/FLWB/PDF/55/3460/55K3460001.pdf, accessed 9 August 2023.

1655 - NUWARD, "NUWARD announces the submission of the NUWARD SMR Safety Options File to the French Safety Authority (ASN), which marks the start of the pre- licensing process", Press Release, 21 July 2023, see https://www.nuward.com/sites/nuward/files/2023-07/230721-NUWARD-SMR-DOS-Submission-EN.pdf, accessed 9 August 2023.

1656 - Kaori Kaneko, Osamu Tsukimori, and Geert De Clercq, "France reviews fast-breeder nuclear reactor project", *Reuters*, as published by WNISR, 29 November 2018, see https://www.worldnuclearreport.org/Reuters-UK-France-reviews-fast-breeder-nuclear-reactor-project.html, accessed 13 July 2024; and René Diez, "Marcoule : Astrid, le réacteur du futur enterré en catimini dans le Gard ?", *Midi Libre*, 24 August 2019 (in French), see https://www.midilibre.fr/2019/08/24/marcoule-astrid-le-reacteur-du-futur-enterre-en-catimini-dans-le-gard,8373770.php, accessed 12 August 2024.

INDIA

Over the past few years, India's government has been increasingly talking about small modular reactors.[1657] A particular focus has been on financial incentives to attract private companies into building SMRs, possibly imported from other countries.[1658] In the government's budget presented in July 2024, India's Finance Minister announced plans to "partner with the private sector for 1) setting up Bharat Small Reactors, (2) research & development of Bharat Small Modular Reactor, and (3) research & development of newer technologies for nuclear energy."[1659] The term Bharat SMR was new and was not defined in the official language. A member of India's Atomic Energy Commission has since clarified that it was just a modification of the traditional 220 MW Pressurized Heavy Water Reactor design widely deployed in India, but this design was going to be handed "over to the private sector".[1660]

Among foreign countries, France put out a statement following a state visit in July 2023, saying that both countries had "decided to launch an ambitious cooperation programme on Small Modular Reactors (SMRs) and Advanced Modular Reactors (AMRs)."[1661] And in March 2024, a Rosatom spokesperson was quoted as saying that the company was "in talks with India for small modular reactors."[1662]

At the same time, SMRs are unlikely to dominate India's nuclear plans. In December 2023, the government's spokesperson announced in response to a question in India's Parliament that the country was working on small nuclear reactors, but "SMRs are not expected to serve as replacement to conventional large-sized nuclear power plants."[1663]

What is peculiar about all these announcements about SMRs, including plans to import them, is that India's Department of Atomic Energy (DAE) has been engaged in the development of its own SMR design, the Advanced Heavy Water Reactor (AHWR), since the 1990s. Back in 2007, the then Director of the Reactor Design and Development Group at India's leading nuclear R&D organization, the Bhabha Atomic Research Centre, announced that construction of the AHWR

1657 - Press Information Bureau, "Union Minister Dr Jitendra Singh says, India taking steps for development of Small Modular Reactors (SMR), with up to 300 MW capacity to fulfill its commitment to Clean Energy transition", Press Release, Department of Atomic Energy, Government of India, 27 November 2022, see https://pib.gov.in/Pressreleaseshare.aspx?PRID=1879298; and Press Information Bureau, "Government is working on new technologies such as Small Nuclear Reactors to make clean energy transition", Press Release, Department of Atomic Energy, Government of India, 6 December 2023, see https://pib.gov.in/PressReleasePage.aspx?PRID=1982958; both accessed 12 August 2024.

1658 - Rituraj Baruah, "Govt plans sops for making small modular N-reactors", *Mint*, 3 November 2023, see https://www.livemint.com/news/india/govt-plans-sops-for-making-small-modular-nreactors-11699032050249.html, accessed 13 July 2024.

1659 - Nirmala Sitharaman, "Budget 2024-2025", Minister of Finance, Government of India, 23 July 2024, see https://www.indiabudget.gov.in/doc/budget_speech.pdf, accessed 12 August 2024.

1660 - Avinash Nair, "Bharat Small Reactors being readied, modification of 220 MW reactors under way, says Atomic Energy Commission's Grover", *BusinessLine/The Hindu*, 17 August 2024, see https://www.thehindubusinessline.com/economy/bharat-small-reactors-being-readied-modification-of-220-mw-reactors-under-way-says-atomic-energy-commissions-grover/article68535895.ece, accessed 18 August 2024.

1661 - French Presidency, "Visit to France of Prime Minister MODI – 13 and 14 July—Summary of deliverables by the French Presidency", Government of France, July 2023, see https://www.elysee.fr/admin/upload/default/0001/15/3255fa4b21ffddaebe3f269e8b30df9bb1a3d07a.pdf, accessed 12 August 2024.

1662 - M. Ramesh, "Rosatom in talks with India for small modular reactors", *Business Line*, 26 March 2024, see https://www.thehindubusinessline.com/news/rosatom-in-talks-with-india-for-small-modular-reactors/article67994176.ece, accessed 13 July 2024.

1663 - Government of India, "Government is working on new technologies such as Small Nuclear Reactors to make clean energy transition", 6 December 2023, op. cit.

was expected to begin by the end of the year.[1664] As described in WNISR2022 and WNISR2023, there is no indication that construction is due to start anytime soon. Earlier this year, when the head of the Nuclear Power Corporation of India was asked by *The Hindu*, a prominent newspaper, why the AHWR had been delayed by "so many years", he just responded with "I don't think there is any delay. We are on the right track" and the non-sequitur "Our three-stage programme is the best in the world".[1665] However, in light of the recent announcements about imported SMRs as well as new designs to be developed, there is good reason to think that the indigenously designed AHWR might have been shelved.

RUSSIA

Russia continues to develop a range of SMR designs,[1666] with a special focus on barge-mounted reactors for coastal locations also referred to as "floating" nuclear reactors or power plants. The first such project based on the KLT-40S design, a pressurized light water reactor, is operational since December 2019. Another project based on a fast neutron reactor design is under construction since June 2021.

Light Water Reactor Designs

Russia operates two KLT-40S SMRs loaded on a barge called the Akademik Lomonosov that is stationed near the town of Pevek in the Chukotka Autonomous region. The reactors were commissioned in May 2020 after lengthy delays and cost overruns that have been detailed in earlier WNISR editions. In November 2023, the first of these reactors was refueled with a full core of fresh fuel.[1667] According to the IAEA's PRIS database, the two reactors had load factors of just 26.6 and 43.4 percent in 2023, and lifetime load factors of just 32 and 28.2 percent.

Two more SMR projects based on light water reactor designs are underway. One is intended for supplying power to mining and processing plants in the Chukotka Autonomous region; according to the deputy head of Rosatom's engineering division, the target commissioning date for the first of four 55 MW RITM-200S reactors would be 2028.[1668] Earlier, at an event on the sidelines of the COP28 climate conference, Rosatom announced plans for these reactors to start supplying power "by 2029".[1669] The 55 MW RITM-200S is based on the RITM-200 series used in nuclear-powered icebreaker ships. Reportedly, the estimated cost of the project

1664 - T. S. Subramanian, "Innovative reactor", *Frontline*, 4 May 2007, see https://frontline.thehindu.com/other/advertorial/article30191213.ece, accessed 13 July 2024.

1665 - T. S. Subramanian, "India will 'commission a nuclear power reactor every year': NPCIL chief", *The Hindu*, 18 January 2024, see https://www.thehindu.com/sci-tech/science/npcil-commission-nuclear-power-reactor-every-year-pathak-interview/article67751083.ece, accessed 18 January 2024.

1666 - Vladimir Kuznetsov, "Small modular reactors (SMRs): The case of Russia", Chapter 19, in "Handbook of Small Modular Nuclear Reactors", Second Edition, ed. by Mario D. Carelli, *Woodhead Publishing*, 2021, see https://www.sciencedirect.com/science/article/pii/B9780128239162000199, accessed 19 June 2023.

1667 - Rosatom, "Newsletter #271—Akademik Lomonosov Refueled", November 2023, see https://rosatomnewsletter.com/2023/11/29/akademik-lomonosov-refueled/, accessed 13 August 2024.

1668 - Alfie Shaw, "Floating nuclear power plant to provide energy for Russian mining", *Power Technology*, 26 June 2024, see https://www.power-technology.com/news/russia-to-install-another-floating-nuclear-power-plant/, accessed 26 June 2024.

1669 - Rosatom, "ROSATOM demonstrates progress in implementing low-capacity nuclear power projects at the SMR Day", Press Release, 4 December 2023, see https://www.rosatom.ru/en/press-centre/news/rosatom-demonstrates-progress-in-implementing-low-capacity-nuclear-power-projects-at-the-smr-day/, accessed 13 August 2024.

is RUB900 billion (US$10 billion).[1670] Keel laying for the barge—considered as the equivalent of construction start for floating reactors—that is to hold two RITM-200S reactors commenced in August 2022.[1671] The barge is being built in China, by Wison (Nantong) Heavy Industries, which in 2021 won the contract at a reported price of US$226 million.[1672]

Another SMR project that is starting up is in Yakutia, in the Arctic region of the country, and involves a (land-based) RITM-200N reactor design. The project received a license to construct in April 2023.[1673] Over a year later, in May 2024, the Russian Natural Resources Supervision Authority (Rosprirodnadzor) approved the environmental impact assessment.[1674] As of mid-2024, the plan is to commission the reactor in 2028.[1675] However, in June 2024, Rosatom and the local government announced that the project might expand from building one reactor to two reactors, citing anticipations that future energy demands might be higher than envisioned earlier.[1676]

Fast Neutron Reactor Designs

Russia is also constructing SMR designs based on fast neutron technology. The first of these, the lead-cooled BREST-300, was developed by the NA Dollezhal Research and Development Institute of Power Engineering (Nikiet) and is under construction at the Siberian Chemical Combine (SCC) in Seversk.[1677] When construction started in June 2021, the reactor was officially expected to begin to operate in 2026,[1678] and the cost of the reactor, according to one source, was RUB100 billion (US$$_{2021}$1.4 billion).[1679] However, the BREST-300 is only intended to be a demonstration unit; if it is successful, Rosatom plans to follow up with a 1200 MW unit.

1670 - Alfie Shaw, "Floating nuclear power plant to provide energy for Russian mining", *Power Technology*, 26 June 2024, op. cit.

1671 - Rosatom, "Keel-laying ceremony for the first Arctic-type Floating Power Unit with RITM-200 transport reactor vessels", Press Release, 30 August 2022, see https://rosatom-mena.com/press-centre/news/keel-laying-ceremony-for-the-first-arctic-type-floating-power-unit-with-ritm-200-transport-reactor-v/, accessed 5 October 2022.

1672 - Amber Wang, "First Chinese firm wins contract for Russian floating nuclear power project", *South China Morning Post*, 16 September 2021, see https://www.scmp.com/news/china/diplomacy/article/3148884/first-chinese-firm-wins-contract-russian-floating-nuclear, accessed 8 August 2023.

1673 - Rosatom, "Rosatom obtained a license for the first land-based SMR in Russia", Press Release, 24 April 2023, see https://rosatom-asia.com/press-centre/news/rosatom-obtained-a-license-for-the-first-land-based-smr-in-russia/, accessed 13 August 2024.

1674 - Rosatom, "The innovative SNPP in Yakutia obtained positive conclusion for the power unit construction from the Russian Natural Resources Supervision Authority", Press Release, 23 May 2024, see https://atommedia.online/en/2024/05/23/innovacionnaya-yakutskaya-asmm-poluchil/, accessed 31 May 2024.

1675 - Afrikantov OKBM JSC, "The RITM-200N reactor as a terrestrial unit", Atomenergomash/Rosatom, as published in *Nuclear Engineering International*, 26 June 2024, see https://www.neimagazine.com/analysis/the-ritm-200n-as-a-terrestrial-unit/, accessed 28 June 2024.

1676 - Atom Media, "Rosatom and the Republic of Sakha (Yakutia) have signed an agreement on Yakut small modular reactor nuclear power plant capacity loading", Press Release, Rosatom, 6 June 2024, see https://atommedia.online/en/2024/06/06/rosatom-i-respublika-saha-yakutiya-podp/, accessed 13 August 2024.

1677 - Darrell Proctor, "Nuclear First—Work Starts on Russian Fast Neutron Reactor", *POWER Magazine*, 8 June 2021, see https://www.powermag.com/nuclear-first-work-starts-on-russian-fast-neutron-reactor/, accessed 27 June 2021.

1678 - Rosatom, "ROSATOM starts construction of unique power unit with BREST-OD-300 fast neutron reactor", Press Release, 8 June 2021, see https://www.rusatom-energy.ru/en/media/rosatom-news/rosatom-starts-construction-of-unique-power-unit-with-brest-od-300-fast-neutron-reactor/, accessed 13 August 2024.

1679 - *TASS*, "Cost of BREST fast reactor construction estimated at $1.3 bln, says Rosatom", 8 June 2021, see https://tass.com/economy/1300401, accessed 14 August 2024.

Export Prospects

Rosatom also continues with its plans to export SMRs. In May 2024, Russia signed a contract with Uzbekistan to build an SMR.[1680] Alexey Likhachev stated, "This is not a provisional agreement—we will start the construction immediately, as soon as this summer." The project is to construct a 330 MW nuclear power plant, consisting of six 55-MW RITM-200 SMRs, to be built in the Jizzakh Region of Uzbekistan; the "first unit is scheduled to go critical in late 2029" and the "units will be commissioned one by one."[1681] No cost estimate has been announced but it has been reported that Russia and Uzbekistan have "set up a joint fund of US$500 million to finance projects in Uzbekistan, with US$400 million coming from the Russian side."[1682]

SOUTH KOREA

South Korea has long been developing the System-Integrated Modular Advanced Reactor (SMART), a 100-MW pressurized water reactor design, but even though it was licensed in 2012, there have been no orders because of its high estimated construction cost per unit of capacity (see earlier WNISR editions). Efforts to develop other designs, including a smaller capacity (70 MW thermal) light-water design called Advanced Reactor for Multipurpose Research Applications (ARA), the innovative SMR (i-SMR), a molten salt reactor, and a sodium-cooled fast reactor (SFR), have also been detailed in earlier WNISR editions.

Despite its non-existent domestic prospects, the SMART design continues to be offered to external markets. In December 2023, the Korea Atomic Energy Research Institute (KAERI) signed an MoU with Hyundai Engineering "aimed at advancing international projects involving SMART technology".[1683] The agreement should be seen in light of the adverse economics of SMART, with a "target overnight plant construction cost" for a first of a kind plant being estimated at US$10,000/kW(e).[1684] Efforts to export SMART reactors to Saudi Arabia have resulted in multiple MoUs (for example, in 2015 and 2020) and statements, but no orders.

The poor prospects for SMART led to a number of Korean institutions, in particular, Korea Hydro and Nuclear Power (KHNP) and KAERI, starting work in 2020 on a new offering, the "i-SMR" for "innovative SMR".[1685] According to KAERI analysts, the "target capital costs" for

1680 - Rosatom, " The Russian Federation and Uzbekistan sign an agreement on the construction of a small nuclear power plant", Press Release, 27 May 2024, see https://www.rosatom.ru/en/press-centre/news/-the-russian-federation-and-uzbekistan-sign-an-agreement-on-the-construction-of-a-small-nuclear-powe/, accessed 13 August 2024; and Catherine Putz, "Uzbekistan, Russia to Start Construction of Small Nuclear Power Plants", *The Diplomat*, 29 May 2024, see https://thediplomat.com/2024/05/uzbekistan-russia-to-start-construction-of-small-nuclear-power-plants/, accessed 31 May 2024.

1681 - Rosatom, "Newsletter #278—First SMRs for Export", June 2024, see https://rosatomnewsletter.com/2024/06/28/first-smrs-for-export/, accessed 14 July 2024.

1682 - Catherine Putz, "Uzbekistan, Russia to Start Construction of Small Nuclear Power Plants", *The Diplomat*, 29 May 2024, op. cit.

1683 -KAERI, "SMART Collaboration: KAERI and Hyundai Engineering Pave the Way for Global Nuclear Innovation", 12 December 2023, accessed 13 August 2024; and NEI Magazine, "KAERI and Hyundai Engineering to promote export of SMART SMR", Nuclear Engineering International, 13 December 2023, see https://www.neimagazine.com/news/kaeri-and-hyundai-engineering-to-promote-export-of-smart-smr-11369646/, accessed 11 June 2024.

1684 -IAEA, "Advances in Small Modular Reactor Technology Developments—A Supplement to IAEA Advanced Reactors Information System (ARIS) 2020 Edition", International Atomic Energy Agency, September 2020, p. 56, see https://aris.iaea.org/Publications/SMR_Book_2020.pdf, accessed 8 August 2023.

1685 - IAEA, "Advances in Small Modular Reactor Technology Developments—A Supplement to: Advanced Reactors Information System (ARIS) 2022 Edition", September 2022; and Jung Min-hee, "KHNP to Accelerate Development of Innovative SMRs", *Businesskorea*, 20 April 2021, see http://www.businesskorea.co.kr/news/articleView.html?idxno=65179, accessed 24 June 2021.

this design, in order "to be competitive in the global market", should be "around [US]$4,000/kWe for FOAK [First-of-a-kind] unit and around [US]$3,000/kWe for NOAK [Nth-of-a-kind] units".[1686] The project became more prominent in July 2023, when the Ministries of Trade, Industry and Energy, and Science and ICT [Information and Communication Technology] announced KRW399 billion (US$$_{2023}$306 million) in funding to establish the "Innovative [SMR] Technology Development Project" with the goal of obtaining the Standard Design Approval (SDA) by 2028.[1687] The updated timeline, according to the i-SMR Development Agency's website as seen in August 2024, envisions approval by 2029 (or the end of 2028), construction to start by 2029 and be completed by 2031, followed by "continuous construction".[1688]

As of May 2024, the national regulator expects to receive an SDA application in 2026.[1689] The same month, the President and CEO of KHNP told *Energy Intelligence Weekly* that the aim was to "complete the first-of-a-kind unit of the i-SMR by the early 2030s" but also said that "efforts are being made to expedite the schedule".[1690] Also, the working-level draft of the 11th Basic Plan on Electricity Supply and Demand released the same month included plans to build 0.7 GW of SMR capacity by 2033–34.[1691] That capacity corresponds to four i-SMR units of 170 MW each.[1692]

At the 28th United Nations Climate Change Conference (COP28) in December 2023, KHNP signed MoUs with Indonesia's PLN Nusantara Power and the Jordan Atomic Energy Commission to explore deploying i-SMRs in these countries.[1693] Going by past history, these MoUs might not lead to any definite orders. For example, Jordan signed an MoU in March 2017 with Saudi Arabia's King Abdullah City for Atomic and Renewable Energy to study the feasibility of constructing "two small modular reactors in Jordan for the production of electricity and desalinated water"; the King Abdullah City for Atomic and Renewable Energy had signed an agreement with KAERI in September 2015 to cooperate on developing the SMART.[1694] That has

1686 - Kee-Hwan Moon and Seung-Su Kim, "An Exploratory Study on a Target Capital Cost and Cost Reduction Methodologies of Innovative SMR in Korea", Korea Atomic Energy Research Institute, in "Transactions of the Korean Nuclear Society Virtual Spring Meeting", 9–10 July 2020, see https://www.kns.org/files/pre_paper/43/20S-659-%EA%B9%80%EC%8A%B9%EC%88%98.pdf, accessed 18 August 2024.

1687 - *Yonhap*, "Korea launches project team to foster small modular reactor", *The Korea Times*, 10 July 2023, see https://www.koreatimes.co.kr/www/tech/2023/07/419_354648.html, accessed 18 July 2023; and MOTIE, "Korea kicks off Project Team for innovative SMRs", Press Release, Ministry of Trade, Industry and Energy, 14 July 2023, see https://english.motie.go.kr/en/pc/pressreleases/bbs/bbsView.do?bbs_cd_n=2&bbs_seq_n=1358, accessed 8 August 2023.

1688 - Innovative Small Modular Reactor Development Agency, "Milestone", 2023, see https://ismr.or.kr/eng/sub/milestone, accessed 18 August 2024.

1689 - NSSC, "Competition for New Projects to Preemptively Prepare SMR Regulatory Framework", Press Release, Nuclear Safety and Security Commission, 27 March 2024, see https://www.nssc.go.kr/en/cms/FR_BBS_CON/BoardView.do?MENU_ID=90&CONTENTS_NO=1&SITE_NO=3&BOARD_SEQ=1&BBS_SEQ=46288, accessed 13 August 2024.

1690 - Jessica Sondgeroth, "Interview: KHNP CEO Whang Joo-ho on Czech Bid and Deploying the i-SMR", Interview with Whang Joo-ho, President and CEO, KHNP, *Energy Intelligence*, 3 May 2024, see https://www.energyintel.com/0000018f-348a-dae0-afbf-fc8f85a50000, accessed 7 May 2024.

1691 - Dong-Seok Oh, John Sangho Park et al., "Key Contents of the Working-Level Draft of the 11th Basic Plan on Electricity Supply and Demand", Kim & Chang, 10 June 2024, see https://www.kimchang.com/en/insights/detail.kc?sch_section=4&idx=29746, accessed 18 August 2024.

1692 - Innovative Small Modular Reactor Development Agency, "i-SMR—Innovative Design", Undated, see https://ismr.or.kr/eng/sub/innovation, accessed 13 August 2024.

1693 - *WNN*, "KHNP touts i-SMR to international audience", 4 December 2023, see https://world-nuclear-news.org/Articles/KHNP-touts-i-SMR-to-international-audience, accessed 27 May 2024.

1694 - *WNN*, "Jordan and Saudi Arabia team up on uranium, SMRs", 29 March 2017, see http://www.world-nuclear-news.org/Articles/Jordan-and-Saudi-Arabia-team-up-on-uranium,-SMRs, accessed 24 June 2019; Joy Nasr and Ali Ahmad, "Middle East Nuclear Energy Monitor: Country Perspectives 2018", Energy Policy and Security Program, Issam Fares Institute for Public Policy and International Affairs, American University of Beirut, January 2019.

not led to SMART being built in Jordan. The i-SMR will also not meet other goals expressed by Jordan's policymakers in the past, including electricity generation costs that are economically competitive and not wanting their country to be a guinea pig for new designs.[1695]

In recent years, South Korean organizations have also announced plans to develop designs other than light water reactors. In June 2024, Hyundai Engineering & Construction and KAERI signed a further agreement to "develop a sodium-cooled fast reactor (SFR) through a public-private partnership."[1696] A few months earlier, a subsidiary of Hyundai announced it was making plans with TerraPower in the U.S. to develop its Molten Chloride Fast Reactor design for shipping applications.[1697] Earlier, in 2021, KAERI paired with Samsung Heavy Industries to announce plans "to develop molten salt reactors for marine propulsion and floating nuclear power plants".[1698]

UNITED KINGDOM

The United Kingdom's SMR program is about a decade old and can be dated to a 2014 feasibility study carried out by the government's National Nuclear Laboratory and funded by seven organizations with nuclear activities, including Rolls-Royce.[1699] The study talked about positioning the U.K. "as a global technology vendor" even as it admitted that no U.K. based firm had produced a suitable SMR design. As Prof. Stephen Thomas pointed out in a submission to the U.K. Parliament, this mismatch is "hard to understand", and the report's forecast for SMR demand was "unrealistically high" in 2014 and "blatantly unachievable" by the time he wrote this submission in 2023.[1700]

The absence of a U.K. design ceased to be a problem after 2017 when Rolls-Royce announced its own SMR design, initially rated at 440 MW of electricity,[1701] i.e., not really meeting the definition of a small reactor as one designed to generate under 300 MW of power. By 2021 the Rolls-Royce SMR design was further uprated to 470 MW, and its Chief Technical Officer

1695 - M.V Ramana and Ali Ahmad, "Wishful thinking and real problems: Small modular reactors, planning constraints, and nuclear power in Jordan", *Energy Policy*, Vol. 93, June 2016, see https://www.sciencedirect.com/science/article/abs/pii/S0301421516301136, accessed 11 April 2020.

1696 - Hyundai Engineering & Construction, "Hyundai E&C and KAERI Cooperate to Commercialize Next-Generation SMR, SFR", Press Release, 12 June 2024, see https://www.hdec.kr/en/newsroom/news_view.aspx?NewsSeq=996&NewsType=LATEST&NewsListType=news_clist, accessed 13 August 2024.

1697 - Marcus Hand, "HD Hyundai accelerates maritime nuclear development with TerraPower", *Seatrade Maritime*, 6 February 2024, see https://www.seatrade-maritime.com/shipyards/hd-hyundai-accelerates-maritime-nuclear-development-terrapower, accessed 11 June 2024; and HD Korea Shipbuilding and Offshore Engineering, "HD현대, 글로벌 SMR 선도기업과 손잡고 해상 원자력 시장 개척 나선다", Press Release (in Korean), HD Hyundai, 3 February 2024, see https://www.hdksoe.co.kr/media01_view, accessed 23 August 2024.

1698 - Charles Lee, "South Korea companies develop molten salt reactor for shipping, power generation", S&P Global Platts, 22 June 2021, see https://www.spglobal.com/platts/en/market-insights/latest-news/metals/062221-south-korea-companies-develop-molten-salt-reactor-for-shipping-power-generation, accessed 23 June 2021.

1699 - NNL, "Small Modular Reactors (SMR) Feasibility Study", National Nuclear Laboratory, December 2014, see https://www.nnl.co.uk/wp-content/uploads/2019/02/smr-feasibility-study-december-2014.pdf, accessed 13 August 2024.

1700 - Stephen Thomas, "The UK SMR programme", University of Greenwhich, Written Evidence submitted to U.K. Parliament, November 2023, see https://committees.parliament.uk/writtenevidence/126328/pdf/, accessed 21 July 2024.

1701 - Rolls Royce, "UK SMR: A National Endeavour", September 2017, see https://nuclear.foe.org.au/wp-content/uploads/Rolls-Royce-2017-SMR-national-endeavour-see-p22.pdf, accessed 6 July 2019.

traced the increase to a desire "to minimise the cost of energy coming out…the cost being the historical challenge of nuclear power."[1702]

In April 2024, Rolls-Royce announced that it would not build its own factory to manufacture the pressure vessels for its design, and would instead purchase these from a different company.

In April 2024, Rolls-Royce announced that it would not build its own factory to manufacture the pressure vessels for its design, and would instead purchase these from a different company.[1703] The decision might be part of efforts by the new head of Rolls-Royce, Tufan Erginbilgic, to avoid "costly side bets" and focus on its core business of "making aero engines and diesels", as an aviation analyst put it.[1704]

In a sign of uncertainty about the readiness of the Rolls-Royce design, in February 2024, Community Nuclear Power passed up Rolls-Royce for its North Teesside project, choosing instead Westinghouse's AP300 reactor design.[1705] This loss was balanced to some extent when in May 2024, the Polish Government announced that it had taken a decision in principle on ordering the Rolls-Royce SMR,[1706] and by Rolls-Royce being short-listed by Vattenfall for the Ringhals site in Sweden in June 2024; the other company with a design under consideration by Vattenfall is GE-Hitachi.[1707]

As of January 2023, six SMR designs had been submitted to the Office for Nuclear Regulation (ONR) for Generic Design Assessments (GDAs).[1708] The designs were:

- GE-Hitachi's BWRX-300 boiling water reactor,
- Holtec's SMR-160 pressurized water reactor,
- X-energy's high-temperature gas cooled reactor,
- Newcleo's lead-cooled fast reactor,
- Copenhagen Atomics's thorium molten salt reactor, and
- a Cumbrian engineering group called GMET, which said it is developing a small reactor called NuCell but has not even specified what kind of reactor design it is.

1702 - *WNN*, "Rolls-Royce on track for 2030 delivery of UK SMR", 11 February 2021, see https://world-nuclear-news.org/Articles/Rolls-Royce-on-track-for-2030-delivery-of-UK-SMR, accessed 27 June 2021.

1703 - Matt Oliver, "Rolls-Royce scales back plans to build nuclear factories in UK", *The Telegraph*, 27 April 2024, see https://www.telegraph.co.uk/business/2024/04/27/rolls-royce-plans-build-smr-water-vessel-factory-uk/, accessed 21 July 2024.

1704 - Howard Mustoe, "The 'ruthless' axeman carving out a new future for Rolls-Royce", *The Telegraph*, 28 May 2023, see https://www.telegraph.co.uk/business/2023/05/28/rolls-royce-tufan-erginbilgic/, accessed 31 May 2023.

1705 - Philip Whiterow, "Rolls-Royce snubbed for UK's first private nuclear plant", ProactiveInvestors UK, 8 February 2024, see https://www.proactiveinvestors.co.uk/companies/news/1040531/rolls-royce-snubbed-for-uk-s-first-private-nuclear-plant-1040531.html, accessed 21 July 2024.

1706 - Rolls Royce, "Polish Government issues decision in principle on Rolls-Royce SMRs", Press Release, 14 May 2024, see https://www.rolls-royce-smr.com/press/polish-government-issues-decision-in-principle-on-rolls-royce-smrs, accessed 27 July 2024.

1707 - Vattenfall, "Vattenfall takes the next step for new nuclear power at Ringhals in Sweden", Press Release, 12 June 2024, see https://group.vattenfall.com/press-and-media/pressreleases/2024/vattenfall-takes-the-next-step-for-new-nuclear-power-at-ringhals-in-sweden, accessed 12 June 2024.

1708 - *Professional Engineering*, "SMR developers submit 6 designs for UK approval", Institution of Mechanical Engineers, 6 January 2023, see https://www.imeche.org/news/news-article/smr-developers-submit-6-designs-for-uk-approval, accessed 16 July 2023; and BEIS, "Policy Paper—Advanced Nuclear Technologies", U.K. Government, as archived on Wayback Machine, Updated 4 January 2023, see https://web.archive.org/web/20230104203516/https://www.gov.uk/government/publications/advanced-nuclear-technologies/advanced-nuclear-technologies#regulation, accessed 14 August 2024.

In April 2024, however, ONR's newsletter reported that it was "currently carrying out Generic Design Assessments (GDAs) on Small Modular Reactor (SMR) technologies proposed by Rolls-Royce SMR Ltd, Holtec International and GE-Hitachi Nuclear Energy International LLC".[1709] In a response dated 13 June 2024 to a letter from the chair of U.K./Ireland Nuclear Free Local Authorities Steering Committee, a senior official from the Department of Energy Security and Net Zero (DESNZ) confirmed that "UK Atomics, Newcleo and GMET did not meet the GDA entry criteria as set out in the GDA Entry Guidance."[1710]

Although the official did not say anything about X-energy, it would seem that it too was not found ready for a Generic Design Assessment, because it was not listed as being under review for GDA entry criteria. In April 2024, however, DESNZ had announced a £3.34 million (US$4.2 million) grant under the Future Nuclear Enabling Fund to Cavendish Nuclear, which has partnered with X-Energy to develop the reactor design.[1711] Other recipients of grants from DESNZ under this fund are GE-Hitachi with £33.6 million (US$$_{2023}$41.8 million) in January 2023 and Holtec Britain Limited which was awarded £30.05 million (US$$_{2023}$37 million) in December 2023.

The fact that four of six reactor designs mentioned in the January 2023 announcement (see above) were not accepted in the GDA process is consistent with the suggestion made by Thomas late last year that the January 2023 announcement "is not related to any subsequent developments".[1712]

In February 2024, Westinghouse announced that it had submitted an application to the DESNZ for the AP300 SMR design to be put through the Generic Design Assessment process.[1713] As of mid-2024, the ONR was not evaluating the AP300.[1714] Nevertheless in May 2024, Westinghouse announced that it "has signed an agreement with Community Nuclear Power… to deploy the U.K.'s first privately-financed small modular reactor fleet."[1715] Community Nuclear Power is a newly created company, incorporated only in September 2022, with no track record of building nuclear reactors or any electricity plants. In its confirmation statement dated 4 September 2023, its "principal activity" was listed as "management consultancy activities other than financial

1709 - ONR, "ONR News - April 2024", Office for Nuclear Regulation news, 19 April 2024, see https://news.comms.onr.gov.uk/p2h8/send/mj-te43, accessed 21 July 2024.

1710 - NFLA, "NFLA Policy Briefing No. 302—Correspondence with DESNZ and EA over nuclear design justification", Nuclear Free Local Authorities, 16 July 2024, see https://www.nuclearpolicy.info/briefings/nfla-policy-briefing-302-correspondence-with-desnz-and-ea-over-nuclear-design-justification/, accessed 1 August 2024.

1711 - Department of Energy Security and Net Zero, "Future Nuclear Enabling Fund: successful applicants", U.K. Government, Updated 4 April 2024, see https://www.gov.uk/government/publications/future-nuclear-enabling-fund-shortlisted-applications/future-nuclear-enabling-fund-successful-applicant, accessed 1 August 2024.

1712 - Stephen Thomas, "The UK SMR programme", Written Evidence submitted to U.K. Parliament, November 2023, op. cit.

1713 - Westinghouse, "Westinghouse Initiates UK Generic Design Assessment Process for the AP300™ Small Modular Reactor", Press Release, 13 February 2024, see https://info.westinghousenuclear.com/news/westinghouse-initiates-uk-generic-design-assessment-process-for-the-ap300-small-modular-reactor, accessed 1 April 2024.

1714 - ONR, "Generic Design Assessment—Assessment of reactors—Current assessments", Updated 1 August 2024, see https://www.onr.org.uk/generic-design-assessment/assessment-of-reactors/, accessed 13 August 2024.

1715 - Westinghouse, "Westinghouse and UK's Community Nuclear Power Collaborate to Deploy Fleet of AP300™ Small Modular Reactors", Press Release, 7 May 2024, see https://info.westinghousenuclear.com/uk/news-insights/westinghouse-and-uks-community-nuclear-power-collaborate-to-deploy-fleet-of-ap300-small-modular-reactors, accessed 8 May 2024.

management”.[1716] Its balance sheet, as of 30 September 2023, consisted of 100 shares of £1 each, i.e., a total of £100 (US$$_{2023}$124) in all.[1717]

A seemingly separate government process to support SMRs has been through the “Great British Nuclear (GBN)” program, first announced in April 2022 and then re-announced in March 2023 as part the 2023 Spring Budget, which declared that SMRs “will be the initial focus of GBN, but further gigawatt-scale projects will also be considered in future.”[1718] In July 2023, then Energy Security Secretary Grant Shapps announced that GBN “will drive the rapid expansion of new nuclear power plants in the UK at an unprecedented scale and pace” and called upon companies to “register their interest with GBN to participate in a competition to secure funding support to develop their products” which could “result in billions of pounds of public and private sector investment in small modular reactor (SMR) projects in the UK.”[1719]

GBN then announced that it had set up a selection process “to identify the best, most appropriate, SMR technologies” and that it would offer financial support to companies whose designs are selected to help them further develop their technologies in preparation for “a Final Investment Decision” to be made by 2029.[1720] In a separate notice, GBN indicated that the estimated value of total funding is £20 billion (US$$_{2023}$25 billion) for 186 months (i.e., till 2039).[1721] Ironically, in July 2024, the chancellor appointed by the recently elected Labour government accused the Conservatives of “hiding a £21.9bn [US$27.8 billion] government overspend”.[1722]

In October 2023, GBN announced that EDF, GE-Hitachi, Holtec, NuScale, Rolls-Royce and Westinghouse were now allowed to bid for funding.[1723] Subsequently, in July 2024, EDF withdrew from the competition.[1724]

1716 - Community Nuclear Power Limited, “Advanced Company Search—Community Nuclear Power Limited—Filing History—Confirmation Statement”, filed with Companies House, confirmed 4 September 2023, see https://find-and-update.company-information.service.gov.uk/company/14337637/filing-history, accessed 1 August 2024.

1717 - Community Nuclear Power Limited, “Community Nuclear Power Limited—Dormant Accounts”, filed with Companies House, as of 30 September 2023, approved 11 June 2024, see https://find-and-update.company-information.service.gov.uk/company/14337637/filing-history, accessed 1 August 2024.

1718 - U.K. Government, “Policy Paper—Spring Budget 2023”, Updated 21 March 2023, see https://www.gov.uk/government/publications/spring-budget-2023/spring-budget-2023-html, accessed 13 August 2024.

1719 - Department for Energy Security and Net Zero, Great British Nuclear, and Nuclear Decommissioning Authority, “British nuclear revival to move towards energy independence”, Press Release, U.K. Government, 18 July 2023, see https://www.gov.uk/government/news/british-nuclear-revival-to-move-towards-energy-independence, accessed 4 July 2024.

1720 - Great British Nuclear, “Small Modular Reactors: competitive technology selection process”, U.K. Government, 19 July 2023, see https://www.gov.uk/guidance/small-modular-reactors-competitive-technology-selection-process, accessed 3 August 2023.

1721 - Great British Nuclear, “Contract Notice—Small Modular Reactor Technology Partner”, Notice 2023/S 000-020640, 18 July 2023, see https://www.find-tender.service.gov.uk/Notice/020640-2023?origin=SearchResults&p=1, accessed 16 July 2024.

1722 - *BBC*, “Rachel Reeves's spending audit at-a-glance”, 29 July 2024, see https://www.bbc.com/news/articles/cd1r7d76vdlo, accessed 1 August 2024.

1723 - Department for Energy Security & Net Zero and Great British Nuclear, “Six companies through to next stage of nuclear technology competition”, U.K. Government, 2 October 2023, see https://www.gov.uk/government/news/six-companies-through-to-next-stage-of-nuclear-technology-competition, accessed 13 August 2024.

1724 - *WNN*, “EDF withdraws from UK's SMR selection competition”, 9 July 2024, see https://world-nuclear-news.org/Articles/EDF-pulls-out-of-British-SMR-competition, accessed 9 July 2024.

UNITED STATES

Industry claims, official announcements, and media coverage related to SMRs in the United States continue to portray them as the future of nuclear power. An example of this kind of presentation surrounded a June 2024 ceremony in Wyoming where TerraPower, the company behind the Natrium design, stated in a press release that it had marked "the start of construction on the Natrium reactor demonstration project," and claimed further that it was "the first advanced reactor project to move from design into construction".[1725] Bill Gates, founder of TerraPower, proclaimed at the ceremony: "The ground we broke in Kemmerer will soon be the bedrock of America's energy future," adding "I'm thrilled to see so much economic growth happening, because Kemmerer will soon be home to the most advanced nuclear facility in the world."[1726]

The claims were far out of proportion to the preliminary stage at which TerraPower is in its plans, with many possible hurdles ahead. The company had just submitted a construction permit application to the Nuclear Regulatory Commission (NRC) a few months prior to this event.[1727] It had not received an approval to start any nuclear construction.[1728] Instead, what it received from the NRC in March 2024 was a list of around 50 items that need to be addressed, establishing that the application "needs work" as *Reuters* described the situation.[1729] Nor has TerraPower secured future access to High-Assay Low-Enriched Uranium (HALEU) fuel that it needs to put into the core of the reactor.[1730]

Even if all these problems were to be overcome, the Natrium reactor will be uneconomical. When asked by *CBS News* how much the Wyoming reactor would cost, Bill Gates admitted:

> Well, if you count all the first of a kind costs, you know, where we've been working for many years designing this thing, you could get a number close to [US$]10 billion. But the key number to look at is, as you're building more and more units and you're getting all the components or your suppliers are bringing their costs down, the payoff for the investors is if we build a lot. (…)

1725 - TerraPower, "TerraPower Begins Construction on Advanced Nuclear Project in Wyoming", Press Release, 10 June 2024, see https://www.terrapower.com/downloads/grounbreaking-press-release.pdf, accessed 14 June 2024.

1726 - Rana Jones, "TerraPower breaks ground for nuclear power plant", *Wyoming Business Report,* 18 June 2024.

1727 - TerraPower, "TerraPower Submits Construction Permit Application to the U.S. Nuclear Regulatory Commission for the Natrium Reactor Demonstration Project", Press Release, 29 March 2024, see https://www.terrapower.com/terrapower-submits-cpa-nrc/, accessed 1 April 2024.

1728 - *WNN*, "TerraPower breaks ground for Natrium plant", 11 June 2024, see https://www.world-nuclear-news.org/Articles/TerraPower-breaks-ground-for-Natrium-plant, accessed 11 June 2024.

1729 - U.S. NRC, "Subject: TerraPower, LLC - preapplication readiness assessment report for Kemmerer Power Station Unit 1 preliminary construction permit application", addressed to TerraPower, 19 March 2024, see https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML24060A227, accessed 7 July 2024; and Timothy Gardner, "US says Gates-backed reactor company's planned application needs work", *Reuters*, 22 March 2024, see https://www.reuters.com/business/energy/us-says-gates-backed-reactor-companys-planned-application-needs-work-2024-03-22/, accessed 8 July 2024.

1730 - *WNN*, "HALEU fuel availability delays Natrium reactor project", 15 December 2022, see https://world-nuclear-news.org/Articles/HALEU-fuel-availability-delays-Natrium-reactor-pro, accessed 14 August 2023; and Paul Day, "First TerraPower advanced reactor on schedule but fuel a concern", *Reuters*, 9 May 2024, see https://www.reuters.com/business/energy/first-terrapower-advanced-reactor-schedule-fuel-concern-2024-05-09/, accessed 13 May 2024; also Framatome, "Framatome and TerraPower agree to develop HALEU metallization pilot production facility", Press Release, 29 May 2024, see https://www.framatome.com/medias/framatome-and-terrapower-agree-to-develop-haleu-metallization-pilot-production-facility/, accessed 2 June 2024.

> We have discussions with utilities about building tens of these, but, you know, we really only have huge impact and success if we get past 100.[1731]

That figure of 100 reactors exceeds the total number of power reactors operating today in the United States.

The Natrium reactor is designed to generate 345 MW, but because it would be storing part of its output as heat in molten salt,[1732] it could theoretically produce up to 500 MW for around 5.5 hours.[1733] Thus, on average, it could theoretically generate around 380 MW (which means it does not really fit the definition of a small reactor as designed to generate under 300 MW of electric power). If the total cost of the Natrium reactor is US$10 billion, the per unit cost works out to be over US$26,000/kW. The cost figure of US$10 billion should be compared to the final cost estimate of US$9.3 billion for NuScale's 462 MW Utah Associated Municipal Power Systems (UAMPS) project, or around US$20,000/kW, which led to that project being abandoned.[1734]

Despite such obvious problems, the U.S. Government continues to offer large amounts of funding for SMRs and slightly larger reactors. In June 2024, the U.S. Department of Energy announced US$900 million of funding to support the deployment of light-water small modular reactors, with US$800 million earmarked for "up to two first-mover teams of utility, reactor vendor, constructor, and end-users or power off-takers committed to deploying a first plant while at the same time facilitating a multi-reactor, Gen III+ [Generation III+] SMR orderbook" and up to US$100 million to fix "key gaps" troubling the domestic nuclear industry in areas including "design, licensing, supplier development and site preparation", with the goal of spurring additional Gen III+ SMR deployments.[1735] Gen III+ SMR refers to light water reactor technologies, and it is expected that NuScale will be one of the beneficiaries of this funding, since it has already received at least US$560 million from DOE.[1736] While the DOE is providing millions of dollars to NuScale, the U.S. Department of State has been, according to NuScale's Second Quarter 2024 earnings presentation, advocating "for NuScale internationally, advancing prospective customer conversations globally."[1737]

1731 - Margaret Brennan, "Transcript: Bill Gates on 'Face the Nation'", Interview with Bill Gates, *CBS News*, 16 June 2024, see https://www.cbsnews.com/news/bill-gates-transcript-face-the-nation-06-16-2024/, accessed 20 July 2024.

1732 - This feature might add a couple of billion dollars to the cost. See M. V. Ramana and Arjun Makhijani, "Look before you leap on nuclear", *Casper Star-Tribune*, 16 October 2021, see https://trib.com/opinion/columns/ramana-makhijani-look-before-you-leap-on-nuclear/article_4508639b-d7e6-50df-b305-07c929de40ed.html, accessed 16 October 2021.

1733 - TerraPower, "TerraPower Submits Construction Permit Application to the U.S. Nuclear Regulatory Commission for the Natrium Reactor Demonstration Project", Press Release, March 2024, op. cit.

1734 - UAMPS, "Talking Points", Utah Associated Municipal Power Systems, 2 January 2023, see https://ieefa.org/sites/default/files/2023-01/UAMPS%20Talking%20Points%20_%20Class%203%20_%2020230102%20_%20Final.pdf, accessed 9 June 2023; and NuScale, "Utah Associated Municipal Power Systems (UAMPS) and NuScale Power Agree to Terminate the Carbon Free Power Project (CFPP)", Press Release, 8 November 2023, see https://nuscale-prod-pbpdt9uqe-nuscale-power.vercel.app/news/press-releases/2023/uamps-and-nuscale-power-agree-to-terminate-the-carbon-free-power-project, accessed 8 November 2023.

1735 - U.S. DOE, "DOE Announces $900 Million to Accelerate the Deployment of Next-Generation Light-Water Small Modular Reactors", U.S. Department of Energy, United States Government, 17 June 2024, see https://www.energy.gov/articles/doe-announces-900-million-accelerate-deployment-next-generation-light-water-small-modular, accessed 14 August 2024; and Diana DiGangi, "DOE offers $900M for next-generation small modular reactors", *Utility Dive*, 18 June 2024, see https://www.utilitydive.com/news/energy-department-900-million-dollar-nuclear-small-modular-reactors-DOE/719243/, accessed 6 July 2024.

1736 - Jack Devanney, "The NuScale Scam", *Gordian Knot News* on Substack, 2 July 2024, see https://jackdevanney.substack.com/p/the-nuscale-scam, accessed 3 July 2024.

1737 - NuScale Power, "Second Quarter 2024 Earnings Presentation", August 2024, see https://www.nuscalepower.com/-/media/nuscale/pdf/investors/2024/smr-2q24-presentation.pdf, accessed 14 August 2024.

Such announcements have boosted NuScale's stock value, although the share price has fluctuated a lot over the past year. One reason for the fluctuation has been periodic announcements by institutional investors and others about why NuScale was not a good bet. In October 2023, for example, Iceberg Research questioned NuScale's agreement with a blockchain company called Standard Power.[1738] NuScale put out a statement claiming that Iceberg's report, "designed solely to drive down the Company's stock price," was inaccurate.[1739] Some months later, analysts at Wells Fargo cut their price target for NuScale's shares.[1740] Later, in May 2024, Iceberg Research accused NuScale of "deceiving investors" about the certification of its reactor and estimated that NuScale had only "14-21 months of cash" reserves.[1741]

X-energy is another company facing trouble at the market. In December 2022, X-energy announced that it was going to go public by setting up a special purpose acquisition company (SPAC).[1742] SPACs are "shell companies that have no operations or business plan other than to acquire a private company using the money raised through an IPO [Initial Public Offering], thereby enabling the latter to go public quickly."[1743] For some years, the U.S. Securities and Exchange Commission has been concerned about the growth in SPAC transactions because of the risk of scams.[1744] In October 2023, X-energy Reactor Company and the publicly-traded SPAC called Ares Acquisition Corporation "mutually agreed to terminate their previously announced business combination agreement" citing "challenging market conditions, peer-company trading performance and a balancing of the benefits and drawbacks."[1745] But in April 2024, the DOE awarded a US$148.5 million tax credit to X-energy for building a fuel fabrication facility.[1746]

1738 - Iceberg Research, "NuScale Power ($SMR): A Fake Customer and a Major Contract in Peril Cast Doubt on NuScale's viability", 19 October 2023, see https://iceberg-research.com/2023/10/19/nuscale-power-smr-a-fake-customer-and-a-major-contract-in-peril-cast-doubt-on-nuscales-viability/, accessed 20 October 2023.
NuScale's announcement about Standard Power is available at NuScale, "Standard Power Chooses NuScale's Approved SMR Technology and ENTRA1 Energy to Energize Data Centers", Press Release, 6 October 2023, see https://nuscale-prod-pbpdt9uqe-nuscale-power.vercel.app/news/press-releases/2023/standard-power-chooses-nuscales-approved-smr-technology-and-entra1-energy-to-energize-data-centers, accessed 25 November 2023.

1739 - NuScale Power, "NuScale Power Comments on Inaccurate Short Seller Report", Press Release, as published on *BusinessWire*, 24 October 2023, see https://www.businesswire.com/news/home/20231024578361/en/NuScale-Power-Comments-on-Inaccurate-Short-Seller-Report, accessed 30 October 2023.

1740 - William White, "Wells Fargo Just Slashed Its Price Target on NuScale Power (SMR) Stock", *InvestorPlace*, 19 March 2024, see https://investorplace.com/2024/03/wells-fargo-just-slashed-its-price-target-on-nuscale-power-smr-stock/, accessed 20 March 2024.

1741 - Iceberg Research, "NuScale ($SMR) Has Deceived Investors about the Certification of its Reactor", 16 May 2024, see https://iceberg-research.com/2024/05/16/nuscale-smr-has-deceived-investors-about-the-certification-of-its-reactor/, accessed 21 May 2024.

1742 - X-energy and ARES Acquisition Corporation, "X-energy, a Leading Developer of Small Modular Nuclear Reactor and Fuel Technology for Clean Energy Generation, to Go Public via Business Combination with Ares Acquisition Corporation", Press Release, as published by X-energy, 6 December 2022, see https://x-energy.com/media/news-releases/x-energy-to-go-public-via-business-combination-with-ares-acquisition-corporation, accessed 1 August 2024.

1743 - Ivana Naumovska, "The SPAC Bubble Is About to Burst", *Harvard Business Review*, 18 February 2021, see https://hbr.org/2021/02/the-spac-bubble-is-about-to-burst, accessed 16 July 2023.

1744 - Thomas J. Krysa, Brooke D. Clarkson, and Adrian L. Jensen, "SEC Signals Enhanced Scrutiny of SPAC Transactions", Foley & Lardner LLP, 2 April 2021, see https://www.foley.com/en/insights/publications/2021/04/sec-signals-enhanced-scrutiny-of-spac-transactions, accessed 16 July 2023.

1745 - X-energy and ARES Acquisition Corporation, "X-energy and Ares Acquisition Corporation Mutually Agree to Terminate Business Combination Agreement", Press Release, X-energy, 31 October 2023, see https://x-energy.com/media/news-releases/x-energy-ares-mutually-terminate-business-agreement, accessed 14 August 2024.

1746 - X-energy, "X-energy Awarded $148.5 Million Investment Tax Credit for First-of-a-Kind TRISO-X Fuel Fabrication Facility", Press Release, 23 April 2024, see https://x-energy.com/media/news-releases/x-energy-awarded-148m-investment-tax-credit-for-triso-x-fuel-fabrication-facility, accessed 19 August 2024.

Another reactor design that the DOE has committed to fund is Kairos. In February 2024, the DOE and Kairos Power signed a Technology Investment Agreement under which "DOE will provide up to [US]$303 million to Kairos Power using a performance-based, fixed-price milestone approach, wherein the company will receive fixed payments upon demonstrating the achievement of significant project milestones" on the Hermes project.[1747] Hermes is a 35 MW (thermal) reactor concept that is not designed to generate electricity. In December 2023, the NRC voted to issue a permit to construct the reactor.[1748] Kairos Power is using the two-step 10 CFR Part 50 licensing process for this reactor and therefore will need to submit a separate application for an operating license, which would subsequently have to be approved by NRC before the Hermes reactor can start operating.

Despite the unfavorable economics and the business challenges confronting SMRs, the U.S. Government continues to actively promote these unproven concepts around the world.

Although the award was originally announced in 2020, it took nearly four years for Kairos and DOE to agree on the details.[1749] The US$303 million from DOE is part of a larger Advanced Reactor Demonstration Program award of "initial funding for Risk Reduction projects" totaling US$629 million,[1750] but neither Kairos Power nor the DOE has clarified where the remaining US$326 million will come from. Nor is there any announcement about the estimated total construction cost. Although the Hermes reactor is not designed to generate electricity, such a reactor might be modified to produce around 14 MW of power if one assumes a conversion efficiency of 40 percent. Even at the minimum cost estimate of US$629 million, such a reactor would cost around US$45,000/kW, several times higher than current reactors.

Despite the unfavorable economics and the business challenges confronting SMRs, the U.S. Government continues to actively promote these unproven concepts around the world. Some of these promotional activities take place in countries like the Czech Republic, Ghana,

1747 - Kairos Power, "U.S. Department of Energy and Kairos Power Execute Novel Performance-Based, Fixed-Price Milestone Contract", Press Release, 21 February 2024, see https://kairospower.com/external_updates/u-s-department-of-energy-and-kairos-power-execute-novel-performance-based-fixed-price-milestone-contract-to-enable-investment-in-advanced-reactor-demonstration-project/, accessed 19 August 2024.

1748 - Kairos Power, "Nuclear Regulatory Commission Approves Construction Permit for Hermes Demonstration Reactor", Press Release, 12 December 2023, see https://kairospower.com/external_updates/nuclear-regulatory-commission-approves-construction-permit-for-hermes-demonstration-reactor/, accessed 23 August 2024.

1749 - Matt Bowen, "DOE's Innovative New Approach for Partnering with Advanced Energy Companies", Center on Global Energy Policy, Columbia University, 21 February 2024, see https://www.energypolicy.columbia.edu/does-innovative-new-approach-for-partnering-with-advanced-energy-companies/, accessed 19 August 2024.

1750 - U.S. DOE, "Energy Department's Advanced Reactor Demonstration Program Awards $30 Million in Initial Funding for Risk Reduction Projects", Department of Energy, United States Government, 16 December 2020, see https://www.energy.gov/ne/articles/energy-departments-advanced-reactor-demonstration-program-awards-30-million-initial, accessed 23 August 2024.

Poland, Slovakia, and Slovenia.[1751] Many of these countries, for example Poland, also seem to be interested in SMRs as part of larger geopolitical and military ties.[1752]

CONCLUSION

Although a number of countries are promoting small modular reactors as the future of nuclear energy, the experience with them so far does not suggest that they will resolve the problems confronting the industry. SMRs lose out on economies of scale and thus any power they generate will be more costly.[1753] The few existing cost estimates—and these are necessarily speculative—all show that SMRs will be more expensive per unit of installed capacity than large reactors.

During a conference call announcing the termination of the UAMPS project (see WNISR2023) in November 2023, NuScale's Chief Executive Officer explained the decision by saying: "Once you're on a dead horse, you dismount quickly. That's where we are here."[1754] The metaphor of dismounting from a dead horse might be a fit for other efforts to promote SMRs.

1751 - *WNN*, "USA announces new cooperation to support Ghana SMR plans", 3 June 2024, see https://www.world-nuclear-news.org/Articles/USA-announces-new-cooperation-to-support-Ghana-SMR; and SE, "It's already getting underway: Project Phoenix for SMRs in Slovakia", Press Release, Slovenské Elektrárne, 14 February 2024, see https://www.seas.sk/en/news/project-phoenix-start-smr-slovakia/; also U. S. Embassy Ljubljana, "Slovenia partners with the United States under Project Phoenix – on Advancing a Coal-to-Nuclear Clean Energy Transition.", Press Release, United States Embassy in Slovenia, 6 February 2024, see https://si.usembassy.gov/press-release/; all accessed June 2024; and "US furthers overseas support for coal-to-SMR projects", 8 September 2023, see https://www.world-nuclear-news.org/Articles/US-furthers-overseas-support-for-coal-to-SMR-proje, accessed 6 July 2024.

1752 - Maha Siddiqui and M. V. Ramana, "Eastern Europe's purchase of US nuclear reactors is primarily about military ties, not climate change", *Bulletin of the Atomic Scientists*, 2 August 2024, see https://thebulletin.org/2024/08/eastern-europes-purchase-of-us-nuclear-reactors-is-primarily-about-military-ties-not-climate-change/, accessed 19 August 2024.

1753 - Stephen Thomas and M. V. Ramana, "A hopeless pursuit? National efforts to promote small modular nuclear reactors and revive nuclear power", *WIREs Energy and Environment*, 12 January 2022, see https://onlinelibrary.wiley.com/doi/abs/10.1002/wene.429, accessed 31 January 2022.

1754 - Will Wade, "First US Small Nuke Project Canceled After Costs Surge 53%", *Bloomberg*, as published by *Financial Post*, 8 November 2023, see https://financialpost.com/pmn/business-pmn/first-us-small-nuke-project-canceled-after-costs-climb-53, accessed 1 August 2024.

NUCLEAR POWER VS. RENEWABLE ENERGY DEPLOYMENT

INTRODUCTION

2023-24 continues to mark a period in which the global energy landscape is being reshaped alongside national, continental, and global climate ambitions while facing persistent economic pressures, including inflation and geopolitical tensions. It is also possible to observe the return of fossil-oriented energy security thinking in the wake of the Russian aggression on Ukraine, with strategic moves to keep the existing fossil infrastructures in place or even develop new ones, such as liquefied natural gas (LNG). As the opportunity to achieve net-zero emissions by 2050 diminishes, a rapid and thorough transformation of the energy sector becomes increasingly crucial.

Against the backdrop of urgency, the COP28 climate summit at the end of 2023 showed commitments to transforming energy systems, including, for the first time, the inclusion of language on the need to move away from using fossil fuels. The Global Renewables and Energy Efficiency Pledge, endorsed by 133 national governments, including the E.U., aims to triple global renewable energy capacity to 11,000 GW (11 TW) and double the annual rate of energy efficiency improvements to over four percent by 2030. At the same time, the Declaration to Triple Nuclear Energy Capacity,[1755] endorsed by 25 national governments, sets a goal to triple global nuclear capacity by 2050 and urges international financial institutions to include nuclear energy in their lending policies. This contrasts starkly with the pledge on renewables and energy efficiency, which, if achieved, would put global emissions back on track to meet the 1.5°C target of the Paris Agreement.[1756]

2023 witnessed extraordinary advancements in renewable energy deployment. Over the year, total renewable energies increased by 14 percent to reach 3.9 TW or 43 percent of installed global power capacity.[1757] According to the International Renewable Energy Agency (IRENA) data, annual additions of solar PV and wind power grew by 73 percent and 51 percent, respectively, resulting in nearly 460 GW of new capacity.[1758] 2023 could have been a tipping point in history as the growth in renewable energy exceeded rising power demand. This, if the

1755 - U.S. DOE, "At COP28, Countries Launch Declaration to Triple Nuclear Energy Capacity by 2050, Recognizing the Key Role of Nuclear Energy in Reaching Net Zero", Department of Energy, U.S. Government, 1 December 2023, see https://www.energy.gov/articles/cop28-countries-launch-declaration-triple-nuclear-energy-capacity-2050-recognizing-key, accessed 4 December 2023.

1756 - States of Albania, Andorra, Angola et al., "COP28: Global Renewables and Energy Efficiency Pledge", United Nations Climate Change, December 2024, see https://www.cop28.com/en/global-renewables-and-energy-efficiency-pledge, accessed 1 August 2024.

1757 - IRENA, "Renewable Energy Statistics", 2024, International Renewable Energy Agency, see https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/Jul/IRENA_Renewable_Energy_Statistics_2024.pdf, accessed 1 August 2024.

1758 - IEA, "Clean Energy Market Monitor 2024", International Energy Agency, March 2024, see https://iea.blob.core.windows.net/assets/d718c314-c916-47c9-a368-9f8bb38fd9d0/CleanEnergyMarketMonitorMarch2024.pdf, accessed 1 August 2024.

trend remained, would mean that we have seen a peak in fossil fuel electricity generation—and emissions.[1759]

China and advanced economies contributed the lion's share of these renewables additions as well as electric vehicle sales, accounting for 90 percent of wind and solar PV capacity increases and over 95 percent of global electric car sales. Global electric vehicle sales saw a remarkable 35 percent increase, reaching 14 million units, with China and the European Union leading the market. On the other hand, global new nuclear capacity was limited to 5 GW—compared to 7.9 GW started up in the previous year—while 6 GW of nuclear capacity was permanently closed during 2023.[1760]

In addition to the year-on-year dynamics reported in this section, the breakthrough of low-cost *and* firm energy from renewables is now entering mainstream thinking, even in the financial and business sectors. Thus, *The Economist*, traditionally not known for a pro-renewable bias, observes in a dossier called "Sun Machines" that the exponential growth of solar power will change the world and that "solar, an energy source that gets cheaper and cheaper, is going to be huge."[1761] The simple reason is that installed solar capacity almost doubles every three years and is accompanied by significant falls in the cost of production. In addition, in terms of energy security concerns, "a world in which more energy is generated without the oil and gas that come from unstable or unfriendly parts of the world will be more dependable."[1762]

Secondly, understanding solar (and other renewables) as a *firm* energy source is also making its way into mainstream financial analysis. The possibility of firm renewable energy systems fueling economies around the world has been studied for decades.[1763] It has now been confirmed by analyses from financial organizations, as evidenced by detailed work on power firming and the subsequent competitive pressure on nuclear power (see chapter on Power Firming and Competitive Pressure on Nuclear). In essence, the costs for system flexibility to deal with variable renewables, such as battery storage and the use of demand-side management (eventually supported by A.I.), are drastically falling. As a result, the firm power costs from renewables outcompete today's levelized costs for new nuclear, gas-peaking plants and other fossil-fuel based options like combined-cycle gas plants in a growing number of markets.

As highlighted in this chapter, the rapid growth and implementation of renewable energy continue to offer hope for a successful energy system transformation away from fossil and fissile energy, which both fall short in addressing today's critical energy and climate needs.

1759 - Molly Lempriere, "Wind and solar are 'fastest-growing electricity sources in history'", *Carbon Brief*, 8 May 2024, see https://www.carbonbrief.org/wind-and-solar-are-fastest-growing-electricity-sources-in-history/, accessed 8 May 2024.

1760 - IEA, "Clean Energy Market Monitor 2024", March 2024, op. cit.

1761 - *The Economist*, "Sun Machines Solar, an Energy Source That Gets Cheaper and Cheaper, Is Going to Be Huge", 20 June 2024, see https://www.economist.com/interactive/essay/2024/06/20/solar-power-is-going-to-be-huge, accessed 1 August 2024.

1762 - *The Economist*, "The Exponential Growth of Solarpower Will Change the World", 20 June 2024, see https://www.economist.com/leaders/2024/06/20/the-exponential-growth-of-solar-power-will-change-the-world.

1763 - E.g. Mark Z. Jacobson and Mark A. Delucchi, "A Plan to Power 100 Percent of the Planet with Renewables", *Scientific American*, 1 November 2009, see https://www.scientificamerican.com/article/a-path-to-sustainable-energy-by-2030/, accessed 1 August 2024.

INVESTMENT

Bloomberg New Energy Finance (BNEF) views achieving carbon neutrality by mid-century as challenging yet feasible,[1764] highlighting that as we navigate through this pivotal decade, emissions and fossil-fuel use peaking across the global energy system must align with a net-zero trajectory. As BNEF argues in its New Energy Outlook 2024, the bulk of emissions reductions needed by 2030 can be driven by cleaner power generation, allowing more time to address challenging sectors like steelmaking and aviation, where cost-effective low-carbon solutions are still emerging. Achieving net zero hinges on tripling renewables capacity and doubling energy efficiency by the end of this decade.

Accelerated investment is crucial. According to BNEF, for every dollar currently allocated to fossil fuels, an average of US$3 must be directed towards low-carbon energy solutions in the future, a significant increase from current levels. Based on the BNEF assessment, fully decarbonizing the global energy system by 2050 may require investments totaling US$215 trillion, "only 19 percent more than in an economics-driven transition," a scenario where Paris Agreement goals are missed and global warming exceeds 2.6°C. Regardless of the ultimate trajectory towards net zero, BNEF observes that "the era of fossil fuels' dominance is coming to an end": even under purely economic drivers, renewables are poised to surpass a 50 percent share of global electricity generation by the decade's end, signaling a profound shift in the global energy landscape.[1765]

For decades renewable energy investment has exceeded that of nuclear, however, 2023 was significant, not just because this trend accelerated, but also new finance for power storage exceeded that for nuclear power. This is highly significant as investments in system flexibility and storage are essential for enabling a greater percentage contribution of solar and wind to overall power supply.[1766]

The trends in the volumes of investment in renewable energy and nuclear power continued to diverge in 2023. According to BNEF the total new investment in renewables in 2023 was US$623 billion, an increase of 8 percent. A significant majority of this was into solar which saw a 12 percent increase in investment, totaling US$393 billion;[1767] however, it is significant to note that falling technology and installation costs meant that there was a 73 percent increase in total installed capacity compared to the previous year. Wind also saw an increase in investment, resulting in US$217 billion, with a slight drop in onshore wind investment more than compensated by a record US$76.7 billion in offshore wind investment, despite supply chain delays as well as permitting and grid connection hurdles.[1768]

1764 - BloombergNEF, "New Energy Outlook 2024", May 2024, see https://about.bnef.com/new-energy-outlook/, accessed 1 August 2024.

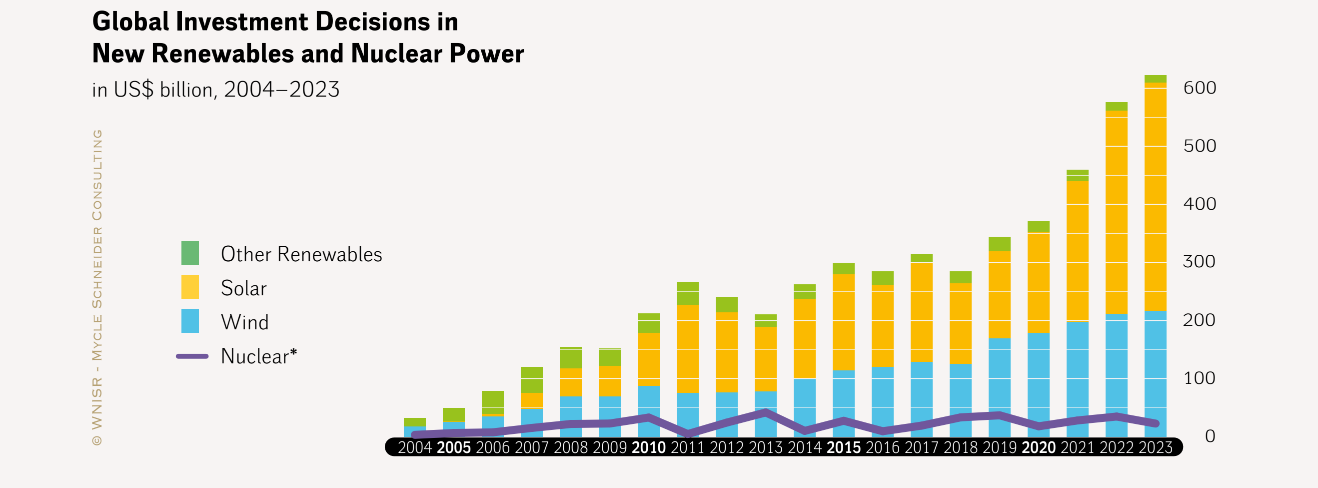
1765 - Ibidem.

1766 - Nat Bullard, "Decarbonization: Stocks and flows, abundance and scarcity, net zero", 31 January 2024, see https://www.nathanielbullard.com/presentations, accessed 14 July 2024.

1767 - BNEF, "Energy Transition Investment Trends 2024—Abridged Version", BloombergNEF, January 2024.

1768 - Oliver Metcalfe, "Offshore Wind Investment Hit All-Time High in 2023", BloombergNEF, 7 February 2024, see https://about.bnef.com/blog/offshore-wind-investment-hit-all-time-high-in-2023/, accessed 9 August 2024.

Figure 56 · Global Investment Decisions in Renewables and Nuclear Power, 2004–2023



Sources: BNEF, 2023 and 2024 and WNISR Original Research, 2024[1769]

In comparison, investment in nuclear has remained largely constant in recent years. WNISR's analysis of the total volume of investment decisions in new nuclear suggests that just US$23 billion was assigned in 2023. BNEF estimated that nuclear investment in 2023 was around US$32.7 billion.[1770] When cumulated over several years the BNEF and WNISR analyses are in the same order of magnitude: WNISR estimates total investment in new nuclear between 2015 and 2023 in the order of US$233 billion and BNEF at US$257 billion. Over the same time period the investment in solar was US$1,924 billion and wind US$1,462 billion. See Figure 56.

The level of investment has been recognized by the European Commission President Ursula von der Leyen as the key stumbling block to nuclear playing a significant role in decarbonization.[1771] There seems to be insufficient appetite for raising funds for nuclear projects without further government fiscal support. At the first Nuclear Energy Summit organized by the IAEA in March 2024, there was a clear message from the international financial institutions that investment in new nuclear was a high risk, low priority investment. European Investment Bank Vice President Thomas Östros said that "the project risks, as we have seen in reality, seem to be very high," while Ines Rocha, a managing director at the European Bank for Reconstruction and Development, and Fernando Cubillos, a banker at the Development Bank of Latin America, reportedly said that they would prioritize investment in grids and renewables, with the latter being quoted as saying "Nuclear comes last."[1772]

Figure 57 details the levels of investment in the different global regions over the past decade. China dominates investment, in both renewables and nuclear power, but the acceleration in its renewable energy investments stands out; in 2023, China's investment was greater than

1769 - BNEF, "Energy Transition Investment Trends 2024", BloombergNEF, January 2024.

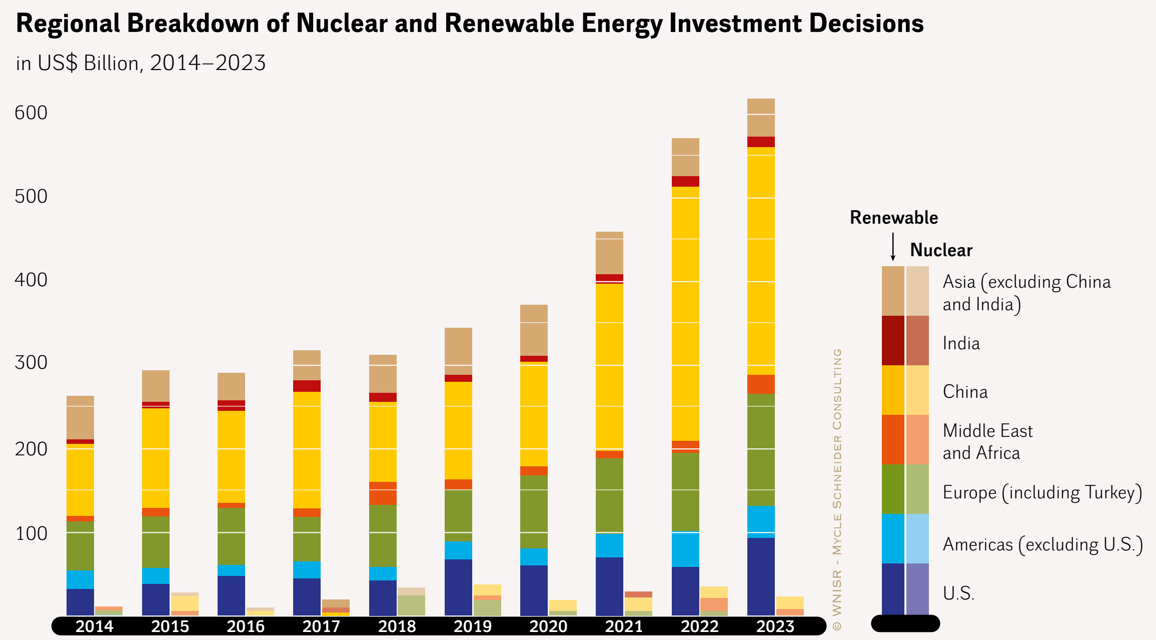
1770 - BNEF, "Energy Transition Investment Trends 2024—Abridged Version", BloombergNEF, January 2024.

1771 - Paul Messad, "Major nuclear projects will have to wait longer for delayed EIB financing", *Euractiv*, 25 March 2024, see https://www.euractiv.com/section/energy-environment/news/major-nuclear-projects-will-have-to-wait-longer-for-delayed-eib-financing/, accessed 6 August 2024.

1772 - Alex Kimani, "Banks Unwilling To Finance $5 Trillion Global Nuclear Development", *OilPrice.com*, 14 April 2024, see https://oilprice.com/Alternative-Energy/Nuclear-Power/Banks-Unwilling-To-Finance-5-Trillion-Global-Nuclear-Development.html, accessed 6 August 2024.

the global total a decade earlier. After a few years of steady growth, Europe and the U.S. saw a rapid increase in investment in 2023, which has been driven by domestic policies supporting renewables. Similarly, in 2023, renewable energy investments increased considerably in the Middle East and infrastructure was rolled out to meet ambitious climate targets. However, despite the increase, renewable energy investment remains relatively low in this region compared to that of fossil fuels.[1773] Other countries and regions have not seen the rate of investment increasing, most notably India and Asia outside China.

Figure 57 · Regional Breakdown of Nuclear and Renewable Energy Investment Decisions, 2014–2023



Sources: REN21, BNEF and WNISR Original Research, 2024[1774]

TECHNOLOGY COSTS

Lazard's annual Levelized Cost of Energy (LCOE) analysis, updated in June 2024,[1775] highlights the trends in electricity generation costs (leveled out over the estimated lifetime of the respective facility), and while the analysis is primarily based on U.S. data, it broadly represents global trends. The latest two editions of Lazard's publication also analyze the costs of firm power, an issue addressed in a dedicated chapter of the present report (see chapter on Power Firming and Competitive Pressure on Nuclear).

The cost degression of solar power has lasted for over two decades, making it the lowest-cost technology in most places around the globe today. The IEA has concluded that "onshore wind

1773 - IEA, "Middle East – World Energy Investment 2024 – Analysis", International Energy Agency, 2024, see https://www.iea.org/reports/world-energy-investment-2024/middle-east, accessed 8 August 2024.

1774 - REN21, "Renewables Global Status Report 2024", 2024, see http://www.ren21.net/gsr-2024, accessed 17 August 2024.

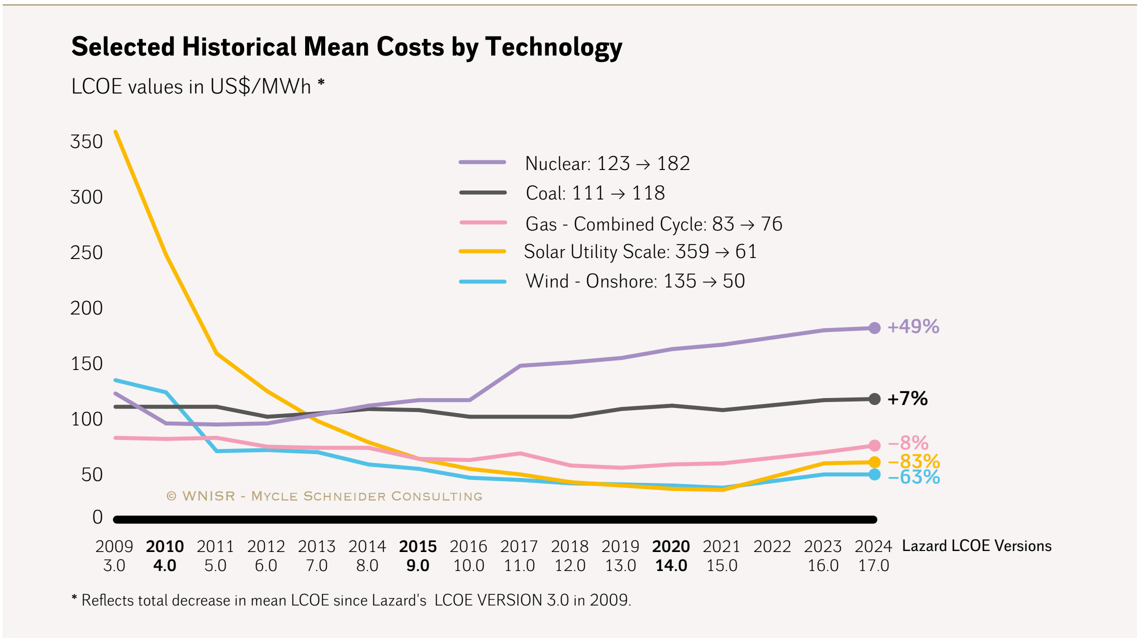
1775 - Lazard, "Levelized Cost of Energy +", Version 17.0, June 2024, see https://www.lazard.com/media/xemfeyok/lazards-lcoeplus-june-2024-_vf.pdf, accessed 1 August 2024.

and solar PV are cheaper today than new fossil fuel plants almost everywhere and cheaper than existing fossil fuel plants in most countries."[1776] In hindsight, it was hardly miraculous to predict the breakthrough of solar once the self-reproducing virtual cycle of "mass production, mass update, cost reduction, and mass production…" was launched over two decades ago. Importantly, renewables are becoming competitive with *existing* power plants and therefore, it is becoming economically attractive to close existing facilities, hence accelerating the transition.

As depicted in Figure 58, from 2009 to 2024, the average LCOE for solar PV (utility-scale) fell from US$359 to US$61 per MWh, an 83 percent decrease, despite recent cost pressures. Onshore wind power's average LCOE dropped from US$135 to US$50 per MWh, a 63 percent decline. Conversely, nuclear power costs rose from US$123 to US$182 per MWh, a 49 percent increase, making it the most expensive utility-scale power source. Coal's LCOE slightly increased from US$111 to US$118 per MWh, while that of combined-cycle gas decreased from US$83 to US$76 per MWh, especially in the U.S. due to the availability of cheap fracking gas.

The report shows that while high interest rates in the recent past have increased the lower end of energy costs, the overall cost range has become more consistent. Well-financed companies are thereby assumed to be better positioned to expand renewable energy projects efficiently, making them likely leaders in the sector despite rising costs.[1777]

Figure 58 • The Declining Costs of Renewables vs. Traditional Power Sources



Source: Lazard Estimates, 2024

Notes: **LCOE**: Levelized Cost of Energy

*This graph reflects the average unsubsidized LCOE values for a given version of LCOE study. It primarily relates to the North American energy landscape but reflects broader/global cost developments. See also Figure 69.

1776 - IEA, "Massive expansion of renewable power opens door to achieving global tripling goal set at COP28", 11 January 2024, see https://www.iea.org/news/massive-expansion-of-renewable-power-opens-door-to-achieving-global-tripling-goal-set-at-cop28, accessed 2 August 2024.

1777 - Lazard, "Levelized Cost of Energy +", Version 17.0, June 2024, op. cit.

INSTALLED CAPACITY AND ELECTRICITY GENERATION

In 2023, total renewable energies increased by 14 percent to reach 3.9 TW or 43 percent of installed global power capacity. According to IRENA, annual additions of solar PV and wind power grew by 73 percent and 51 percent, respectively, resulting in nearly 460 GW of combined new capacity. The global solar PV market saw China adding around 217 GW and the rest of the world 129 GW for a total of 346 GW. [1778]

Solar Power Europe observed that countries installing at least 1 GW *per year* rose from 28 in 2022 to 31 in 2023.[1779] Globally, around 1 GW of new solar capacity is being installed on average *per day*, which is about the same as was started up in a whole year two decades ago.

The average capacity factor for onshore wind increased by nearly a third to 36 percent between 2010 and 2020.

The Global Wind Energy Council (GWEC) reported a record of 117 GW of new wind installations, a 50 percent year-on-year increase. This brought the global cumulative installed wind capacity to over 1 TW, marking a 13 percent growth. Onshore wind added 106 GW, a 54 percent increase compared to the previous year's addition, with China installing 69 GW and the U.S. adding 6.4 GW. Consequently, China alone accounted for 65 percent of new onshore capacity, and the global top five together—China, the U.S., Brazil, Sweden, and India—provided 82 percent. Offshore wind grew by 10.8 GW, led by China with 6.3 GW, and Europe adding 3.8 GW.[1780]

The performance of renewable energy technologies has improved significantly. For example, the global weighted average capacity factor for onshore wind increased by nearly a third from just over 27 percent to 36 percent between 2010 and 2020, while the capacity factor for utility-scale solar PV plants rose from 13.8 percent to 16.1 percent over the same period.[1781] During that time, offshore wind has also seen remarkable improvements, with load factors in Europe rising from 39 percent to 44 percent—from 38 to 40 percent globally—and Equinor's floating offshore wind farm achieving a five-year-average of 54 percent load factor off the coast of Scotland in 2017–2022, surpassing the 52 percent achieved by the French nuclear fleet in 2022.[1782]

1778 - IRENA, "Renewable Energy Statistics", 2024, International Renewable Energy Agency, op.cit.

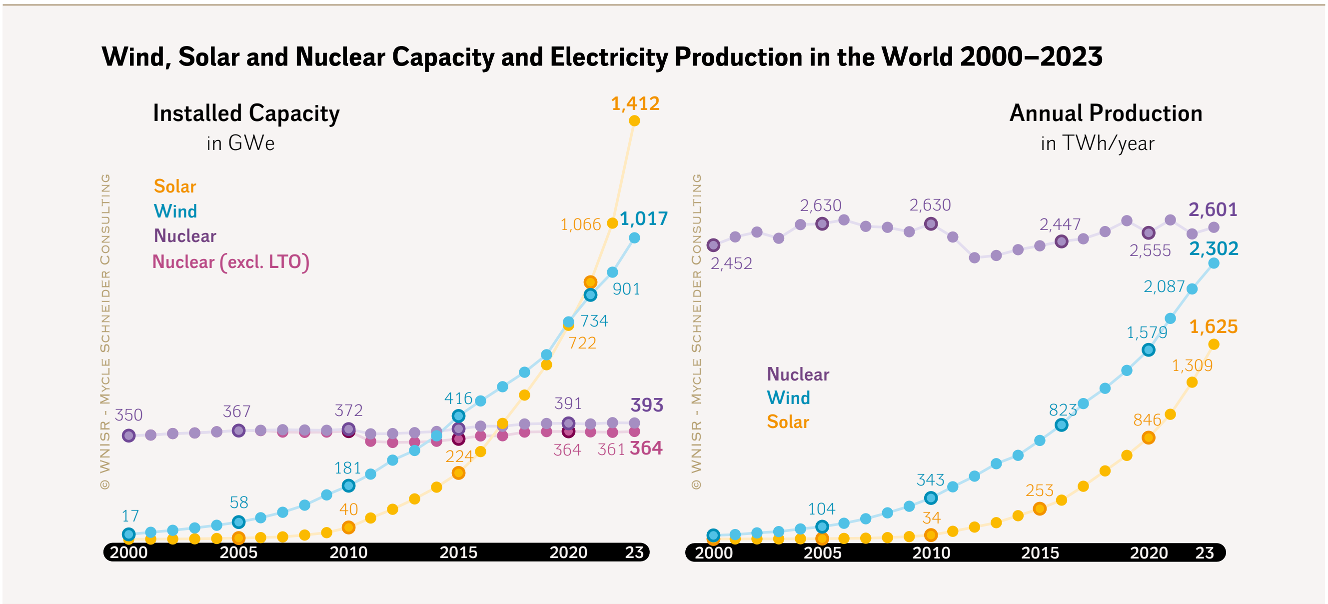
1779 - SolarPower Europe, "Global Market Outlook For Solar Power 2024 - 2028", 2024, see https://www.solarpowereurope.org/insights/outlooks/global-market-outlook-for-solar-power-2024-2028/detail, accessed 1 August 2024.

1780 - GWEC, "Global Wind Report 2024", Global Wind Energy Council, 15 April 2024, see https://gwec.net/global-wind-report-2024/, accessed 1 August 2024.

1781 - IRENA, "Renewable Technology Innovation Indicators: Mapping progress in costs, patents and standards", March 2022, see https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Mar/IRENA_Tech_Innovation_Indicators_2022_.pdf, accessed 9 August 2024.

1782 - Ibidem; and Equinor, "Equinor marks 5 years of operations at world's first floating wind farm", 29 December 2022, see https://www.equinor.com/news/hywind-5-years-world-first-floating-wind-farm, accessed 16 August 2024.

Figure 59 · Wind, Solar, and Nuclear Installed Capacity and Electricity Production in the World



Sources: WNISR with IAEA-PRIS, IRENA, Energy Institute, 2024[1783]

Notes pertaining to Figure 59 to Figure 67 (except Figure 65):

Unless otherwise indicated, production data for renewables and nuclear are in net TWh from Energy Institute "Statistical Review of World Energy 2023 – Consolidated Dataset"; gross production numbers from Energy Institute are used for comparisons with fossil fuels (for which net data are not available). Numbers for installed capacity for renewables are from IRENA, and for nuclear capacity compiled by WNISR, based on IAEA-PRIS indicating operating capacity (i.e. excluding reactors in LTO or Long-term Outage), used for comparison, as well as installed capacity (including reactors in LTO).

Figure 59 highlights the significant deployment and production rate of renewables since the start of the millennium. From 2000 to 2023, solar capacity installations initially grew slowly, reaching only 4.5 GW by 2005, but then accelerated significantly from 2010 onwards, jumping by a factor of 35 from 40.3 GW in 2010 to 1,412.1 GW in 2023. Wind energy saw steady growth from 17 GW in 2000 to 1,017 GW in 2023. In contrast, operating nuclear capacity remained relatively stable over the same period, increasing insignificantly from 350 GW to 364 GW.[1784]

Annual production[1785] trends paint a similar picture. Solar energy production rose slowly from 1.1 TWh in 2000 to 33.6 TWh in 2010, then accelerated significantly to 1,625.2 TWh in 2023. The 48-times greater solar power generation between 2010 and 2023, a much faster growth than the capacity increase, reflects the efficiency increase of the solar cells over the period.

Wind energy production increased from 31.1 TWh in 2000 to 343 TWh in 2010, reaching 2,302.1 TWh by 2023. Nuclear energy production fluctuated but remained relatively stable at around 2,500 TWh; it peaked at 2,660 TWh in 2006 and stood at 2,601 TWh in 2023.

These trends highlight the stark growth in renewables and the stagnation of nuclear energy production. In 2023, solar and wind together generated 50 percent more energy than nuclear,

1783 - IRENA, "Renewable Energy Statistics", 2024, International Renewable Energy Agency, op. cit.; and Energy Institute, KPMG and Kearney, "Statistical Review of World Energy 2024 - Consolidated Dataset", June 2024, see https://www.energyinst.org/__data/assets/excel_doc/0004/1540552/merged_narrow.xlsx, accessed 24 June 2024; and IAEA-PRIS, "Net Capacity of Reactors", July 2024.

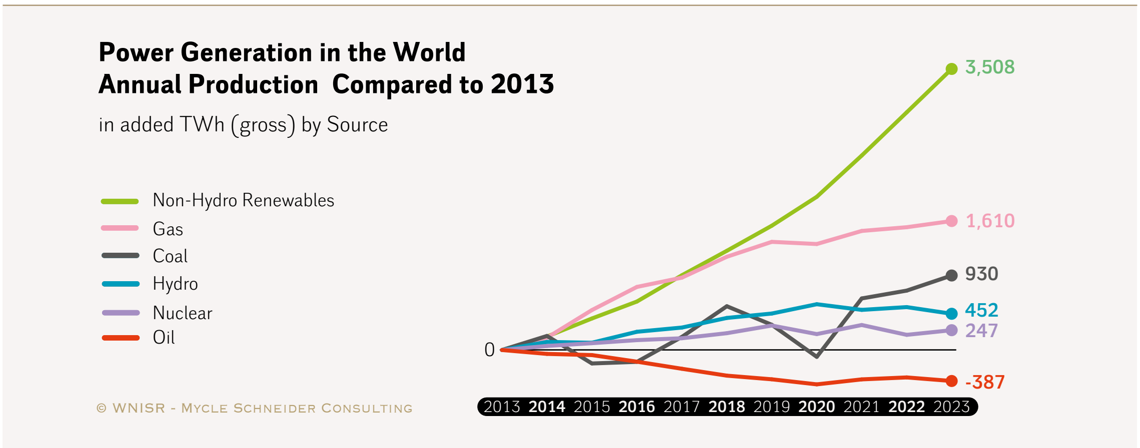
1784 - IRENA, "Renewable Energy Statistics", 2024, op. cit.

1785 - Unless otherwise indicated, all production data in this chapter refer to net production, from Energy Institute, KPMG and Kearney, "Statistical Review of World Energy 2024 - Consolidated Dataset", op. cit.

and a good wind year such as 2024 could see wind alone overtaking nuclear electricity generation.

Figure 60 shows the addition in gross electricity production by various energy sources compared to 2013. Non-hydro renewables have seen the most significant growth, adding 3,508 TWh by 2023, 14 times more than the increase in nuclear power. Gas has increased by 1,610 TWh, followed by coal with 930 TWh. Hydro has modestly risen by 452 TWh. Nuclear energy, however, has only increased by 247 TWh, making it one of the least-growing sectors. Conversely, oil has seen a decline, decreasing by 387 TWh. While the continuous rise in fossil fuel use is particularly concerning, non-hydro renewables still added 1.4 times more power output than coal and gas combined.[1786]

Figure 60 · Added Electricity Generation by Power Source, 2013–2023



Source: Energy Institute, 2024

Note: See Figure 59.

In 2019, for the first time, non-hydro renewables—solar, wind, and mainly biomass—generated more power than nuclear plants, marking the beginning of a continuously and rapidly widening gap between renewable energy and nuclear power in electricity generation. In 2023, non-hydro renewables already generated 80 percent more power than nuclear plants (see Figure 61).

The transition to renewable energy is crucial for achieving net-zero emissions by 2050. The total investment required to decarbonize the global energy system by 2050 is estimated at US$215 trillion in BNEF's New Energy Outlook 2024, just 19 percent more than in a scenario where Paris Agreement goals are missed.[1787] The Outlook forecasts that "the era of fossil fuels' dominance is coming to an end" with renewables, driven by accelerated investment and technological advancements, expected to surpass a 50 percent share of global electricity generation by the decade's end.[1788] For solar energy, annual installations are projected to reach 614 GW by 2025 and 876 GW by 2028, with global capacity exceeding 2 TW by 2024 and 5.1 TW by 2028, according to SolarPower Europe's "Medium Scenario" which is intended to reflect

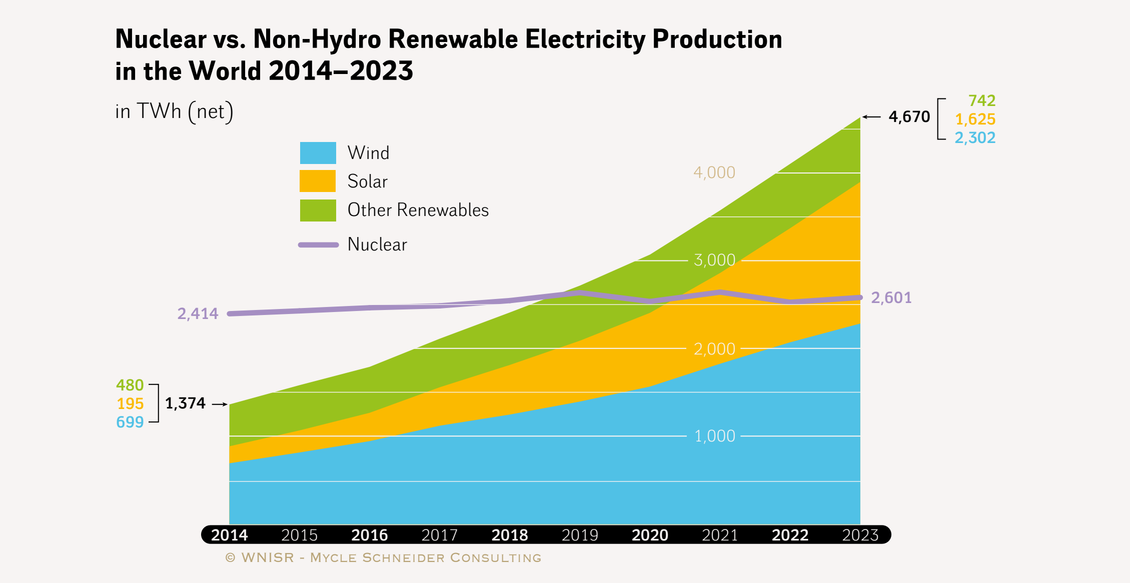
1786 - Energy Institute, "Statistical Review of World Energy 2024 - Consolidated Dataset", op. cit.

1787 - BNEF, "Energy Transition Investment Trends 2024", BloombergNEF, January 2024.

1788 - Ibidem.

the "most likely development given the current state of play of the market."[1789] Per the Global Wind Energy Council, under current policies, wind energy is forecasted to add 791 GW of new capacity by 2028, averaging 158 GW annually, with onshore wind expected to contribute 653 GW and offshore wind 138 GW.[1790]

Figure 61 • Nuclear vs. Non-Hydro Renewable Electricity Production in the World



Sources: Energy Institute, 2024

Note: See Figure 59.

STATUS AND TRENDS IN CHINA, THE EUROPEAN UNION, INDIA, AND THE UNITED STATES

China

In 2023, the renewable energy sector again played an essential role in China's economic development. There was a range of discrepancies between different sources regarding the exact figures for renewable energy additions, with China being the most significant source of uncertainty. Overall, it is assumed that China added 217 GW of new solar PV capacity, which marked a 151 percent year-on-year increase in the rate of growth, whereas the rest of the world installed 129 GW, a significant acceleration of the solar expansion.[1791] In 2023, once again solar and wind individually exceeded nuclear in annual power production. While nuclear produced 413 TWh, solar with 578 TWh exceed it by a factor of 1.4 and wind with 877 TWh exceeded it by a factor of two (see Figure 62).[1792] This means that electricity generation from renewable energies has increased around 8-fold in the past decade, while electricity from nuclear power

1789 - SolarPower Europe, "Global Market Outlook For Solar Power 2024 - 2028", 2024, op. cit.

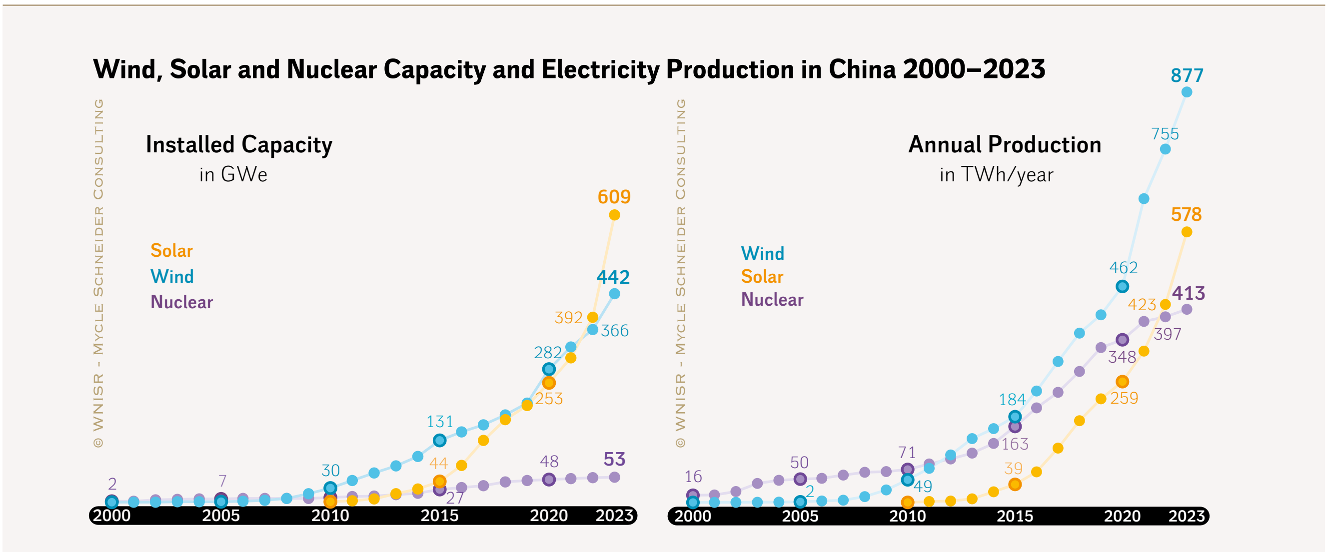
1790 - GWEC, "Global Wind Report 2024", Global Wind Energy Council, 15 April 2024, op. cit.

1791 - SolarPower Europe, "Global Market Outlook For Solar Power 2024 - 2028", 2024, op. cit.

1792 - Energy Institute, "Statistical Review of World Energy 2024 - Dataset", op. cit.

has only increased 3-fold, which is remarkable given China is, by far, the world leader in the expansion of nuclear power.

Figure 62 · Wind, Solar and Nuclear Installed Capacity and Electricity Production in China, 2000–2023



Sources: WNISR with IRENA, Energy Institute, IAEA-PRIS, 2024

Note: See Figure 59.

Investment in "clean energy" technologies, including a broad range of technologies from nuclear to batteries, rose by 40 percent year-on-year to CNY6.3 trillion (US$$_{2023}$889 billion), nearly matching global investments in fossil fuel supplies. Solar power, electric vehicles, and batteries were the main foci, with solar industry investments reaching CNY2.5 trillion (US$$_{2023}$353 billion).[1793] Wind power also saw substantial growth, with 76 GW installed during 2023, a 100 percent year-on-year increase in the rate of growth, with onshore wind capacity additions representing 90 percent.[1794]

Non-hydro renewables, that is solar, wind, and mainly biomass, in 2023 generated 1,643 TWh, four times as much as nuclear power plants (see Figure 63).

China approved ten new nuclear power units, with total investment rising by 45 percent to CNY87 billion (US$$_{2023}$12 billion), concentrated in coastal provinces like Guangdong, Fujian, and Zhejiang.[1795]

According to a Carbon Brief analysis, China's strategic shift in macroeconomic policy, redirecting capital from real estate to high-end manufacturing, has positioned the renewable energy industry as a critical part of its economic and industrial policy.[1796] This led to the formulation of ambitious targets to build 1200 GW of renewable capacity by 2030, a goal likely to be achieved five years ahead of schedule. By the end of 2024 it is expected that the capacity

1793 - Lauri Myllyvirta, "Analysis: Clean energy was top driver of China's economic growth in 2023", *Carbon Brief*, 25 January 2024, see https://www.carbonbrief.org/analysis-clean-energy-was-top-driver-of-chinas-economic-growth-in-2023/, accessed 1 August 2024.

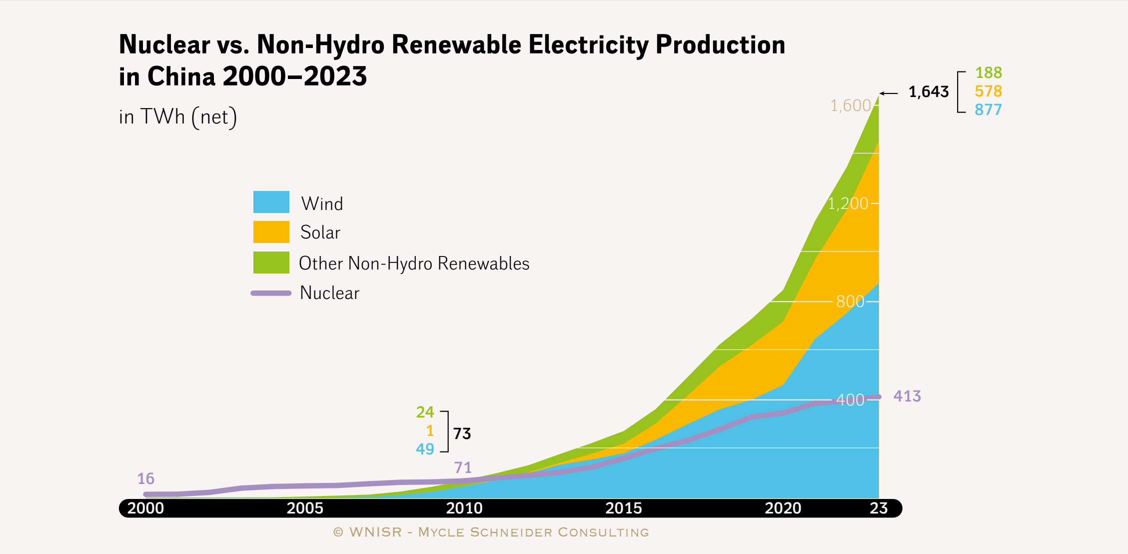
1794 - IRENA, "Renewable Energy Statistics", 2024, op. cit.

1795 - Lauri Myllyvirta, "Analysis: Clean energy was top driver of China's economic growth in 2023", *Carbon Brief*, 2024, op. cit.

1796 - Ibidem.

of solar and wind will be more than 40 percent of the total installed capacity of the power sector.[1797]

Figure 63 · Nuclear vs. Non-Hydro Renewables in China, 2000–2023



Source: Energy Institute, 2024

Note: See Figure 59.

European Union

In 2023, the E.U. made significant strides in its energy system transformation, moving further away from fossil fuels and showing record reductions in coal, fossil gas, and thus greenhouse-gas emissions. Power sector emissions in 2023 dropped to almost half (-46 percent) of its 2007-peak level. Renewable electricity rose to a record 44 percent share, surpassing the 40 percent mark for the first time. The E.U. achieved its largest annual renewable capacity addition ever (see Figure 64) and wind and solar continued to drive this growth, contributing 27 percent (721 TWh) of the E.U.'s gross electricity generation (see Figure 65).[1798]

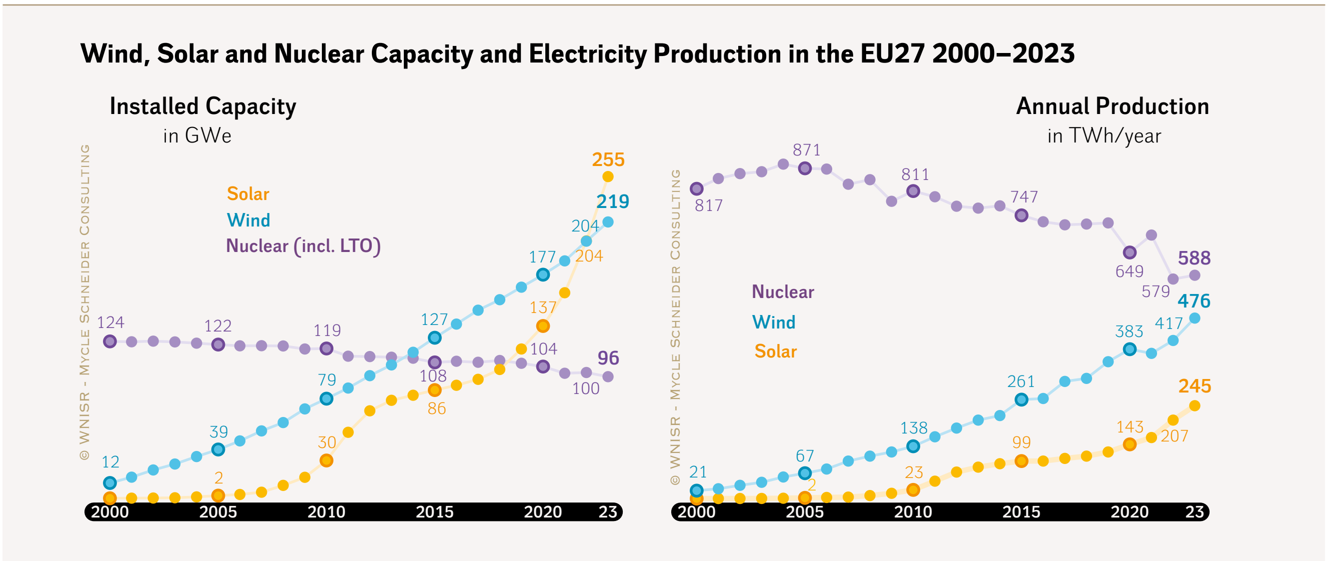
Figure 64 illustrates the installed capacity of wind, solar, and nuclear energy from 2000 to 2023 in the E.U. According to IRENA, wind energy capacity grew from a mere 12 GW in 2000 to 219 GW in 2023, depicting an overall steady increase. Solar energy capacity surged from 6 GW in 2000 to 255 GW in 2023, with a particularly pronounced acceleration from 2015 onwards, reflecting significant technological development as well as the effect of supporting policy measures. The rapid increase between 2020 and 2023 underscores solar PV's crucial role in the energy mix. In contrast, installed nuclear capacity declined continuously from 124 GW in 2000 to 96 GW in 2023.

1797 - Yujie Xue, "Wind and solar to surpass 40% of China's power capacity by year-end", *South China Morning Post*, 28 July 2024, see https://www.scmp.com/business/commodities/article/3272181/wind-and-solar-surpass-40-chinas-power-capacity-year-end, accessed 2 August 2024.

1798 - Ember, "European Electricity Review 2024", February 2024, see https://ember-climate.org/app/uploads/2024/02/European-Electricity-Review-2024.pdf, accessed 10 April 2024.

Consequentially, solar power generation exhibited stark increases, rising from under 1 TWh in the early 2000s to just below 100 TWh by 2015, 143 TWh in 2020, and reaching 245 TWh by 2023, illustrating accelerated growth, particularly after 2010. Wind energy generation also demonstrated substantial and consistent progress, increasing steadily from 21 TWh in 2000 to 476 TWh in 2023. Conversely, nuclear energy production peaked at 882 TWh in 2004 but then experienced a steady decline, dropping to 747 TWh by 2015, 649 TWh in 2020, and 588 TWh by 2023, indicating a shift away from nuclear power.[1799]

Figure 64 · Wind, Solar, and Nuclear Capacity and Electricity Production in the EU27



Sources: WNISR with IRENA, IAEA-PRIS, Energy Institute, 2024

Note: See Figure 59.

Notably, in 2023, for the first time ever, non-hydro renewables generated more power than all fossil fuels combined, and wind alone surpassed fossil gas. Fossil fuels generally dropped by a record 19 percent, reaching their lowest level ever and accounting for less than one-third of the E.U.'s electricity generation.[1800]

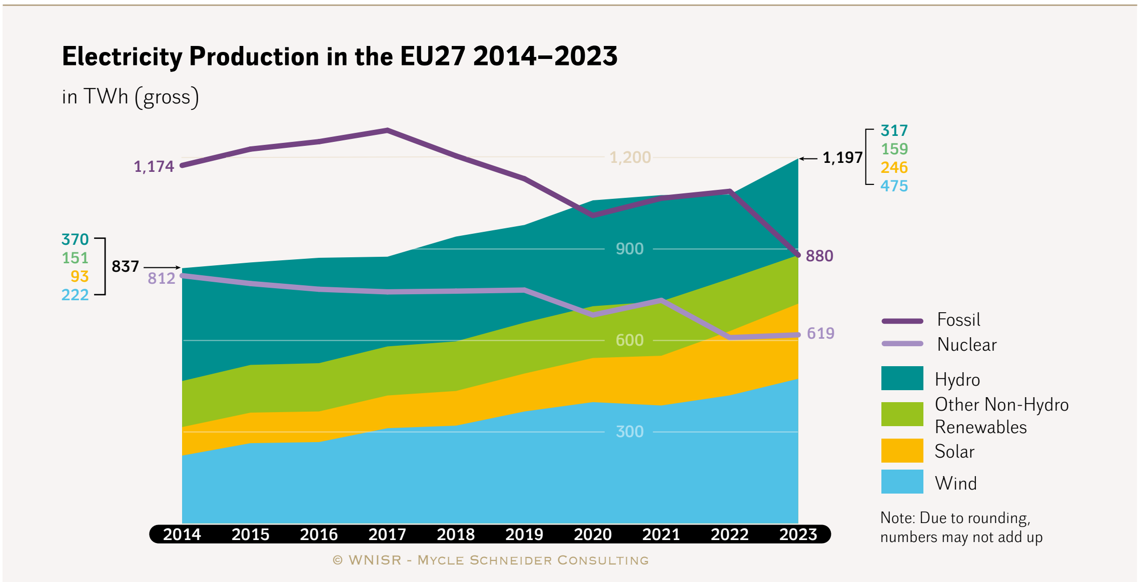
It also helped that power demand fell by 94 TWh or 3.4 percent in 2023 and remained even 6.4 percent lower than in 2021. This decrease in demand and the increase in renewable energy contributed to reducing fossil fuel generation. In total, 24 countries achieved a record solar share in their electricity mix in 2023.[1801]

1799 - Energy Institute, KPMG and Kearney, "Statistical Review of World Energy 2024", 73rd Edition, June 2024, op. cit.

1800 - Ember, "European Electricity Review 2024", February 2024, op. cit.

1801 - Ember, "European Electricity Review 2024", February 2024, op. cit.

Figure 65 · Electricity Generation in the EU27 by Fuel, 2013–2023



Source: Ember, 2024

Country-specific highlights for 2023:[1802]

- Denmark produced 58 percent of its electricity from wind, up from 54 percent in 2022.
- Germany added 14 GW of solar capacity—that is twice its, then world-record, 2012–2013 annual additions of 7 GW—and increased its wind generation by 16 TWh, producing 55 percent of its (net) electricity from renewable sources.[1803]
- Ireland increased its wind share from 33 percent to 36 percent.
- Lithuania achieved a 46 percent share of wind energy in its electricity mix.
- The Netherlands experienced a 36-percent surge in wind electricity generation but, with 16 percent, its share of solar production dropped from first to fourth place in the E.U. (behind Greece, Hungary, and Spain) due to grid congestion and other issues including lack of space for ground-mounted PV systems and the anticipated phaseout of the net-metering scheme.
- In Portugal, renewables provided 73 percent of electricity throughout the year.
- Spain saw a spectacular 26-percent increase (+9.4 TWh) in solar power generation.

Gross fossil fuel generation saw an unprecedented decline. Coal generation fell by 26 percent (-116 TWh) to 333 TWh, its lowest level ever, representing 12 percent of the E.U. electricity mix. Gas generation fell by 15 percent (-82 TWh) to 452 TWh, marking the largest annual reduction ever. Nuclear power generation was slightly up by 1.5 percent to 619 TWh (gross). The recovery of French nuclear generation can mainly account for this after its huge falls

1802 - Unless otherwise noted, Ember, "European Electricity Review 2024", February 2024, op. cit.

1803 - AGEB, "Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2023 (in TWh), Deutschland insgesamt", AG Energiebilanzen e.V., February 2024 (in German), see https://ag-energiebilanzen.de/wp-content/uploads/2024/04/STRERZ_Abg_02_2024_korr.pdf, accessed 5 June 2024.

in 2022 due to extended plant outages. Overall, however, the combined wind and solar generation outpaced nuclear generation.

This transformation highlights the importance of enablers such as grids, storage, and demand-response in supporting the future clean power system.[1804]

Coal generation fell by 26 percent (-116 TWh) to 333 TWh, its lowest level ever

Regarding policy, the E.U. has introduced several measures to support this energy transition. The Fit-for-55 package under the European Green Deal, introduced in 2021, includes amongst many areas provisions for renewable energy, decarbonized gas and hydrogen markets, and infrastructure development.[1805] The REPowerEU plan, established in 2022, aims "through energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy to replace fossil fuels in homes, industry and power generation."[1806] The revised Renewable Energy Directive E.U./2023/2413 raises the E.U.'s binding renewable energy target for 2030 to a minimum of 42.5 percent, up from the previous 32 percent target, with an aspiration to reach 45 percent.[1807] The E.U. has not established any targets for nuclear power development.

The Grid Action Plan proposed in late November 2023 seeks to "make Europe's electricity grids stronger, more interconnected, more digitalised and cyber-resilient" through a "14-point action plan". It aims to modernize and expand Europe's electricity infrastructure to support the energy system transformation and accommodate growing demand, projected to increase by 60 percent by 2030. Key actions include accelerating the implementation of Projects of Common Interest (PCIs) and Projects of Mutual Interest (PMIs) with enhanced support and funding starting from 2024, improving access to finance, and incentivizing grid usage and rollout.

India

Despite the goal of tripling renewable energy capacity by 2030, renewable energy subsidies in FY2023 were less than 10 percent of total energy subsidies, while fossil fuel subsidies increased by 63 percent, reaching a nine-year high of roughly US$39.3 billion.[1808] Policy measures like capping retail fuel prices and tax cuts have bolstered fossil fuel support, hindering renewable energy progress.

1804 - Ember, "European Electricity Review 2024", February 2024, op. cit.

1805 - European Council, "Fit for 55", Council of the European Union, Updated 12 April 2024, see https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55/, accessed 16 August 2024.

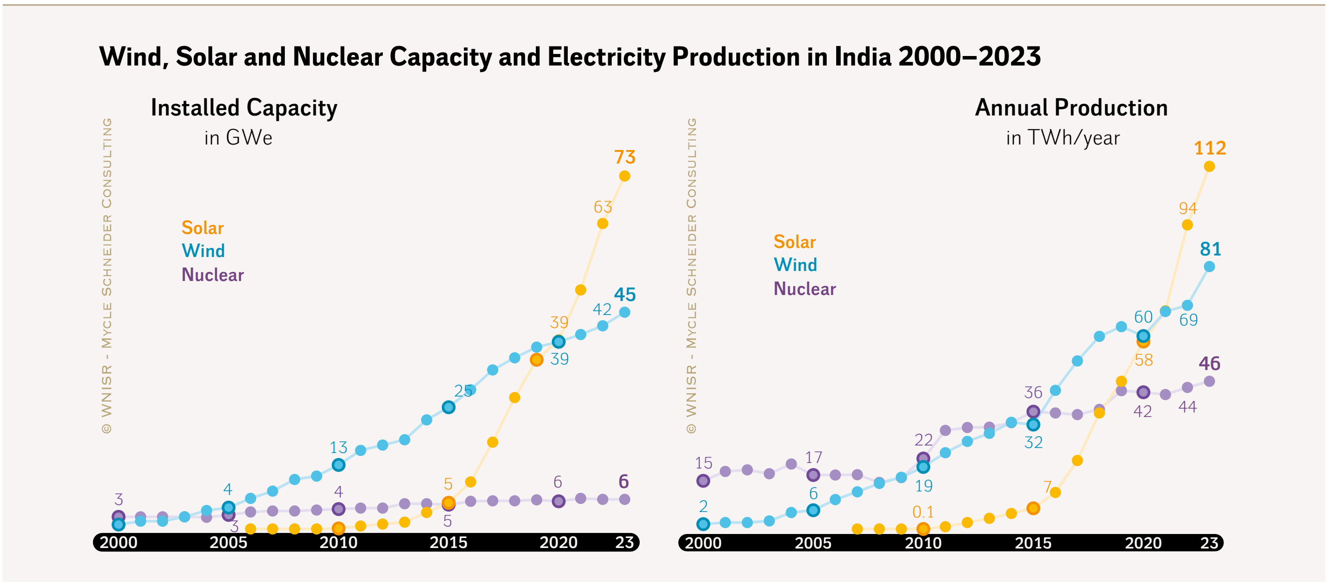
1806 - European Commission, "REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition*", Press Release, 18 May 2022, see https://ec.europa.eu/commission/presscorner/detail/en/ip_22_3131; and European Commission, "REPowerEU: time to address our energy dependencies", Press Release, 18 May 2022, see https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_22_3176; both accessed 16 August 2024.

1807 - European Parliament, "Directive (Eu) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652", *Official Journal of the European Union*, 31 October 2023, see https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ:L_202302413, accessed 16 August 2024.

1808 - Swasti Raizada, Deepak Sharma, et al., "Mapping India's Energy Policy 2023—A decade in action", Global Subsidies Initiative, International Institute for Sustainable Development, March 2024, see https://www.iisd.org/publications/report/mapping-india-energy-policy-2023, accessed 16 August 2024.

As shown in Figure 66, wind energy in India has grown continuously, with installed capacity increasing from 0.9 GW in 2000 to 44 GW in 2023. Over the same period, electricity production from wind sources rose from 1.6 TWh in 2000 to 81.3 TWh in 2023, a 50-fold increase. From 2022 to 2023, wind energy production in India increased by approximately 17 percent. Solar energy has experienced even more dramatic growth. Starting from virtually no capacity in 2000, solar power had only reached 68 MW by 2010. However, 2010 to 2015 saw a rapid increase to 5.4 GW, followed by an even more significant surge to 39.4 GW by 2020. By 2023, installed solar capacity soared to 73 GW, with electricity production rising from nearly zero in 2000 to 112.3 TWh. Compared to 2022, solar energy production saw a year-on-year increase of about 19 percent. Globally, India's influence on the solar sector is increasing, and in 2023 it overtook Japan to be the third largest solar power generator.[1809]

Figure 66 · Wind, Solar, and Nuclear Installed Capacity and Electricity Production in India



Sources: WNISR with IRENA, IAEA-PRIS and Energy Institute, 2024

Note: See Figure 59.

On the other hand, nuclear energy has seen very modest, very slow but steady growth. It took the industry 20 years to just over double its installed capacity from 2.5 GW in 2000 to 5.7 GW by 2020. By 2023, nuclear operating capacity stood at a still modest 6.1 GW, with electricity production tripling from 15 TWh in 2000 to 45.8 TWh. India has plans to add 18 new nuclear reactors by 2031–2032, which would increase total nuclear capacity to 22.4 GW,[1810] although given recent nuclear development history these targets are unlikely to be met. (See India in Annex 1)

Despite these nuclear plans, recent trends show substantial investments in renewable energy. The gap between renewables and nuclear output is expected to widen further due to the faster growth of wind and solar capacities.

1809 - Ember, "India | Electricity Trends", Updated May 2024, see https://ember-climate.org/countries-and-regions/countries/india/, accessed 2 August 2024.

1810 - *Power Technology*, "India to build 18 nuclear reactors with 13.8GW of capacity by 2032", 26 February 2024, see https://www.power-technology.com/news/india-18-nuclear-reactors-2032/, accessed 1 August 2024.

United States

Driven by recent legislative actions and substantial investments, the U.S. also saw a significant uptake in renewables, while fossil and nuclear energy sources remain prominent. The utility-scale 2023-power mix comprised 60 percent from fossil fuels, 19 percent from nuclear energy, and 21 percent from renewable sources.[1811]

According to the Solar Energy Industries Association (SEIA), solar power experienced remarkable growth, with a record 31 GW of new solar capacity installed—a 55 percent increase compared to the 2022 additions. This surge positions solar as the fastest-growing power source in the U.S., accounting for half of all new utility-scale generating capacity through the third quarter of the year, with the total installed solar capacity reaching 161 GW and contributing approximately 5 percent to the nation's electricity production.[1812]

Wind energy saw a more modest growth compared to solar, with about 8 GW added in 2023, bringing the total installed capacity to 148 GW or roughly 12 percent of the U.S. utility scale installed capacity.[1813]

Battery storage installations also saw significant growth, surpassing all of 2022's installations by the third quarter of 2023. This trend is expected to continue, with projections indicating a doubling of capacity in 2024.[1814]

The U.S.'s 54 nuclear power plants remain a significant contributor to the grid.[1815] Illinois leads with eleven reactors, representing 12 percent of the nation's nuclear capacity. The legislative framework supporting renewable energy has been instrumental in driving recent progress. The Inflation Reduction Act (IRA), Bipartisan Infrastructure Law, and CHIPS (Creating Helpful Incentives to Produce Semiconductors) Act have collectively provided a foundation for renewable energy growth and infrastructure development[1816] (see United States Focus for details, including on nuclear subsidies). The IRA includes significant tax incentives and funding for renewable energy projects, encouraging substantial investment in solar and wind power and energy storage solutions. The Bipartisan Infrastructure Law has facilitated improvements in grid infrastructure, which is essential for accommodating the growing share of renewables in the energy mix.[1817]

As depicted in Figure 67, wind and solar energy have grown significantly in installed capacity and electricity production since 2000. Wind capacity grew from 2.4 GW in 2000 to 148 GW in

1811 - U.S. EIA, "Electricity generation, capacity, and sales in the United States", United States Energy Information Administration, July 2024, see https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php, accessed 1 August 2024.

1812 - Lori Bird and Joseph Womble, "State of the US Clean Energy Transition: Recent Progress, and What Comes Next", World Resources Institute, 7 February 2024, see https://www.wri.org/insights/clean-energy-progress-united-states, accessed 1 August 2024; and SEIA, "Solar Poised for Record-Setting 2023 while Economic Challenges Mount", Solar Energy Industries Association, 7 December 2023, see https://www.seia.org/news/solar-poised-record-setting-2023-while-economic-challenges-mount, accessed 10 August 2024.

1813 - IRENA, "Renewable Energy Statistics", 2024, op.cit.

1814 - Ibidem.

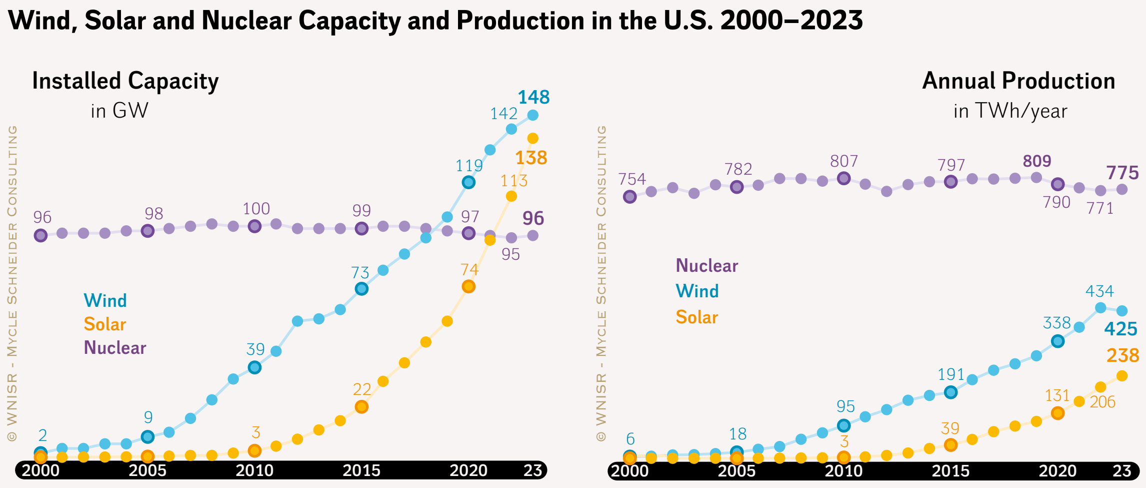
1815 - U.S. EIA, "Frequently Asked Questions (FAQs)- How many nuclear power plants are in the United States, and where are they located?", May 2024, see https://www.eia.gov/tools/faqs/faq.php?id=207&t=21, accessed 1 August 2024.

1816 - Lori Bird and Joseph Womble, "State of the US Clean Energy Transition: Recent Progress, and What Comes Next", World Resources Institute, 7 February 2024, op. cit.

1817 - Ibidem.

2023, with electricity production rising from 5.6 TWh to 425 TWh in the same period. On-grid solar capacity increased from 0.2 GW in 2000 to 138 GW in 2023, with production jumping from 0.5 TWh to 238 TWh. This represents a notable 15.7 percent increase in solar production from 2022 to 2023. Meanwhile, nuclear capacity has remained relatively stable at 96 to 100 GW over the 2000–2023 period with production fluctuating between 754 and 809 TWh.

Figure 67 • Wind, Solar, and Nuclear Installed Capacity and Electricity Production in the United States



Sources: WNISR with Energy Institute, IRENA, IAEA-PRIS, 2024

Note: See Figure 59.

Operating nuclear capacity was overtaken by wind in 2019 and by solar in 2022; in comparison, electricity production from nuclear has remained above both wind and solar. In 2023, nuclear energy generated approximately 1.8 times more electricity than wind energy and 3.3 times more than solar energy. However, wind and solar are expected to close the gap over the coming years due to their rapid expansion. Their cumulated production already represented 85.5 percent of the nuclear output in 2023.

With strong policy support and continuous technological advancements, the U.S. is on a promising path toward a more sustainable and resilient energy system. The ongoing efforts to expand grid capacity and enhance storage solutions will be crucial in managing the increased share of intermittent renewable energy sources. As the country continues to invest in renewable energy, the expectation is that renewables will play an increasingly dominant role in the U.S. electricity generation mix in the coming years.[1818] As of 2023, active capacity that was awaiting grid connection included over 1 TW of solar, over 1 TW of storage, and 366 GW of wind, according to a Lawrence Berkeley National Laboratory study.[1819]

1818 - Ibidem.

1819 - Joseph Rand, Nick Manderlink et al., "Queued Up: 2024 Edition Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2023", Berkeley Lab, April 2024, see https://emp.lbl.gov/sites/default/files/2024-04/Queued%20Up%202024%20Edition_R2.pdf, accessed 16 August 2024.

CONCLUSION ON NUCLEAR POWER VS. RENEWABLE ENERGY DEPLOYMENT

Despite some easing of immediate pressures from the global energy crisis in 2022, the markets remain volatile with ongoing geopolitical tensions, including the prolonged conflict in Ukraine and heating rivalry between the global economic powerhouses.

Overall, however, the dominance of fossil fuels is slowly waning. In 2023, global renewable energy deployment surged to new heights, primarily driven by significant contributions from China and advanced economies. Renewable energies consistently outperform nuclear power in terms of cost and deployment speed and are therefore chosen over nuclear power in most countries.

The urgency of accelerating renewable energy adoption was also reflected at the COP28 summit at the end of 2023, with nations committing to shifting away from fossil fuels, aiming for net-zero emissions by 2050—commitments that have yet to be fulfilled. Doubling the level of energy efficiency and trebling the use of renewables by 2030 will put emissions back on track to meeting the 1.5-degree target of the Climate Paris Agreement. This contrasts with the pledge to triple nuclear operating capacity by 2050, which appears unrealistic[1820] and makes hardly any contribution to the next, critical decade.

1820 - François Diaz-Maurin, "Nuclear expert Mycle Schneider on the COP28 pledge to triple nuclear energy production: 'Trumpism enters energy policy'", interview with Mycle Schneider, *Bulletin of the Atomic Scientists*, 18 December 2023, see https://thebulletin.org/2023/12/nuclear-expert-mycle-schneider-on-the-cop28-pledge-to-triple-nuclear-energy-production-trumpism-enters-energy-policy/, accessed 31 January 2024.

POWER FIRMING AND COMPETITIVE PRESSURE ON NUCLEAR

Nuclear power faces a growing competitive threat from renewable energy, with the Levelized Cost Of Energy (LCOE) for both wind and utility scale solar now well below that for new reactors. Lazard's most recent U.S.-focused LCOE estimates, excluding tax subsidies, again show newbuild nuclear as the most expensive energy resource, at an average of US$182/MWh in 2024, versus utility scale solar at US$61/MWh and onshore wind at US$50/MWh.[1821] (See Figure 58). Recognizing that delivery delays and cost overruns on most nuclear projects mean that the cost of capital for nuclear should be higher than that of wind and solar further worsens the problem for nuclear, which is more sensitive to capital costs than other generation technologies.[1822] (See Nuclear Power vs. Renewable Energy Deployment).

Renewable technologies such as hydro and geothermal, with weighted global means of 45 percent and 75 percent, respectively, can operate at capacity factors comparable to fossil generation and nuclear, at weighted global means of 48 percent and 81 percent, respectively.[1823] However, the fast-growing onshore wind and solar segments are variable generators with significantly lower average load factors, at 23 and 12 percent, respectively.[1824] Newer turbines continue to make improvements. Within the United States, onshore wind had an average capacity factor of 33.5 percent in 2023 and 38.2 percent among wind plants built in 2022.[1825] According to Wind Europe, the capacity factor for new wind farms within the E.U. ranged from 30 percent to 48 percent, with new offshore wind "consistently 50%."[1826] Specific projects, such as the Hywind offshore wind plant in Scotland, achieved capacity factors averaging 54 percent over five years in 2017–2022.[1827]

Moreover, U.S. solar PV data, with a median capacity factor of 24 percent, presents a more favorable picture than the global averages, even though it varies widely from 9 to 35 percent depending on location. In addition to available irradiance, the technology also matters. For example, adding panel tracking of solar radiation boosts solar capacity factors by about 4 percentage points (and nearly 5 percentage points in high-insolation regions). As costs have

1821 - Lazard, "LCOE+", Version 17.0, June 2024, p. 16, see https://www.lazard.com/media/xemfeyok/lazards-lcoeplus-june-2024-_vf.pdf, accessed 5 July 2024.

1822 - Ibidem, p. 13.

1823 - Nathanael Bolson, Pedro Prieto and Tadeusz Patzek, "Capacity factors for electrical power generation from renewable and nonrenewable sources", Proceedings of the National Academy of Sciences of the United States, Vol. 119, No. 52, 20 December 2022, p. 1, see https://www.pnas.org/doi/epdf/10.1073/pnas.2205429119, accessed 6 July 2024.

1824 - Ibidem.

1825 - Lawrence Berkeley National Laboratory, "Land-based Wind Market Report, 2024 Edition" August 2024, p. 34, see https://emp.lbl.gov/sites/default/files/2024-08/Land-Based%20Wind%20Market%20Report_2024%20Edition.pdf accessed 20 August 2024.

1826 - Wind Europe, "The EU built a record 17 GW of new wind energy in 2023 – wind now 19% of electricity production", 12 January 2024, see https://windeurope.org/newsroom/press-releases/the-eu-built-a-record-17-gw-of-new-wind-energy-in-2023-wind-now-19-percent-of-electricity-production/, accessed 21 August 2024.

1827 - Equinor, "Equinor marks 5 years of operations at world's first floating wind farm", 29 December 2022, see https://www.equinor.com/news/hywind-5-years-world-first-floating-wind-farm, accessed 12 August 2024.

fallen sharply, trackers are being installed in nearly all new U.S. projects,[1828] with rapid growth worldwide as well.[1829]

Given the load factor differentials, nuclear proponents have argued that wind and solar are not direct competitors to nuclear. They view LCOE as a misleading metric in terms of competitiveness in the market,[1830] and suggest that high costs on an LCOE basis should not affect the growing subsidies to all parts of the nuclear fuel chain. In a survey of its members, the Nuclear Energy Institute, the main industry trade association in the U.S., noted that "Governors, legislators, and regulators will play a critical role in shaping policies that enhance the development and commercial deployment of these technologies," and provided nine pages outlining their desired supports for new reactors.[1831]

Indeed, starting in 2023, global investment in solar PV exceeded investments in all other generating technologies combined and is estimated to reach US$500 billion in 2024.

While the generation profiles do differ, the substantial cost advantage of wind and solar generation, their shorter and more predictable project completion times, and their resulting rapidly growing global capacity have resulted in significant investment and innovation to address variability concerns. Indeed, starting in 2023, global investment in solar PV exceeded investments in all other generating technologies combined and is estimated to reach US$500 billion in 2024.[1832] Strategies at both the generation asset and the grid levels to address variability are declining in cost and being increasingly adopted. In combination, such strategies help provide more predictable and dispatchable electricity that cost-efficiently integrates inexpensive wind and solar generation.

There are four main drivers behind these gains. First, the cost of battery storage continues to drop sharply, allowing intermittent and variable renewables to be paired (or "firmed") with batteries to provide a more predictable supply of electricity over a greater number of hours per day. This pairing is critical: the International Energy Agency (IEA) estimates that energy storage is required to enable the market penetration of solar to rise above 20 percent in the grid.[1833] The joint levelized costs of wind and solar paired with supply options to "firm" them are already well below the LCOE for new nuclear and gas peaking plants in the U.S.[1834] and are expected to drop below many other generation options in most markets within a few years.

1828 - Mark Bolinger, Joachim Seel et al., "Utility-Scale Solar, 2023 Edition—Empirical Trends in Deployment, Technology, Cost, Performance, PPA Pricing, and Value in the United States", Lawrence Berkeley National Laboratory, October 2023, pp. 25, 26, see https://emp.lbl.gov/sites/default/files/utility_scale_solar_2023_edition_slides.pdf, accessed 8 July 2024.

1829 - Simon Yuen, "Global solar tracker installations to reach 752GW between 2024 and 2030", PV Tech, 16 July 2024, see https://www.pv-tech.org/global-solar-tracker-installations-to-reach-752gw-between-2024-and-2030/, accessed 22 August 2024.

1830 - Matthew Wald, "Dollars, Sense, and Kilowatt-Hours", The Breakthrough Institute, 2 May 2023, see https://thebreakthrough.org/issues/energy/lcoe-lazard-misleading-nuclear, accessed 13 August 2024.

1831 - See for example, Nuclear Energy Institute, "Policy Options for States to Support New Nuclear Energy", November 2022, see https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/State-Policy-Options-to-Support-New-Nuclear-Energy-NEI.pdf accessed 14 August 2024.

1832 - IEA, "World Energy Investment 2024", International Energy Agency, June 2024, p. 6, see https://iea.blob.core.windows.net/assets/60fcd1dd-d112-469b-87de-20d39227df3d/WorldEnergyInvestment2024.pdf, accessed 6 July 2024.

1833 - IEA, "Batteries and Secure Energy Transitions", World Energy Outlook Special Report, International Energy Agency, April 2024, p. 126, see https://iea.blob.core.windows.net/assets/cb39c1bf-d2b3-446d-8c35-aae6b1f3a4a0/BatteriesandSecureEnergyTransitions.pdf, accessed 20 August 2024.

1834 - Lazard, "LCOE+", Version 17.0, June 2024, op. cit., p. 15

Second, power reliability needs to be evaluated at the grid-level, not from a single generation point. Grid operators have a variety of options to integrate variable power resources into their supply and mitigate single-source performance issues by mixing renewables with different generation profiles, using power storage strategically situated on the grid (i.e., not linked to a specific generator), and pooling disparate generators over a larger geographic area. Improved grid interconnections across countries are important elements of the process, as integration increases the ability to move inexpensive or surplus energy from one region to others with shortages, thus better balancing supply and providing improved backup capacity in the face of supply disruptions from weather or other factors. Interconnections across European countries are well developed but not always robust. As part of addressing this problem, the E.U. has set an interconnect target that would allow at least 15 percent of the domestically-produced power to be exported if desired by 2030.[1835]

Third, there are increasing options to adjust power demand to better fit supply options, often termed demand-response, reducing both the need for, and the market power of, continuous generation from nuclear and other thermal plants.

Finally, reactors also push some costs onto the grid that should be integrated into their LCOE for resources to be equally compared. This includes uncounted subsidies to nuclear, costs of addressing nuclear technology's limited ramping capability, and larger scale and more unpredictable outages that are more expensive to plan for than renewable variability and asset failures. Like renewables, nuclear reactors also produce electric power that the grid does not need. Historically, "to cope with excess nuclear output at low-demand times, at least 15.5 GW of U.S. hydro pumped storage plants, each ≥1 GW, got built by the owners of nearby U.S. nuclear plants. Their cost was an undeclared 'inflexibility tax'."[1836] Were these attributes to be bundled into the LCOE for nuclear the way renewable generators and storage are expected to be paired, the competitive position of nuclear would further weaken.

Projections about using surplus nuclear in ancillary markets such as desalination and hydrogen production as a value-added offtake for intermittent surpluses largely fail because these other options generally require a 24/7 power supply to be economic. Due to large losses on the round trip of hydrogen and associated high costs, this approach is unlikely to be used absent very large subsidies. Further, hydrogen is also expensive to store and ship, which has led to the assumption that hydrogen would be produced and supplied on a routine basis and would therefore not serve as a "battery" for nuclear. Industrial applications for hydrogen (in the "hard-to-decarbonize" sectors) require a prioritized supply with no interruptions. Thus, these alternative uses of low carbon nuclear compete with existing residential and commercial power customers in peak and off-peak times alike.[1837]

Asset level firming pairs variable renewables with another power resource via co-located or hybrid plants to backfill hours when solar and wind are not available. The two approaches

1835 - European Commission, "Towards a sustainable and integration Europe", report of the Commission Expert Group on Electricity Interconnection Targets", November 2017, see https://energy.ec.europa.eu/document/download/77d58c11-629c-48a1-a503-f1ab20286ad2_en?filename=report_of_the_commission_expert_group_on_electricity_interconnection_targets.pdf, accessed 21 August 2024.

1836 - Amory B. Lovins, "US nuclear power: Status, prospects, and climate implications", *The Electricity Journal*, Vol. 35, Issue 4, May 2022, p. 7, see https://www.sciencedirect.com/science/article/pii/S1040619022000483, accessed 3 July 2024.

1837 - Mycle Schneider, Antony Froggatt et al., "The World Nuclear Industry Status Report 2023", December 2023, pp. 388–394, see https://www.worldnuclearreport.org/IMG/pdf/wnisr2023-v5.pdf, accessed March 2024.

are slightly different. With co-location, plants are both behind a shared interconnect but can be modeled and dispatched separately. Hybrid plants involve a single bidding approach for multiple resources behind a shared interconnection. Both models are viable according to analysis by the U.S. Lawrence Berkeley National Laboratory. While national and global data on model preferences were not reported, patterns within the California Independent System Operator (CAISO) region of the U.S. indicate that the co-location approach is more popular.[1838] As co-location provides an ability but not a requirement for assets to be bid jointly, it may offer some additional economic flexibility to asset owners.

Battery storage is increasingly used for firming, boosting reliability and availability for variable producers while also providing some additional market power to store and later sell power when prices are higher. These strategies are already less expensive than newbuild nuclear, and their cost advantage is expected to grow in the future particularly as longer-duration storage options develop.

INCREASING NUMBER OF HYBRID PLANTS, MOSTLY PAIR SOLAR AND STORAGE

Power firming is already an important and growing strategy for variable renewables. Within the United States, there were 374 hybrid power plants operating at the end of 2022, excluding hydro pumped storage. These comprised more than 40 GW of generating capacity, of which more than half were PV plus storage, five times the storage capacity of the next closest hybrid pair (which was fossil plus storage). Most of these installations occurred since 2020, which is indicative of the rapid improvements in the viability and market attractiveness of utility scale batteries. These plants also had the highest average storage capacity to generation capacity ratio of the hybrid pairings, at 49 percent (roughly 1 MW of storage for every 2 MW of PV capacity), with a storage capacity of 12.5 GWh. Thirty-five plants were an unspecified fossil source plus PV; however, the PV nameplate capacity was only 2.3 percent of fossil capacity, indicating that the PV capacity was providing incidental generation only.[1839]

The market impacts of this increased storage are already evident. In recent months, battery storage in the U.S. state of California has sometimes met more than 20 percent of peak power demand (between 7 and 10 pm), contributing more than 7 GW at one point. The stored power was mostly excess solar power from earlier in the day.[1840] Surging solar power production in California has also resulted in growing curtailment of the resource. However, data indicate that the main cause of the curtailments has not been overcapacity, but rather grid congestion that prevented the energy from being distributed to market.[1841] Success in improving the reliability of variable renewables can also be seen in wholesale power capacity markets, which

1838 - Mark Bolinger, Will Gorman et al., "Hybrid Power Plants—Status of Operating and Proposed Plants, 2023 Edition", Lawrence Berkeley Laboratory, 10 August 2023, pp. 8–10, see https://emp.lbl.gov/sites/default/files/emp-files/hybrid_plant_tracking_2023_08.08.2023.pdf, accessed 17 June 2024, p. 21.

1839 - Ibidem, pp. 8–10.

1840 - Brad Plumer and Nadja Popovich, "Giant batteries are transforming the way the U.S. used electricity", *The New York Times*, 7 May 2024, see https://www.nytimes.com/interactive/2024/05/07/climate/battery-electricity-solar-california-texas.html, accessed 17 June 2024.

1841 - U.S. Energy Information Administration, "Today in Energy: Solar and wind power curtailments are rising in California", 20 October 2023, see https://www.eia.gov/todayinenergy/detail.php?id=60822, accessed 6 July 2024.

reward generators if they can provide reliable power capacity under contract. In the recent 2027–28 capacity auction by ISO New England (an Independent System Operator covering six states in the northeastern U.S.), more than 16 GW of solar and solar plus storage projects won capacity payments.[1842] In the U.K., battery energy-storage systems captured the largest share among clean energy options for the 2024–25 capacity auctions. While natural gas and nuclear plants continued to capture most of the capacity auction payments, it is notable that demand-side management and battery storage took third and fourth place.[1843] These resources are likely to increasingly challenge conventional generation over time, eroding an important revenue source for plants reliant on 24/7 operation to achieve adequate returns.

Within the E.U., battery storage is also growing quickly, nearly doubling between 2022 and 2023. Of this, only about one-fifth of the installed capacity in 2023 was utility-scale though this segment of the market is expected to gain market share, comprising nearly half of the battery storage-capacity installed in 2024 (11 GWh) and 46 percent of projected 2028 installations (36 GWh).[1844] Utility-scale batteries as a share of total cumulative installed European capacity are estimated to grow from 35 percent (20.4 GWh) in 2024 to 44 percent (114.6 GWh) in 2028.[1845] The deployments remain geographically concentrated for now: across all battery storage installers, Germany, Italy, and the U.K. alone comprised nearly 70 percent of new capacity deployed in 2023 and 68 percent of the cumulative installations.[1846]

Proposed grid interconnects provide a metric of future investment and growth patterns by resource type. In the U.S., these proposals suggest that rapid growth in battery storage, with high levels of pairing with solar, will continue. As discussed below, however, interconnect challenges likely mean that actual installations will lag the scale of the proposals.

As of the end of 2023, hybrids comprised nearly 45 percent of the capacity in interconnect queues, and of these, most were PV plus storage.[1847] Solar was also leading in terms of total proposed new capacity, with 1086 GW as of the end of 2023. Close behind was storage with 1028 GW, of which about 53 percent was hybrid with solar and the rest standalone, the latter's share growing sharply in recent years. Wind was a distant third at 366 GW of proposed new capacity.[1848] The cumulative wind, solar, and storage capacity of 2,480 GW in the queue—of which less than half is expected to be implemented—corresponds to almost twice the entire installed power generating capacity of 1,279 GW in the U.S. at the end of 2023.[1849]

1842 - John Fitzgerald Weaver, "Solar wins hundreds of millions in US capacity payments", *PV Magazine*, 5 March 2024, see https://www.pv-magazine.com/2024/03/05/solar-wins-hundreds-of-millions-in-us-capacity-payments/, accessed 7 July 2024.

1843 - Lena Dias Martins, "BESS wins highest percentage among clean energy technologies in UK Capacity Market auction", *Energy Storage News*, 21 February 2024, see https://www.energy-storage.news/bess-wins-highest-percentage-uk-capacity-market-auction/, accessed 13 August 2023.

1844 - Solar Power Europe, "European Market Outlook for Battery Storage 2024-2028", June 2024, pp. 5, 45 and 47, see https://api.solarpowereurope.org/uploads/1424_SPE_BESS_report_12_mr_84bdb6c5ae.pdf, accessed 7 July 2024.

1845 - Ibidem, p. 49.

1846 - Ibidem, pp. 5–6, and 23.

1847 - Lawrence Berkeley Laboratory, "Hybrid Power Plants—Status of Operating and Proposed Plants, 2023 Edition", August 2023, op. cit., p. 3 and 23.

1848 - Lawrence Berkeley National Laboratory, "Queued Up: 2024 Edition Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2023" April 2024, p. 11 and 23, see https://emp.lbl.gov/sites/default/files/2024-04/Queued%20Up%20 2024%20Edition_R2.pdf, accessed 18 June 2024.

1849 - Ibidem, p. 14 and 45.

Despite potentially high load factors, geothermal in active queue was less than 2 GW.

The increase in the share of standalone storage is likely to further accelerate since standalone installations can now access tax credits that previously applied only to battery storage if it was paired with PV plants.[1850] While other forms of storage are part of the marketplace, batteries were the technology of choice in about 99 percent of proposed storage capacity additions within the U.S.[1851] Proposed new U.S. nuclear capacity, though up more than 50 percent from 2022, was only 10 GW in total.[1852] Global spending on nuclear was expected to reach US$80 billion in 2024, up significantly since 2018, though focused primarily on life extensions of existing reactors rather than newbuild.[1853] In comparison, despite it being a new industry, spending on battery storage is estimated to be over US$50 billion in 2024, heavily concentrated in the OECD economies and China.[1854] Investments in stationary storage outpaced new nuclear investments in 2023.[1855]

The investments in storage appear to have a rapid and significant impact on power market opportunities and dynamics. Project returns are location dependent but appear quite high. Case studies conducted by Lazard estimated an internal rate of return of nearly 29 percent for standalone storage in the CAISO market and above 20 percent for PV-plus-storage and wind-plus-storage projects within the Electric Reliability Council of Texas (ERCOT) region.[1856]

Despite potentially high load factors, geothermal in active queue was less than 2 GW.[1857]

Not surprisingly, regions with strong solar and wind and higher curtailment rates seem particularly interested in firming. Within CAISO, which serves most of California and a portion of Nevada, for example, 98 percent of all solar capacity and 34 percent of all wind capacity in the queues as of the end of 2023 is proposed as a hybrid.[1858] Most other ISOs (Independent System Operators) across the U.S. include hybrid projects for less than half of the proposed capacity on solar projects and even lower for wind. Due to such high demand in the Western United States, however, hybrid projects still comprise 53 percent of proposed capacity nationally.[1859]

Proposed projects include a higher storage-capacity to generation-capacity ratio than those currently on the grid. Lazard notes that the availability of a tax credit for both paired and standalone battery storage, along with lower cell pricing and technology improvements, "is leading to an increasing trend of oversizing battery capacity to offset future degradation and

1850 - Lawrence Berkeley Laboratory, "Hybrid Power Plants—Status of Operating and Proposed Plants, 2023 Edition", August 2023, op. cit., p. 3.

1851 - Ibidem, p. 33.

1852 - Lawrence Berkeley National Laboratory, "Queued Up: 2024 Edition Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2023" April 2024, p. 18.

1853 - IEA, "World Energy Investment 2024", International Energy Agency, June 2024, p. 9 and 59.

1854 - Ibidem, p. 9.

1855 - Nat Bullard, "Decarbonization: Stocks and flows, abundance and scarcity, net zero" 31 January 2024, see https://www.nathanielbullard.com/presentations, accessed 14 July 2024.

1856 - Lazard, "LCOE+", Version 17.0, June 2024, op. cit., p. 25.

1857 - Lawrence Berkeley National Laboratory, "Queued Up: 2024 Edition Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2023" April 2024, op. cit., pp. 18–19.

1858 - Ibidem, p. 24.

1859 - Ibidem.

useful life considerations."[1860]This is extending the useful life of the projects and boosting overall returns.

An important caveat is that while connection queues are an indication of interest, progression to grid connection and commercial operation is a years-long process with low relative completion rates. Delays in the U.S. have been increasing; progressing from an interconnection request to commercial operation now takes an average of five years.[1861] More than 70 percent of the interconnection requests get withdrawn, with most withdrawals occurring in the earlier, feasibility study stage.[1862] Standalone battery projects have been processed much faster than others in recent years, at least through the point of approval.[1863] The speed to the start of commercial operation is less impressive across resources: median duration from an interconnection request to the start of commercial operations has risen to roughly 60 months for solar and more than 65 months for wind. Solar plus battery projects are somewhat faster, but still take around 55 months. In comparison, achieving interconnection agreements took about 15 months for standalone batteries and less than 12 months for natural gas; however, project completion through start of commercial operation was still sluggish at about 45 and 60 months, respectively.[1864]

Within the E.U., grid expansion plans suggest inadequate capacity will be in place to meet the policy targets for low-carbon generation in 10 of 26 regions. The overall shortfall averaged about 8 percent within this subgroup, though it varied by country. For example, capacity shortfalls for grid expansion for wind and solar in Bulgaria were estimated to be 63 percent of target, while in others the grid capacity was expected to run above policy targets.[1865]

GROWTH IN UTILITY-SCALE STORAGE AND COST TRENDS

Global utility scale battery storage capacity continues to grow rapidly, expanding the opportunities to reduce curtailment losses on renewable energy, manage around grid congestion, and increase the ability of variable renewables generators to meet market needs. Multiple sources of value from utility-scale storage support continued rapid growth. Figure 68 highlights five major areas in which storage adds value within U.S. power markets. Grid services and renewable firming dominate the use cases for wind while peak shaving is an additional area of importance for PV. These additional sources of value help to propel and accelerate storage installations.

1860 - Lazard, "LCOE+", Version 17.0, June 2024, p. 5.

1861 - Lawrence Berkeley National Laboratory, "Queued Up: 2024 Edition Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2023", April 2024, op. cit., p. 3.

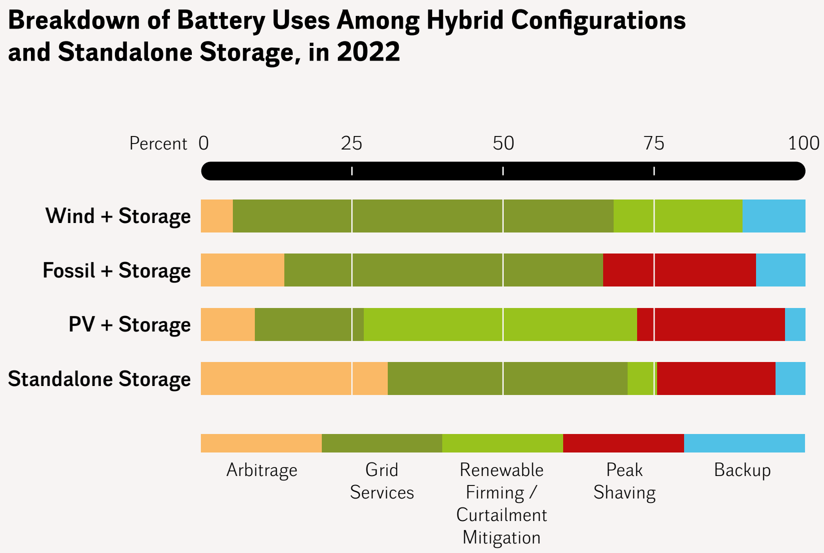
1862 - Ibidem, p. 27 and 30.

1863 - Ibidem, p. 36.

1864 - Ibidem, p. 36 and 43.

1865 - Elisabeth Cremona and Chris Rosslowe, "Putting the mission in transmission: Grids for Europe's energy transition", Ember, 13 March 2024, p. 8, see https://ember-climate.org/app/uploads/2024/03/Grids-for-Europes-Energy-Transition-Report-1.pdf, accessed 13 August 2023.

Figure 68 · Multiple Service Areas for Storage



Source: Lawrence Berkeley National Laboratory, 2023[1866]

Within the E.U., battery storage is expected to add significant value to variable renewable energy resources as well. Modeling of the value of battery storage and PV (in terms of the share of market price that could be attained) across Germany, Greece, Italy, Netherlands, Poland, and Spain indicated price gains from paired storage of between 8 and 15 percentage points.[1867] Energy Systems Catapult estimated that battery storage with a duration of 4–12 hours could reduce wind power curtailment in the U.K. by up to 65 percent.[1868] At present, battery storage is limited to about 4 hours in duration for most deployments, which improves but does not entirely solve the variability aspect of renewables.

Globally, utility-scale storage additions jumped from just over 10 GW added in 2022 to more than 25 GW in 2023. Most of this is focused on energy shifting and capacity provision according to the International Energy Agency (IEA). Although multiple battery technologies are under intensive development, storage currently relies predominantly on the lithium iron phosphate technology and is expected to remain that way through 2030.[1869] Total installed capacity was nearly 52 GW at the end of 2023,[1870] and early indications are that 2024 will continue this trend. U.S. grid-scale battery capacity deployments for the first quarter of 2024 were up 101 percent relative to the first quarter of 2023 (130 percent on a GWh basis), and grid-scale battery system

1866 - Mark Bolinger, Will Gorman et al., "Hybrid Power Plants—Status of Operating and Proposed Plants, 2023 Edition", Lawrence Berkeley Laboratory, 10 August 2023, op. cit, p. 13.

1867 - Ember, "European Electricity Review 2024", February 2024, p. 40, see https://ember-climate.org/app/uploads/2024/02/European-Electricity-Review-2024.pdf, accessed 22 June 2024.

1868 - Energy Systems Catapult, "Battery storage project could help reduce wind power curtailments by 65%", Undated, see https://es.catapult.org.uk/news/battery-storage-project-help-reduce-wind-curtailments/, accessed 14 July 2024.

1869 - IEA, "Batteries and Secure Energy Transitions", April 2024, op. cit., p. 39 and 91.

1870 - Calculation based on IEA, "Batteries and Secure Energy Transitions", 2024, op. cit., p. 39; and associated background data.

prices were down by 40 percent. Price declines are attributed to overcapacity in battery cell production and fierce competition within China.[1871]

Although multiple battery technologies are under intensive development, storage currently relies predominantly on the lithium iron phosphate technology and is expected to remain that way through 2030.

Scaling of lithium-ion battery production across a range of uses has helped achieve economies of scale in production and cost declines of more than 80 percent between 2013 and 2023.[1872] These are on par with those realized by wind and utility-scale solar. This scale has been driven primarily by electric vehicle demand (the market for 90 percent of the lithium-ion batteries produced), though "[t]rends from the automotive industry have often transferred to the power sector."[1873] Lazard's estimate for the unsubsidized levelized cost of storage (using 100 MW, 4 hour standalone) has been relatively flat. They estimated a range of US$204–298/MWh in 2018 versus US$170–296/MWh in 2024,[1874] which is a decline in real dollar terms but not commensurate with the declines in cell and battery pack prices. Lazard notes that despite reductions in cell prices and reduced shortages of key materials, there were "significant increases in engineering, procurement and construction ("EPC") pricing driven, in part, by high demand, increased timeline scrutiny, skilled labor shortages and prevailing wage requirements."[1875] Longer-term, there are concerns about overbuilding of lithium battery manufacturing capacity as many countries have rushed to secure capacity with subsidized production lines. For example, Bloomberg New Energy Finance noted recently that 7.9 TWh of capacity are projected by the end of 2025 versus 1.6 TWh of expected demand.[1876] While this will likely eventually spur project cancellations and market exits, in the medium term the overcapacity is likely to be a tailwind for accelerated deployment of battery storage.

ECONOMICS OF RENEWABLE PLUS STORAGE HYBRIDS

IEA's models of solar plus storage in key markets adjust the raw LCOE for impacts to the grid that reduce the option's value relative to other resources. This "value-adjusted" LCOE, or VALCOE, has been criticized as too high, an outcome of ignoring low-cost grid balancing technologies for variable renewables and not penalizing incumbent thermal technologies

1871 - Wood Mackenzie Power & Renewables and American Clean Power Association, "US Energy Storage Monitor—Q2 2024 Executive Summary", June 2024, p. 6, see https://go.woodmac.com/l/131501/2024-06-17/32hrpj/131501/17186295615HUEABSS/Wood_Mackenzie_ACP_US_ESM_Q2_2024_Executive_Summary.pdf, accessed 7 July 2024.

1872 - IEA, "World Energy Outlook Special Report—Batteries and Secure Energy Transitions", April 2024, op. cit., p. 21.

1873 - Ibidem.

1874 - Lazard, "Lazard's Levelized Cost of Storage Analaysis—Version 4.0", November 2018, p. 11, see https://www.lazard.com.au/media/sckbar5m/lazards-levelized-cost-of-storage-version-40-vfinal.pdf, accessed 27 August 2024; and Lazard, "LCOE+", Version 17.0, June 2024, op. cit., p. 20.

1875 - Lazard, "LCOE+", Version 17.0, June 2024, op. cit., p. 5.

1876 - Colin McKerracher, "China Already Makes as Many Batteries as the Entire World Wants", BloombergNEF, 19 April 2024, see https://about.bnef.com/blog/china-already-makes-as-many-batteries-as-the-entire-world-wants/, accessed 13 August 2024.

for the burdens they place on the grid from unpredictable outages. These burdens include increased reserve margin, spinning reserve, part-load penalties, and cycling costs.[1877]

Even with these adjustments being less favorable to renewable hybrid options than perhaps is warranted, IEA modeling nonetheless indicates that solar PV plus battery storage is already competitive with coal- and natural gas-fired power in some markets, and "its competitiveness will soon spread to most leading markets, opening massive potential for growth."[1878] The following are among the milestones noted for solar plus storage using the VALCOE metric and integrating existing policies in place:[1879]

- Costs are expected to fall below those of coal-fired and nuclear power plants by around 2025 in China.
- Solar plus storage is already more competitive than coal in India and remains so going forward.
- Costs are expected to drop below those of new efficient gas-fired power plants before 2025 in the U.S., and "substantially extends its lead by 2030."
- Carbon pricing within the E.U. means that solar PV plus battery storage already easily outcompetes natural gas-fired power.
- The cost of solar plus storage is already "significantly lower than nuclear power in most markets today," as well as "highly competitive with other low-emissions sources of electricity that are commercially available today."
- Even if the longer-term low carbon strategies materialize after 2030 (e.g., new nuclear, plants with CCS), "it is likely to be difficult for them to compete successfully in most parts of the world with solar PV plus battery storage."

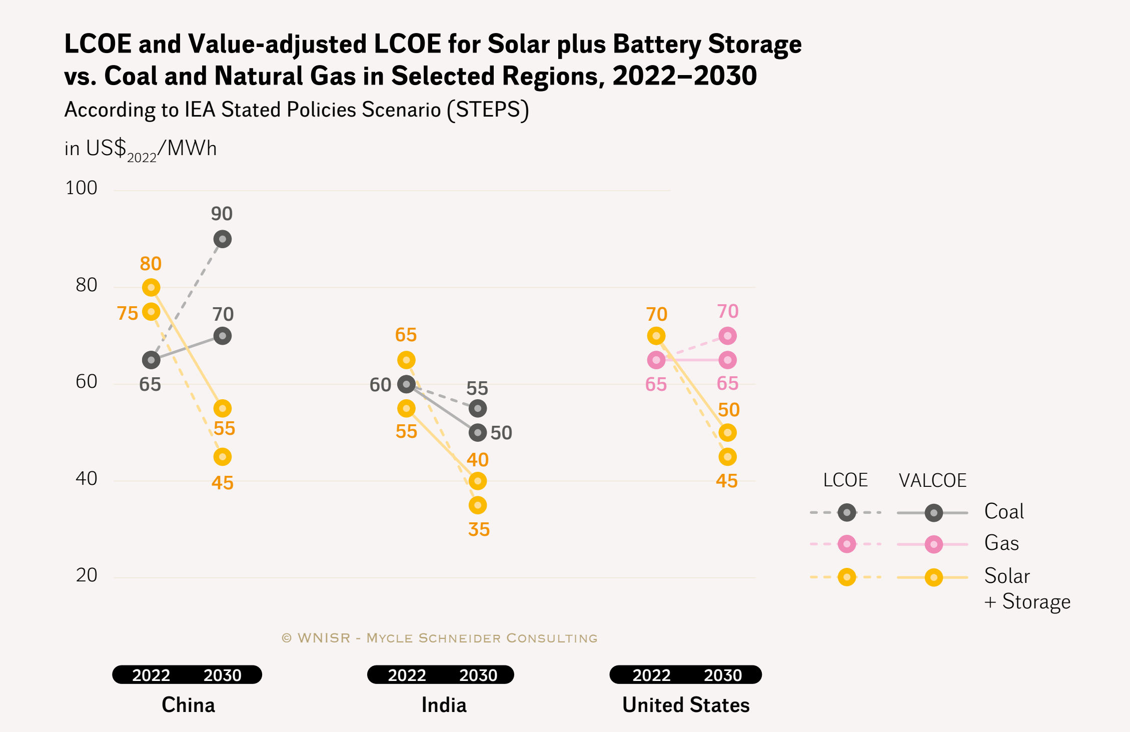
Figure 69 illustrates the projected improving costs for PV plus battery storage on a VALCOE basis, with the hybrid resource besting both coal and natural gas combined cycle in key markets. New nuclear is significantly more expensive than coal and gas, so it would also fare poorly as a competitor to PV plus battery storage.

1877 - Amory B. Lovins, "US nuclear power: Status, prospects, and climate implications", *The Electricity Journal*, Vol. 35, Issue 4, May 2022, p. 4, see https://doi.org/10.1016/j.tej.2022.107122, accessed 21 July 2023.

1878 - IEA, "World Energy Outlook Special Report—Batteries and Secure Energy Transitions", April 2024, op. cit., p. 102.

1879 - Ibidem, p. 103.

Figure 69 · LCOEs for Solar + Storage vs. Coal and Gas in China, India, U.S.



Source: IEA, 2024

Note: **LCOE:** Levelized Cost of Electricity; **VALCOE:** Value-Adjusted LCOE.

Lazard's unsubsidized LCOE estimates for 2024 indicate onshore wind plus storage is less expensive than gas peaking, new nuclear, and coal in many circumstances. It is also significantly less expensive than paired PV and storage, though wind faces more siting challenges, slowing its rollout. At the low-end of the projected cost range, PV plus storage is equally competitive with all of the resources that wind plus storage beats. At the high end of the Lazard range estimate, solar hybrids are still cheaper than gas peaking and nuclear though more expensive than coal even with assumed carbon prices of US$40–60 per ton.[1880]

Regional differences for solar plus storage remain significant across many metrics. Market penetration levels in CAISO are 52 percent, versus only 7 percent in PJM. Penetration of solar plus firming (not necessarily battery storage) are reported at 21 percent in ERCOT. At higher market penetrations, balancing generation rates within a district becomes more challenging which can result in higher curtailment levels and associated increases in the LCOE due to reduced marketable production. Battery storage or other firming approaches can help reduce both curtailment and solar plus storage LCOEs over time. Lazard's 2024 estimates show renewables plus firming as less expensive than natural gas combined cycle in MISO (Midcontinent Independent System Operator), SPP (Southwest Power Pool), ERCOT, and for some configurations in PJM. Unsubsidized PV plus battery storage estimates (US$162/MWh in CAISO and US$160/MWh in PJM) are not yet competitive with standard gas plants

1880 - Lazard, "LCOE+", Version 17.0, June 2024, op. cit., p. 9 and 12.

according to Lazard's models, though less expensive than natural gas peaking plants and new nuclear in many scenarios.[1881]

In contrast to Lazard's estimates, IEA models suggest solar PV plus storage to be much more competitive, at $\text{US\$}_{2022}$70/MWh for the U.S. in 2022 even after applying a downward adjustment for grid integration costs using the VALCOE metric. The estimate for China was $\text{US\$}_{2022}$80/MWh and for India $\text{US\$}_{2022}$55/MWh.[1882]

While the timing at which paired renewables plus storage will be more cost competitive than nuclear in all regions is uncertain, this will happen and likely relatively quickly.

1881 - Ibidem, p. 15

1882 - IEA, "LCOE and value-adjusted LCOE for solar PV plus battery storage, coal and natural gas in selected regions in the Stated Policies Scenario, 2022-2030", Updated 14 April 2024, see https://www.iea.org/data-and-statistics/charts/lcoe-and-value-adjusted-lcoe-for-solar-pv-plus-battery-storage-coal-and-natural-gas-in-selected-regions-in-the-stated-policies-scenario-2022-2030, accessed 14 August 2024.

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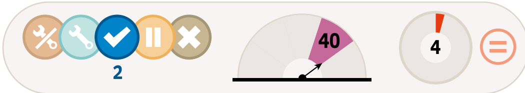
ANNEX 1 – OVERVIEW BY REGION AND COUNTRY

AFRICA

South Africa



South Africa hosts the only commercial nuclear power plant on the African continent, consisting of two 900-MW reactors located at Koeberg, near Cape Town. Both reactors started operating in the mid-1980s. The lifetime load factors of both units until end of 2023, standing at 70.5 percent for Unit 1 and 72.7 percent for Unit 2, remained very modest by international comparison. The plant is nearing the end of its originally projected 40-year lifespan with its operating license expiring in July 2024.[1883]

Recent developments in South Africa's nuclear energy sector are inherently linked to the severe power shortages that had been worsening up to mid-2023 and had resulted in major economic impact and personal hardship. To alleviate the power shortages, several measures were considered, including two nuclear options: extending the lifetime of Koeberg and building new nuclear plants.

Owner Eskom decided to try to keep the Koeberg plant operational for a further 20 years, partly because sufficient new power sources to compensate for its 1800 MW seemed unlikely to emerge in the short-to-medium term. Consequently, the implementation of this lifetime extension has been initiated but remains conditional on the completion of extensive repairs and backfitting currently underway. The initiation of nuclear newbuild, however, has not progressed much due to economic and other factors, despite support from some political parties and preliminary moves from the responsible ministry.

South Africa's Electricity Crisis Unexpectedly Eases

In 2023, South Africa had been experiencing persistent power cuts and record electricity shortfalls that at times exceeded 6 GW.[1884] Scheduled power cuts of two to twelve hours per day had to be implemented on most days that year, with households spending 1,742 hours without power in 2023, almost ten times as much as in 2021.[1885] During 2023, Koeberg generated an average of 928 MW,[1886] i.e., only half of its nameplate capacity, given that at almost all times one of its two units was offline due to the Koeberg lifetime extension work, in particular Koeberg-1 that was shut down in December 2022 and restarted in November 2023. The rolling

1883 - As expected, it was announced in mid-July 2024 that the operating license for Koeberg-1 has been renewed by 20 years, expiring on 21 July 2044; see Eskom, "Koeberg operating licence extended for further 20 years", Press Release, 15 July 2024, see https://www.eskom.co.za/koeberg-operating-licence-extended-for-further-20-years/, accessed 10 August 2024.

1884 - *BusinessTech*, "Stage 6 load shedding extended as units at four stations go down", 21 April 2023, see https://businesstech.co.za/news/energy/682105/stage-6-load-shedding-extended-as-units-at-four-stations-go-down/, accessed 20 August 2023.

1885 - *BusinessTech*, "Load shedding and blackout warning for 2024", 2 January 2024, see https://businesstech.co.za/news/energy/739825/load-shedding-and-blackout-warning-for-2024/, accessed 27 June 2024.

1886 - Eskom, "Eskom Data Portal", Undated, see https://www.eskom.co.za/dataportal/, accessed 21 August 2023.

blackouts continued into March 2024, after which electricity supply recovered sufficiently for the scheduled blackouts to be suspended. As of mid-2024, there seemed to be a small but significant improvement in the power supply situation compared to 2023, and the country has not experienced scheduled power cuts for over three months.[1887] Furthermore, South Africa's power utility Eskom was able to meet electricity demand throughout June, i.e. into the winter months, when electricity usage peaks.

The long-neglected domestic solar industry has been booming as large organizations, businesses, and households scrambled to escape the worsening power cuts by installing rooftop solar systems.

There are several reasons for the improved electricity supply, including temporary repairs to a partly disabled major coal plant, much greater domestic solar panel usage, and Eskom's improved ability to implement plant maintenance and repairs.

The return to operation of three units at the Kusile coal plant, albeit through rudimentary repairs entailing exceptionally high carbon emissions, restored 2.4 GW to the grid, i.e. almost 5 percent of Eskom's maximum generating capacity. Furthermore, Eskom is optimistic that the two previously unfinished units at Kusile and an equally-sized damaged unit at its Medupi plant will all be in operation before end of the year. Together these would add 2.5 GW to the country's generating capacity.[1888] Solar and wind farms currently under construction will also, to a lesser degree, assist in alleviating power shortages.

The long-neglected domestic solar industry has been booming as large organizations, businesses, and households scrambled to escape the worsening power cuts by installing rooftop solar systems.[1889] Tax incentives and loan schemes have also encouraged moves to solar rooftop electricity generation. Eskom estimated that solar rooftop capacity more than doubled from 2.3 GW in July 2022 to 5.4 GW in March 2024.[1890] The removal of restrictive regulations on the development of private facilities in the 1–100 MW capacity range has also boosted the deployment of medium-scale solar and wind farms.[1891]

Eskom has somewhat stabilized and gained slightly better control over the all-too-frequent breakages at its fleet of power plants. Even though the power system is still severely constrained, and the danger of major failures and extensive power cuts persists, the public

1887 - Eskom, "Continued loadshedding suspension marks over three months of steady power supply - Winter Outlook still in force", Press Release, 28 June 2024, see https://www.eskom.co.za/continued-loadshedding-suspension-marks-over-three-months-of-steady-power-supply-winter-outlook-still-in-force/, accessed 28 June 2024.

1888 - Eskom, "Kusile Unit 5 synchronised to the grid for the first time", Press Release, 31 December 2023, see https://www.eskom.co.za/kusile-unit-5-synchronised-to-the-grid-for-the-first-time/; and Eskom, "Eskom adds 800MW to grid as Kusile Unit 5 achieves commercial operation", Press Release, 30 June 2024, see https://www.eskom.co.za/eskom-adds-800mw-to-grid-as-kusile-unit-5-achieves-commercial-operation/; also Eskom, "Media Briefing—State of the System - Winter 2024 Outlook Briefing", 26 April 2024, see https://www.eskom.co.za/wp-content/uploads/2024/04/20240425_State_of_the_system_Draft_postDPE_26-April_FINAL6a.pptx; all accessed 10 July 2024.

1889 - *BusinessTech*, "Solar boom in South Africa as private investors sweep in with R300 million", 31 July 2023, see https://businesstech.co.za/news/energy/707872/solar-boom-in-south-africa-as-private-investors-sweep-in-with-r300-million/, accessed 21 August 2023.

1890 - Myles Illidge, "Eskom report says SA's rooftop solar generation doubled in two years", *BizNews*, 18 April 2024, see https://www.biznews.com/energy/2024/04/18/rooftop-solar-generation-doubled-two-years, accessed 28 June 2024.

1891 - Marianne Merten, "Increase to 100MW embedded generation threshold will give 'oomph' to South African economy, says Ramaphosa", *Daily Maverick*, 10 June 2021, see https://www.dailymaverick.co.za/article/2021-06-10-increase-to-100mw-embedded-generation-threshold-will-give-oomph-to-south-african-economy-says-ramaphosa/, accessed 21 August 2023.

impression, driven by the current lull in blackouts, is that the worst of the electricity crisis is over. One consequence of this is that the typical argument used to leverage for new nuclear builds has been, at least temporarily, weakened.

Developments Related to Proposed Koeberg Lifetime Extension

For practically the entire reporting period, only one of Koeberg's two units has been operational at a time due to major maintenance and upgrading work needed to secure a 20-year lifetime extension beyond the plant's projected 2024 closure date.

Operations to replace a variety of components, in particular the plant's six steam generators, have been planned for over a decade (see previous WNISR editions). As the South African electricity crisis has grown more acute, the need to keep large electricity producing facilities such as Koeberg going for as long as possible has been considered increasingly crucial. A 20-year extension of the ageing nuclear plant has accordingly been recommended in the most recent Integrated Resource Plan (IRP), published in October 2019. To approve the extension, the South African National Nuclear Regulator requires a series of maintenance operations and instrumental replacements to be carried out. The most significant of these is the replacement of the six steam generators.

The steam generator replacements of Koeberg-2 were scheduled to coincide with the unit's refueling outage between January and June 2022.[1892] While never fully explained by the utility, reports indicate that work could not proceed as planned because the utility failed to construct the storage facilities for the contaminated old steam generators in time. With the steam generator replacement operation postponed, Koeberg-2 returned to service with the original steam generators in mid-August 2022 (i.e. 7 months into an outage originally scheduled for 5 months), though two more outages occurred in the following weeks.[1893]

The Koeberg refurbishment project is now two years behind schedule and is set to drag on well past 31 July 2024, when Koeberg's operating license expires. On 10 December 2022, Koeberg-1 was taken offline to start refurbishment work, including the replacement of its three steam generators.[1894] The six months projected for this operation proved insufficient. Koeberg-1 came back on-line in November 2023, and the other unit was then switched off to undergo the same work on 11 December 2023. Since then, details about work progress have been sparse; the responsible Minister and individuals in Eskom said in February that they expected work on Koeberg-2 to be completed in September 2024 and maintained this stance in Eskom's Winter 2024 Outlook, released in April 2024.[1895]

1892 - Eskom, "Update on Koeberg Unit 2 long term outage and steam generator replacement project", Press Release, 4 March 2022, see https://www.eskom.co.za/update-on-koeberg-unit-2-long-term-outage-and-steam-generator-replacement-project/, accessed 4 April 2022.

1893 - Hanno Labuschagne, "Koeberg unit quits again — Here is a timeline of its many troubles in 2022", *My Broadband*, 6 September 2022, see https://mybroadband.co.za/news/energy/459301-koeberg-unit-quits-again-here-is-a-timeline-of-its-many-troubles-in-2022.html, accessed 20 August 2023.

1894 - Eskom, "Koeberg Unit 1 outage delayed to allow stability of the power system", Press Release, 8 December 2022, see https://www.eskom.co.za/koeberg-unit-1-outage-delayed-to-allow-stability-of-the-power-system/, accessed 31 August 2023.

1895 - Zalene Merrington, "End of load shedding is in sight: Ramokgopa", *SABC News*, 14 February 2024, see https://www.sabcnews.com/sabcnews/end-of-load-shedding-is-in-sight-ramokgopa/, accessed 28 June 2024; and Eskom, "State of the System - Winter 2024 Outlook Briefing", Media Briefing, 26 April 2024, see https://www.eskom.co.za/wp-content/uploads/2024/04/20240425_State_of_the_system_Draft_postDPE_26-April_FINAL6a.pptx, accessed 10 July 2024.

The projected costs of the upgrades required for the Koeberg lifetime extension certification were estimated in 2010 at ZAR20 billion (US$$_{2010}$2.7 billion).[1896] There are now indications that the final costs will be considerably higher,[1897] though at present there is still no publicly available updated estimate.

The National Nuclear Regulator extended the existing operating license of Koeberg-2 to 9 November 2025,[1898] arguing that it only came into commercial operation in November 1985, more than a year after Koeberg-1 had reached that milestone. A formal process of soliciting public input regarding the lifetime extension was instituted late, with public hearings held in February 2024, and again in June 2024;[1899] the latter round was reportedly added, after criticism from civil society groups, to enable comment on information that had not been made available earlier.[1900]

Koeberg's power generation dropped again, by almost 20 percent in 2023 to 8.13 TWh following a drop of 17 percent in 2022. This drove down its share in the national electricity mix to 4.4 percent in 2023, half a percentage point less than in the previous year. The decline is a direct consequence of at least one of the units being inoperative for practically the entire year. In the meantime, from 2022 to 2023 wind energy production grew by 19 percent to 11.5 TWh, while utility-scale solar energy production remained steady at 6.3 TWh.[1901]

Developments Related to Potential Newbuild

Following the commissioning of Koeberg in the 1980's, South Africa entered a period of political upheaval and economic downturn, followed by a lengthy transition and consolidation of a new African National Congress led government (see South Africa Focus—Historical Background in WNISR2023). A push for power generation infrastructure development only resurfaced towards the turn of the new millennium, when it became clear that additional electricity sources would be required in the foreseeable future.[1902]

1896 - Chris Yelland, "R20bn life extension of Koeberg power station poses significant risks for South Africa", *Daily Maverick*, 28 November 2021, see https://www.dailymaverick.co.za/article/2021-11-28-r20bn-life-extension-of-koeberg-power-station-poses-significant-risks-for-south-africa/, accessed 20 July 2023.

1897 - Terence Creamer, "R20bn Koeberg life-extension cost estimate of 2010 now 'significantly different'", *Engineering News*, 27 September 2022, see https://www.engineeringnews.co.za/article/r20bn-koeberg-life-extension-cost-estimate-of-2010-now-significantly-different-2022-09-27, accessed 31 August 2023.

1898 - NNR, "National Nuclear Regulator (NRR) Approves the Request from Eskom to Separate the Operational Timelines for Koeberg Unit 1 and Unit 2", Press Release 1/5/6/2, National Nuclear Regulator, 26 January 2024, see https://nnr.co.za/wp-content/uploads/2024/01/NNR-Media-Release-Regulatory-approval-granted-to-separate-Koeberg-Unit1-and-Unit2_260124.pdf, accessed 22 April 2024.

1899 - NNR, "NNR Public Hearings – Koeberg LTO Project", National Nuclear Regulator, Updated 2024, see https://nnr.co.za/nnr-public-hearings-koeberg-lto-project/, accessed 28 June 2024: and Department of Mineral Resources and Energy, and National Nuclear Regulator, "Notice 2420 of 2024—Notice of the second set of National Nuclear Regulator (NNR) public hearings for the application to extend the operating life of the Koeberg Nuclear Power Station (KNPS) by 20 years", Government Gazette, No. 50528, 19 April 2024, see https://www.gov.za/sites/default/files/gcis_document/202404/50528gen2420.pdf, accessed 10 July 2024.

1900 - Marleny Arnoldi, "NNR hosts new round of talks with public over Koeberg's life extension", 4 June 2024, *Engineering News*, see https://www.engineeringnews.co.za/article/nnr-hosts-new-round-of-talks-with-public-over-koebergs-life-extension-2024-06-04, accessed 10 August 2024.

1901 - Eskom, "Eskom Data Portal", op. cit.

1902 - Philip Lloyd, "Restructuring South Africa's Electricity Supply Industry", 2012.

There was an attempt at initiating nuclear newbuild in 2008 that attracted bids from Areva and Westinghouse, but the plan was canceled later in the year due to financial shortfalls.[1903] In 2010, a 9.6 GW mega nuclear newbuild program had been touted as a solution to South Africa's looming electricity shortfall. This initiative failed, partly due to financial considerations and industrial issues, but also because of the suspicious manner in which the project was driven. The process to advance the program was eventually declared illegal and the entire initiative was effectively terminated (see previous WNISR editions).

There was an attempt at initiating nuclear newbuild in 2008 that attracted bids from Areva and Westinghouse, but the plan was canceled later in the year due to financial shortfalls.

Emphasizing the need to explore all potential solutions to the recent acute electricity shortages, the government has made tentative moves to expand the country's nuclear energy generation capacity. South Africa's current electricity generation development roadmap, the 2019 edition of the "Integrated Resource Plan" (IRP) for Electricity, is ambiguous about the construction of new reactors. On the one hand, it marked a significant move away from nuclear energy, in particular, by removing the 9.6 GW newbuild listed in IRP2010; the 2019 edition only explicitly advocated a 20-year lifetime extension of the two units at Koeberg to 2044. On the other hand, it included an unclear reference to a potential 2.5 GW of nuclear envisaged to be operational by 2030 at the earliest (see WNISR2023).

Despite this, the now combined Ministry of Mineral Resources and Energy has been quick to get the ball rolling to lay the ground for a round of expressions of interest. In 2021, the Ministry had announced it would issue a request for proposals in late FY2021 in order to finalize the procurement in 2024.[1904] This has not materialized to date, yet in May 2023, the Ministry reaffirmed its commitment to the 2024 procurement deadline and announced that a Request For Proposals (RFP) would be launched in Q4 of FY2023.[1905] In December 2023, it was announced that the RFP would be issued in March 2024.[1906] The intention to initiate work on adding 2.5 GW of new nuclear capacity was gazetted in January 2024,[1907] but that is a preliminary step and similar developments had proven inconsequential in earlier initiatives. As of mid-2024, the RFP had still not been issued.

1903 - Anthonie Cilliers, "History of nuclear in South Africa", Honorary Research Fellow, University of the Witwatersrand, published in *ESI-Africa*, 18 February 2019, see https://www.esi-africa.com/features-analysis/update-history-of-nuclear-in-south-africa/, accessed 24 September 2023.

1904 - Department of Mineral Resources & Energy, "NERSA Concurrence With the Section 34 Determination for 2 500MW of New Nuclear Generation Capacity", Press Release, Government of South Africa, 27 August 2021, see https://www.energy.gov.za/files/media/pr/2021/NERSA-Concurrence-with-The-Section34Determination-for-2500mw-New-Nuclear-Generation-Capacity.pdf, accessed 31 August 2023.

1905 - Terence Creamer, "Mantashe outlines procurement schedules, including for nuclear, as he confirms IRP delay", *Engineering News*, 16 May 2023, see https://www.engineeringnews.co.za/article/mantashe-outlines-procurement-schedules-including-for-nuclear-by-2024-as-he-confirms-irp-delay-2023-05-16, accessed 21 August 2023.

1906 - Terence Creamer, "South Africa to release 2 500 MW nuclear RFP by March, despite electricity plan review", *Engineering News*, see https://www.engineeringnews.co.za/article/south-africa-to-release-2-500-mw-nuclear-rfp-by-march-despite-electricity-plan-review-2023-12-12, accessed 28 June 2024.

1907 - *BusinessTech*, "South Africa launches plan to get 2,500MW of new nuclear energy", 29 January 2024, see https://businesstech.co.za/news/energy/746051/south-africa-launches-plan-to-get-2500mw-of-new-nuclear-energy-2/, accessed 28 June 2024; and Minister of Electricity, "Government Notice—Determination Under Section 34(1) Of The Electricity Regulation Act, 2006 (Act No.4 Of 2006)", *Staatskoerant*, No. 50037, published 26 January 2024, see https://www.gov.za/sites/default/files/gcis_document/202401/50037gon4274.pdf, accessed 11 July 2024.

In early January 2024, the Ministry of Mineral Resources and Energy published a draft of the latest IRP (IRP2023). This draft described five scenarios to 2050, with only one including nuclear newbuild, and concluded that this was not the preferred scenario.[1908] This highlights the confusing and disjointed manner in which the newbuild project is being driven forward.

The draft IRP2023 has in general received unusually severe and widespread criticism for a range of demonstrated flaws.[1909] A revised draft had not been issued as of mid-2024, and until this document is finalized containing a rational and economical case for a newbuild, it would be very difficult to initiate a nuclear construction program.

Changing National Political Landscape and Russia's Interests

South Africa held a general election in May 2024. The African National Congress (ANC), which had enjoyed a comfortable parliamentary majority for 30 years, performed much worse than in previous elections receiving just 40 percent of the votes. This has forced the ANC into a power-sharing agreement with other parties. As of mid-2024, it was unclear how this arrangement would work or affect the government's energy strategy. Large capital-intensive projects like nuclear newbuild may become more difficult to implement, especially given that many of the ANC's likely partners in government prefer renewable energy-based solutions.[1910]

Russia, through its state nuclear company Rosatom, has shown intense interest in leading nuclear newbuild in South Africa. In late March 2024, in line with similar approaches in potential client countries, Rosatom succeeded in concluding a training agreement with Eskom.[1911] An example of a Rosatom nuclear lobbying success is that the Economic Freedom Fighters (EFF), a South African political party that garnered almost 10 percent of the vote in the recent national election, expressly stated in their election manifesto that projected new nuclear plants should be built by Russia.[1912]

1908 - Department of Mineral Resources and Energy, "Publication for Comments: Integrated Resource Plan, 2023", Government of South Africa, Government Notices/Goewermentskennisgewings, No. 4238, *Staatskoerant*, No. 49974, 4 January 2024, see https://www.gov.za/sites/default/files/gcis_document/202401/49974gon4238.pdf, accessed 28 June 2024.

1909 - OUTA, "IRP 2023: Tear this up, start again and do it properly", Organisation Undoing Tax Abuse, 19 March 2024, see http://www.outa.co.za/blog/newsroom-1/post/irp-2023-tear-this-up-start-again-and-do-it-properly-1328, accessed 28 June 2024.

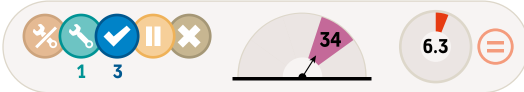
1910 - Hartmut Winkler, "South Africa's electricity crisis: what political parties say in their election manifestos about solving it", *The Conversation*, 27 March 2024, see http://theconversation.com/south-africas-electricity-crisis-what-political-parties-say-in-their-election-manifestos-about-solving-it-226518, accessed 27 June 2024.

1911 - Eskom, "Rosatom and Eskom sign a road map to cooperate on Human-Centricity and increase employment for African graduates of Russian universities", Press Release, 28 March 2024, see https://www.eskom.co.za/rosatom-and-eskom-sign-a-road-map-to-cooperate-on-human-centricity-and-increase-employment-for-african-graduates-of-russian-universities/, accessed 25 May 2024.

1912 - EFF, "2024 manifesto: EFF`s plan of action on jobs, loadshedding etc.", as published on *politicsweb*, 11 February 2024, see https://www.politicsweb.co.za/documents/2024-manifesto-effs-plan-of-action-on-jobs-loadshe, accessed 28 June 2024.

THE AMERICAS

Argentina



Argentina operates three nuclear reactors that provided 9 TWh in 2023, representing just 6.3 percent of the country's electricity generation (compared to a maximum of 19.8 percent in 1990). The volume of electricity produced varies from year to year due to the small number of reactors. The three units were all supplied by foreign reactor builders. Atucha-1 and -2 were built by the German company Siemens, and the CANDU (CANadian Deuterium Uranium) reactor at Embalse by Canadian Atomic Energy of Canada Limited (AECL).

In April 2018, the regulatory authority granted a lifetime-extension license to enable Atucha-1, which was commissioned in 1974, to continue operating until 2024, allowing a 50-year working lifetime.[1913] In early July 2022, it was announced that the owner and operator, Nucleoeléctrica Argentina S.A. (NA-SA), and the regulator had signed a framework agreement for an additional 20 years of operation.[1914] The regulator said that once the reactor has been prepared for long-term operation, it should have a higher level of safety than when it was initially licensed.[1915] However, this is unlikely enough to meet the safety standards of a modern reactor, as Atucha-1 was designed in the 1960s. In October 2023, the operator submitted an Environmental Impact Assessment to the Ministry of Environment of the Province of Buenos Aires.[1916]

Atucha-2 was ordered in 1979, and construction was stop/start over the following decades. Finally, grid connection occurred on 27 June 2014, but it took until 26 May 2016 to enter commercial operation.[1917] Performance has been mediocre in the past four years. Although the unit's annual load factor had been on a slow rise between 2019 and 2021 (from 29 percent to 49 percent and finally 58 percent), according to IAEA-PRIS, it fell to just under 21 percent in 2022, the lowest of its operational history, and only marginally increased to 25 percent in 2023.[1918] In March 2024, the nuclear regulator issued a renewed operating license for the facility, enabling it to operate until 2026.[1919]

1913 - NA-SA, "Atucha I extendió su Licencia de Operación hasta 2024", Press Release, Nucleoeléctrica Argentina, 12 April 2018, see http://www.na-sa.com.ar/prensa/atucha-i-extendi-su-licencia-de-operaci-n-hasta-2024/, accessed 15 April 2018.

1914 - NA-SA, "Nucleoelectrica Argentina Signed the Licensing Framework Agreement For The Long-Term Operation Of Atucha I Nuclear Power Plant", Press Release, 1 July 2022, see https://www.na-sa.com.ar/en/prensa/nucleoelectrica-argentina-signed-the-licensing-framework-agreement-for-the-long-term-operation-of-atucha-i-nuclear-power-plant, accessed 14 April 2024.

1915 - ARN, "Central Nuclear Atucha I - Operación a Largo Plazo", Autoridad Regulatoria Nuclear/Nuclear Regulatory Authority, Government of Argentina, Updated 7 June 2024 (in Spanish), see https://www.argentina.gob.ar/arn/uso-de-la-tecnologia-nuclear-segura-en-argentina/central-nuclear-atucha-i-operacion-largo-plazo, accessed 8 June 2024.

1916 - *NEI Magazine*, "Environmental impact study submitted for Atucha 1", *Nuclear Engineering International*, 31 October 2023, see https://www.neimagazine.com/news/environmental-impact-study-submitted-for-atucha-1-11258934/, accessed 20 August 2024; and NA-SA, "Se presentó el estudio de impacto ambiental para la extensión de vida de Atucha I", Press Release, 25 October 2023, see https://www.na-sa.com.ar/es/prensa/se-presento-el-estudio-de-impacto-ambiental-para-la-extension-de-vida-de-atucha-i, accessed 27 August 2024.

1917 - *WNN*, "Atucha 2 receives full operating licence", *World Nuclear News*, 31 May 2016, see http://www.world-nuclear-news.org/RS-Atucha-2-receives-full-operating-licence-3105165.html, accessed 20 August 2024.

1918 - IAEA, "PRIS - Reactor Details - Atucha-2", Power Reactor Information System, 19 August 2024, see https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=5, accessed 20 August 2024.

1919 - NA-SA "La Central Nuclear Atucha II obtuvo la renovación de su licencia de operación", Press Release (in Spanish), 11 March 2024, see https://www.na-sa.com.ar/es/prensa/la-central-nuclear-atucha-ii-obtuvo-la-renovacion-de-su-licencia-de-operacion, accessed 27 August 2024.

Embalse, which started operating in 1983, was shut down at the end of 2015 for major overhaul, including replacing hundreds of pressure tubes, to enable it to operate for up to 30 more years, to 2049. It eventually returned to service in May 2019, with the refurbishment project estimated to cost US$2.15 billion.[1920] In August 2019, the regulator (ARN) renewed the operating license for ten years to 2029, after which a safety review will establish "the feasibility of continued operation."[1921]

Construction of a prototype 25-MWe PWR, the domestically designed CAREM-25 (Central Argentina de Elementos Modulares—a pressurized-water Small Modular Reactor or SMR) began near the Atucha site in February 2014, with startup planned for 2018. In 2005, CNEA, had estimated that the construction would cost US$105 million,[1922] but by construction start in 2014, estimates had risen to ARS3.5 billion (US$$_{2014}$433 million),[1923] then in 2021, these had further increased to US$750 million,[1924] and by 2024, over US$600 million had reportedly been spent with a further US$260–300 million needed for completion,[1925] now expected by 2028. Construction had been interrupted several times and the current status of activities onsite are unclear. See Argentina in chapter on SMRs.

Given that this reactor has an output of 25 MW it must be close to being the most expensive nuclear power plant per MW ever built—if it is finally completed.

Even at this late stage, its completion cannot be guaranteed as President Javier Milei is attempting to drive down public expenditure, and funding for the National Nuclear Energy Commission (CNEA) has decreased from US$270 million to about US$100 million per year. Diego Hurtado, former vice president of CNEA reportedly said of the cuts, "We are facing dismantling within the nuclear sector, heading towards paralysis that jeopardizes our very existence."[1926]

The Atucha-3 Saga

For the past decade, discussions have been held on the construction of a fourth reactor, a case book example of large infrastructure projects wrapped up in national and international politics and mired in delays. The saga is covered in more detail in WNISR2023, but its critical milestones are:

1920 - WNA, "Nuclear Power in Argentina", World Nuclear Association, May 2024, see https://world-nuclear.org/information-library/country-profiles/countries-a-f/argentina, accessed 20 August 2024.

1921 - ARN, "La ARN emitió la Enmienda a la Licencia de Operación de la Central Nuclear Embalse", Press Release (in Spanish), 9 January 2019, see http://www.arn.gov.ar/es/component/content/article/32-novedades/481-la-arn-emitio-la-enmienda-a-la-licencia-de-operacion-de-la-central-nuclear-embalse, accessed 10 January 2019.

1922 - IAEA, "Technology roadmap for small modular reactor deployment", No. NR-T-1.18, IAEA Nuclear Energy Series, International Atomic Energy Agency, 2021, see https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1944_web.pdf, accessed 20 August 2024.

1923 - *WNN*, "Construction of CAREM underway", 10 February 2014, see http://www.world-nuclear-news.org/NN-Construction-of-CAREM-underway-1002144.html, accessed 20 August 2024.

1924 - GI-Hub, "CAREM 25 (prototype)", Public-Private Infrastructure Advisory Facility, World Bank, 25 January 2021, see https://www.gihub.org/quality-infrastructure-database/case-studies/carem-25-prototype/, accessed 20 August 2024.

1925 - *NEI Magazine*, "New President of CNEA reveals plans for nuclear development in Argentina", 4 June 2024, see https://www.neimagazine.com/news/new-president-of-cnea-reveals-plans-for-nuclear-development-in-argentina/, accessed 27 June 2024; and Maria de Los Angeles Orfila, "Spending cuts imperil Argentina's ambitious nuclear research programs", *Science.org*, 15 May 2024, see https://www.science.org/content/article/spending-cuts-imperil-argentina-s-ambitious-nuclear-research-programs, accessed 20 August 2024.

1926 - Maria de Los Angeles Orfila, "Spending cuts imperil Argentina's ambitious nuclear research programs", *Science.org*, 15 May 2024, op. cit.

- **In February 2015**, Argentina and China ratified an agreement to build an 800-MW CANDU-type reactor at the Atucha site, when Atucha-3 was expected to cost US$5.8 billion.[1927] A framework agreement was also signed during the same year between the two companies to construct a Hualong One reactor, without a site being specified.
- **In May 2017**, a cooperation agreement was signed between Argentina and China whereby China would help build and mainly finance the construction of the two reactors, with the CANDU-6 starting construction in 2018 and the Hualong reactor in 2020.[1928] However, the site for the Hualong reactor had not been agreed on, as the Governor of Rio Negro—the government's preferred location—refused to host the reactor in his province, citing a lack of social acceptance for the project.[1929] The total cost of the Hualong and Atucha-3 projects was expected to be US$12.5 billion (other sources indicated US$15 billion)[1930] financed through a 20-year loan from China at an interest rate of 4.5 percent.
- **In June 2019,** the Argentine Government expressed ongoing support for the project following official meetings with their Chinese counterparts, with Argentina's cabinet chief Marcos Pena saying, "there is an intention to move forward."[1931] CNNC President Jun Gu told delegates at an IAEA conference in **October 2019** that construction of the Hualong One unit would begin in 2020.[1932]
- **In February 2022**, an Engineering, Procurement and Construction (EPC) contract was signed by NA-SA and CNNC for Atucha-3, as a 1,200 MWe HPR1000 or Hualong One reactor involving an investment "of over US$8 billion."[1933]
- **In April 2022**, NA-SA President José Luis Antúnez confirmed that there would be a "maximum term of nine months" to settle and enforce the EPC agreement, indicating expectations that construction would be launched before the year's end and last for eight years.[1934]
- **In May 2022**, according to NA-SA President José Luis Antúnez, the U.S. again expressed concerns over the possible deal through U.S. State Department representative Ann K. Ganzer during a series of meetings with officials in Argentina, notably warning over safety concerns raised by the alleged immaturity of the Hualong design and past issues with the technology.[1935]

1927 - *WNN*, "Argentina-China talks on new nuclear plants", 8 May 2015, see http://www.world-nuclear-news.org/NN-Argentina-China-talks-on-new-nuclear-plants-0805150l.html, accessed 20 August 2024.

1928 - CNNC, "CNNC to build heavy water reactor and HPR 1000 units in Argentina", China National Nuclear Corporation, 19 May 2017, see http://en.cnnc.com.cn/2017-05/19/c_77725.htm, accessed 20 August 2024.

1929 - Phil Chaffee, "Argentina", *Nuclear Intelligence Weekly*, 29 September 2017.

1930 - *WNN*, "Argentina and China sign contract for two reactors", 18 May 2017, see http://www.world-nuclear-news.org/NN-Argentina-and-China-sign-contract-for-two-reactors-1805175.html, accessed 20 August 2024.

1931 - Cassandra Garrison and Hugh Bronstein, "Argentine official, in China, talks nuclear deal and soymeal", *Reuters*, 25 June 2019, see https://www.reuters.com/article/business/argentine-official-in-china-talks-nuclear-deal-and-soymeal-idUSKCN1TQ220/, accessed 27 August 2024.

1932 - *WNN*, "China confident of 'new era' for nuclear, says CNNC president", 9 October 2019, see https://world-nuclear-news.org/Articles/China-confident-of-new-era-for-nuclear-says-CNNC, accessed 20 August 2024.

1933 - *WNN*, "China and Argentina sign nuclear project deal", 2 February 2022, see https://www.world-nuclear-news.org/Articles/China-and-Argentina-sign-nuclear-project-deal, accessed 20 August 2024.

1934 - *NEI* Magazine, "Argentina optimistic about nuclear ties with China", 28 April 2022, see https://www.neimagazine.com/news/newsargentina-optimistic-about-nuclear-ties-with-china-9658784, accessed 20 August 2024.

1935 - *CE NoticiasFinancieras*, "U.S. lobby to block Argentine nuclear power production", 22 May 2022.

- **In April 2023**, Argentina's ambassador to China again pleaded with the Chinese Government to finance the entire investment[1936] while the U.S. pursued its relentless attempts to steer Argentina away from the potential cooperation.[1937]
- **In October 2023**, it was announced that the EPC contract would be extended to remain valid until the end of April 2025 to give the new government more time to make decisions.[1938] However, the project remains stuck due to the Argentinian Government's requirement for 100 percent financing from China.[1939]
- **In late 2023,** *Energy Intelligence* wrote that the election of Javier Milei as President in November 2023 "likely put the nail in the coffin" of the Hualong One-project[1940], due to the fiscal conservatism and anti-China sentiment of his announced policies.

Power Mix and Energy Policies

According to the Energy Institute, in 2023, Argentina's electricity generation was dominated by natural gas (52 percent), followed by hydro (20 percent), non-hydro renewables (14 percent), oil (6 percent), nuclear (6 percent) and coal (1.2 percent).[1941] However, renewables are set to dominate future energy supply and according to a government energy transition plan from June 2023, it is intended to reduce the use of fossil fuels to 35 percent by 2030. This will require 14 GW of new power capacity, of which 10 GW are to come from renewable sources, including 1 GW of distributed generation. In parallel, 5,000 km of new transmission lines are estimated to be needed. The total cost of the 2030 plan is expected to be around US$86 billion.[1942] However, its implementation under the Milei administration is far from certain.[1943]

1936 - *Télam*, "Vaca Narvaja pidió a China que financie la construcción de Atucha III", as published by Energía Nuclear Latinoamericana, 26 April 2023, see https://enula.org/2023/04/vaca-narvaja-pidio-a-china-que-financie-la-construccion-de-atucha-iii/, accessed 20 August 2024.

1937 - Raúl Dellatorre, "Ofensiva para desconectar a la Argentina de China: Maniobras de Estados Unidos para bloquear la cuarta central nuclear, *Página12*, 9 April 2023, see https://www.pagina12.com.ar/538896-ofensiva-para-desconectar-a-la-argentina-de-china, accessed 20 August 2024.

1938 - Nicolás Deza, "El gobierno prorrogó otra vez el contrato de Atucha III", *Econo Journal*, 21 October 2023 (in Spanish), see https://econojournal.com.ar/2023/10/en-medio-de-la-negociacion-con-china-por-el-swap-el-gobierno-prorrogo-otra-vez-el-contrato-de-atucha-iii/, accessed 1 November 2023.

1939 - Evan Ellis, "The Evolution of Chinese Engagement in Argentina under Javier Milei", Center for Strategic & International Studies, 5 June 2024, see https://www.csis.org/analysis/evolution-chinese-engagement-argentina-under-javier-milei, accessed 20 August 2024.

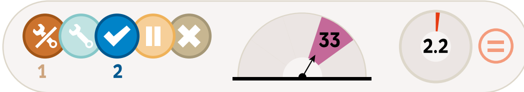
1940 - Jessica Sondgeroth, "Argentina: Milei Government Unlikely to Proceed with Newbuilds", *Energy Intelligence*, 1 December 2023, see https://www.energyintel.com/0000018c-1d3c-da36-a18e-df3cbb630000, accessed 30 December 2023.

1941 - Energy Institute, "Statistical Review of World Energy", June 2024, see https://www.energyinst.org/statistical-review/home, accessed 20 August 2024.

1942 - Fermín Koop, "Argentina targets huge expansion of renewable energy by 2030", Dialogue Earth, 20 July 2023, see https://dialogue.earth/en/energy/374748-argentina-targets-huge-expansion-of-renewable-energy-by-2030/, accessed 19 August 2024.

1943 - Matias Avramow, "Can Argentina still deliver on its climate plans under Milei?", Dialogue Earth, 2 August 2024, see https://dialogue.earth/en/climate/can-argentina-deliver-on-its-climate-plans-under-milei/; and Charles Newbery, "Argentina approves incentives for large oil, gas infrastructure projects", S&P Global, 28 June 2024, see https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/062824-argentina-approves-incentives-for-large-oil-gas-infrastructure-projects; both accessed 27 August 2024.

Brazil



Brazil's two commercial nuclear reactors—Angra-1 and -2—are operated by state-controlled company Eletronuclear at the Central Nuclear Almirante Alvaro Alberto (CNAAA) site and provided the country with 13.7 TWh or 2.2 percent of its electricity in 2023. With Angra-2 being connected to the grid more than two decades ago, the nuclear percentage contribution to Brazil's power sector is gradually decreasing due to rising electricity demand. Construction of the third reactor, that resumed at the end of 2022, was halted again in 2023, and is considered "suspended" in WNISR's data.

Brazil is expanding its uranium enrichment capacities and expects to service the entire fuel supply requirements of its then three (potential) reactors by 2037. The deployment of further nuclear capacity has long been on the agenda of successive governments, but no definite new build plans have been revealed by the previous or the current administration. Over the years, as the Angra-3 project sunk in turmoil, such ambitions were gradually relegated further into the future, but lobbying efforts continue.

The first contract for Angra-1 was awarded to Westinghouse in 1970. The 609-MW PWR went critical in 1981 and is licensed to operate until December 2024. In late 2019, Eletronuclear formally applied for a 20-year lifetime extension with the regulator (CNEN). In October 2020, Westinghouse signed a contract to conduct engineering analyses critical to safety, reliability, and long-term operation as part of the program to extend the working lifetime of Angra-1 until 2044.[1944] The program of work is planned to be implemented between 2024 and 2028 and cost BRL3 billion (US$576.5 million), with a BRL800 million (US$154 million) loan under negotiation with Electronuclear's principal shareholders, Empresa Brasileira de Participações em Energia Nuclear e Binacional S.A (ENBPar) and Eletrobras, as well as a loan from U.S. EXIM Bank (given Westinghouse's involvement).[1945] In May 2024, reporting on the lifetime extension project, an Eletronuclear official stated that "The negotiation process with the agency [CNEN] should last until the end of this year to finalize these stages. But the company is prepared and continues to have constant dialog with CNEN. We are managing to demonstrate that Angra 1 will be able to continue operating efficiently and safely."[1946]

Angra-2 is a large German-designed PWR with a capacity of 1275 MW that was connected to the grid in July 2000, 24 years after construction initially started. A 30-year license set to expire in 2041 was issued in 2011, but Eletronuclear has announced that it will likely request a 20-year extension.[1947] The company indicated in 2022 that studies were already underway to outline a program for managing the "ageing of systems, structures and components at the plant, along the same lines as Angra 1."[1948]

1944 - Westinghouse, "Westinghouse signs Engineering Contract to extend the life of Angra 1", 5 October 2020, see https://www.westinghousenuclear.com/uknuclear/about/news/view/westinghouse-signs-engineering-contract-to-extend-the-life-of-angra-1, accessed 20 August 2024.

1945 - Eletronuclear, "Extensão da vida útil de Angra 1 segue em avanço", Press Release (in Portuguese), 10 May 2024, see https://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/extensao-da-vida-util-de-angra-1-segue-em-avanco.aspx, accessed 13 May 2024.

1946 - Ibidem.

1947 - Electrobras, "Angra Nuclear Power Station Initiatives for Long Term Operation", presented at the International Nuclear Atlantic Conference, 24 November 2013, see https://www.aben.com.br/Arquivos/205/205.pdf, accessed 21 August 2024.

1948 - A Voz da Cidade, "Eletronuclear recebe financiamento externo para estender vida útil de Angra 1", 15 September 2022, see https://avozdacidade.com/wp/eletronuclear-recebe-financiamento-externo-para-estender-vida-util-de-angra-1/, accessed 21 August 2024.

As reported in WNISR2022, after years of uncertainty, successive setbacks and controversy, in 2022, the Bolsonaro Government finalized the privatization of Eletrobras, the biggest power company in Brazil and, until then, the parent entity of Eletronuclear. Requirements for the privatization to succeed included some major restructuring designed to maintain nuclear activities under state control.[1949] Hence, a new state agency taking over Eletrobras' activities "that cannot be privatized"—Empresa Brasileira de Participações em Energia Nuclear e Binacional S.A. (ENBpar)—was created by presidential decree on 10 September 2021.[1950]

In 2022, the Bolsonaro Government finalized the privatization of Eletrobras, the biggest power company in Brazil and, until then, the parent entity of Eletronuclear.

Further institutional changes of recent years include the creation of a new agency to improve the independence of the nuclear regulator. A decree signed by then President Jair Bolsonaro in May 2021 provided for a new regulatory framework and the creation of ANSN (Autoridade Nacional de Segurança Nuclear) which has been reassigned CNEN's (Comissão Nacional de Energia Nuclear) responsibilities to monitor, regulate and inspect nuclear activities and facilities. CNEN will remain in charge of planning, overall policy, and advocacy for nuclear energy.[1951] The new allocation and organization were signed into law in October 2021,[1952] and the statutory structure and organization were approved by decree in July 2022,[1953] but as of mid-2024, ANSN had "not yet started to function" as no "Director-President" has yet been appointed. In July 2023, the Joint Budget Committee and Parliament had approved an Executive Bill to open a special credit line of BRL22.8 million (US$$_{2023}$4.6 million) in the 2023 Budget to provide CNEN with the necessary resources to carry out ANSN's duties.[1954] In March 2024, the Court of Accounts stated that "Although ANSN was created through the publication of Law 14.222/2021, the Agency will only come into effect once its CEO has been appointed, which has not yet happened".[1955]

1949 - *CE Noticias Financieras*, "The Federal Audit Court approves privatization, learn what the next steps will be", 18y 2022.

1950 - Diário Oficial da União, "Decreto Nº 10.791, de 10 De Setembro de 2021", 13 September 2021, see https://www.in.gov.br/en/web/dou/-/decreto-n-10.791-de-10-de-setembro-de-2021-344145312, accessed 21 August 2024.

1951 - Government of Brazil, "Sancionada a lei que cria a da Autoridade Nacional de Segurança Nuclear", 10 November 2022 (in Portuguese), see https://www.gov.br/casacivil/pt-br/assuntos/noticias/2021/outubro/sancionada-a-lei-que-cria-a-da-autoridade-nacional-de-seguranca-nuclear, accessed 21 August 2024.

1952 - Diário Oficial da União, "Lei No°14.2022, de 15 de Outubro de 2021—[Criação do] Autoridade Nacional de Segurança Nuclear (ANSN)", 15 October 2021, published 18 October 2021 (in Portuguese), 2021, see https://www.in.gov.br/en/web/dou/-/lei-n-14.222-de-15-de-outubro-de-2021-352709951, accessed 21 August 2024.

1953 - Government of Brazil, "Decreto aprova a estrutura regimental e quadro de cargos e funções da Autoridade Nacional de Segurança Nuclear (ANSN)", 22 July 2022 (in Portuguese), see https://www.gov.br/secretariageral/pt-br/noticias/2022/julho/decreto-aprova-a-estrutura-regimental-e-quadro-de-cargos-e-funcoes-da-autoridade-nacional-de-seguranca-nuclear-ansn, accessed 21 August 2024.

1954 - Chamber of Deputies, "Projeto abre crédito especial para a Comissão Nacional de Energia Nuclear ", Press Release (in Portuguese), 11 July 2023, see https://www.camara.leg.br/noticias/979074-projeto-abre-credito-especial-para-a-comissao-nacional-de-energia-nuclear/, accessed 21 August 2024.

1955 - TCU, "Autoridade Nacional de Segurança Nuclear precisa nomear seu diretor-presidente para dar efetiva vigência ao órgão", Press Release (in Portuguese), Tribunal de Contas da União/Federal Court of Accounts of Brazil, 4 March 2024, see https://portal.tcu.gov.br/imprensa/noticias/autoridade-nacional-de-seguranca-nuclear-precisa-nomear-seu-diretor-presidente-para-dar-efetiva-vigencia-ao-orgao.htm, accessed 22 August 2024.

The Angra-3 Saga

For a detailed analysis and history of the construction of Angra-3, see Brazil Focus in WNISR2023, the key dates of which are:

- Preparatory work for the construction of Angra-3—a 1405-MW PWR designed by Siemens/KWU—started in 1984 but stopped in 1986.
- In May 2010, Brazil's Nuclear Energy Commission issued a construction license. In early 2011, the Brazilian National Development Bank (BNDES) approved a BRL6.1 billion (US$$_{2011}$3.65 billion) loan for work on the project, and in November 2013, Eletronuclear signed a €1.25 billion (US$$_{2013}$1.7 billion) contract with French builder AREVA for the completion of the plant.[1956]
- In 2015, construction was halted. A major corruption probe led to waves of arrests among plant management, contractors, politicians, and senior Eletronuclear executives between 2015 and 2020, and derailed the project altogether. By 2017, funding had collapsed, and the contracts for the construction work had been declared void.[1957]
- In September 2018, the Federal Court of Accounts (TCU) lifted its recommendation to suspend the program.[1958] However, no partner was found to invest in the endeavor, so in June 2020, the Bolsonaro Government approved plans for carrying out the project "with or without a partner joining Eletronuclear."[1959]
- In March 2021, Eletrobras approved a "Critical Path Acceleration Plan" to complete Angra-3 by 2023 and reach commercial operation by the end of 2026.[1960]
- In October 2021, ahead of the privatization of Eletrobras, the guidelines for pricing of Angra-3 were approved, clarifying that prices of electricity from Angra-3 would be based on BNDES calculations, taking into account "the economic viability of the project and its financing under market conditions."[1961]
- In February 2022, a contract for civil works was signed with a consortium made up of Ferreira Guedes, Matricial and ADtranz,[1962] following the selection of their offer priced at BRL292 million (US$$_{2021}$54.1 million).[1963] The expectation was that the unit would enter

1956 - *WNN*, "Areva contracted to complete Angra 3", 8 November 2013, see https://www.world-nuclear-news.org/C-Areva-contracted-to-complete-Angra-3-081134.html, accessed 21 August 2024.

1957 - *NEI* Magazine, "Contracts for work at Brazil's Angra 3 declared void", 6 February 2017, see http://www.neimagazine.com/news/newscontracts-for-work-at-brazils-angra-3-declared-void-5732236, accessed 21 August 2024.

1958 - TCU, "TCU retira a recomendação de paralisação da usina nuclear de Angra 3", Tribunal de Contas da União/Federal Court of Accounts, 18 September 2018 (in Portuguese), see https://portal.tcu.gov.br/imprensa/noticias/tcu-retira-a-recomendacao-de-paralisacao-da-usina-nuclear-de-angra-3.htm, accessed 21 August 2024.

1959 - Marcela Ayres and Anthony Boadle, "Brazil government approves plan to complete third nuclear plant", *Reuters*, 10 June 2020, see https://www.reuters.com/article/markets/brazil-government-approves-plan-to-complete-third-nuclear-plant-idUSL1N2DN367/, accessed 21 August 2024.

1960 - *NEI Magazine*, "Brazil to resume work on Angra 3", 3 March 2021, op. cit.

1961 - Ministry of Mines and Energy, "Resolução nº 23— Estabelece diretrizes para a definição do preço da energia da Usina Termelétrica Nuclear Angra 3.N°61, de 20 de outubro de 2021. Resolução n°23, de 20 de outubro de 2021, do Conselho Nacional de Política Energética – CNPE", Diário Oficial da União, 22 October 2021, see https://www.gov.br/mme/pt-br/assuntos/conselhos-e-comites/cnpe/resolucoes-do-cnpe/resolucoes-2021/ResoluesCNPE23_2021.pdf, accessed 20 August 2024.

1962 - Eletrobras Termonuclear S.A., "Notas explicativas às demonstrações financeiras intermediárias condensadas do período findo em 31 de março de 2022", Eletronuclear, 2022 (in Portuguese), see https://www.eletronuclear.gov.br/Quem-Somos/Governanca/Documents/Demonstra%C3%A7%C3%B5es%20Financeiras%20Trimestrais/2022/NE%20MAR2022%20ELETRONUCLEAR.pdf, accessed 28 August 2024.

1963 - *NEI Magazine*, "Consortium chosen for preliminary work to complete Angra 3", 29 July 2021.

commercial operation in November 2026.[1964] By May 2022, the project's total completion costs were said to be BRL19.4 billion (US$$_{2022}$3.8 billion).[1965]

- In June 2022, the capitalization of Eletrobras occurred[1966], bringing the construction of Angra-3 one step closer to resumption, as it was said to be crucial to the completion of the project.[1967]
- On 11 November 2022, Eletronuclear announced the "resumption of concrete pouring," marking the official restart of construction.[1968]
- By order of local government, work was halted again in April 2023.
- The following month, Energy Minister Alexandre Silveira de Oliveira of the new Lula da Silva administration reportedly stated before Parliament that an additional BRL20 billion (US$$_{2023}$4 billion) were required to complete the project, bringing total costs to BRL27.8 billion (US$$_{2023}$5.6 billion). [1969]
- Despite confidence from the utility, in late June 2023, Minister Alexandre Silveira de Oliveira reportedly stated that the decision to restart this "big challenge" was still pending, with a final ruling expected by year's end.[1970]
- On 17 June 2024, Eletronuclear announced two major developments: first, that a court had lifted the municipal "embargo" on construction at Angra 3.[1971] And, second, that it had terminated its contract with the Ferreira Guedes–Matricial–Adtranz consortium following alleged breaches of the agreement terms, including failure to comply with the order of execution and the enclosed schedule.[1972]
- As of mid-2024, Eletronuclear was still waiting for a BNDES report on the costs of completing Angra-3. This analysis was expected to be used by the Ministry of Mines and Energy and the National Energy Policy Council to decide on whether to proceed with the project.[1973]

1964 - *BNAmericas*, "Brazil launches tender to resume Angra 3 nuclear plant works", 26 February 2021, see https://www.bnamericas.com/en/news/brazil-launches-tender-to-resume-angra-3-nuclear-plant-works, accessed 20 August 2024.

1965 - *CE Noticias Financieras*, "Angra 3 nuclear power plant needs R$19.4 billion to be ready", 17 May 2022.

1966 - Eletrobras, "History", Undated, see https://eletrobras.com/en/Paginas/History.aspx, accessed 28 August 2024.

1967 - *BNAmericas*, "Failure of Eletrobras privatization could make Angra 3 unviable – BNDES", *Business News Americas*, 7 April 2022, see https://www.bnamericas.com/en/news/failure-of-eletrobras-privatization-could-make-angra-3-unviable--bndes, accessed 21 August 2024.

1968 - Eletronuclear, "Reinício da concretagem marca retomada das obras de Angra 3", Press Release (in Portuguese), 11 November 2022, see https://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Rein%C3%ADcio-da-concretagem-marca-retomada-das-obras-de-Angra-3.aspx, accessed 18 November 2022.

1969 - *Reuters*, "Governo projeta mais R$ 20 bi para terminar Angra 3 e começar operação até 2029", as published by *CNN Brasil*, 3 May 2023, see https://www.cnnbrasil.com.br/economia/governo-projeta-mais-r-20-bi-para-terminar-angra-3-e-comecar-operacao-ate-2029/, accessed 21 August 2024.

1970 - Catarina Demony, "Exclusive: Brazil aims to pass offshore wind, green hydrogen laws by year-end, energy minister says", *Reuters*, 27 June 2023, see https://www.reuters.com/sustainability/climate-energy/brazil-aims-pass-offshore-wind-green-hydrogen-laws-by-year-end-energy-minister-2023-06-27/, accessed 21 August 2024.

1971 - Eletronuclear, "Justiça concede recurso da Eletronuclear e suspende embargo das obras de Angra 3", Press Release, (in Portuguese), 17 June 2024, see https://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/justica-concede-recurso-da-eletronuclear-e-suspende-embargo-das-obras-de-angra-3.aspx, accessed 27 August 2024.

1972 - Eletronuclear, "Eletronuclear rescinde contrato com o Consórcio Ferreira Guedes - Matricial - Adtranz", Press Release (in Portuguese), 17 June 2024, see https://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Eletronuclear-rescinde-contrato-com-o-Cons%C3%B3rcio-Ferreira-Guedes---Matricial---Adtranz.aspx, accessed 28 August 2024.

1973 - Ibidem.

Earlier this year, Jorge Oliveira, Minister of the Federal Court of Accounts, assessed that "What can be said, without a shadow of a doubt, from the studies carried out by the TCU (...) regardless of the potential positive externalities of the project for national nuclear policy, charges to consumers will be much higher if the construction of Angra 3 continues than if the project is abandoned."[1974]

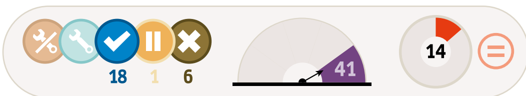
Strong Expansion of Renewable Energy Generation

Brazil has the eleventh largest economy in the world, but more than that, it has significant geopolitical influence. It will host the G20 in 2024, and preside COP30 in 2025, which is of particular significance within the UNFCCC cycles considering all countries are expected to produce revised emissions reductions plans on that occasion. Consequently, Brazil's domestic energy plans have a significant impact globally.

Brazil's power sector is dominated by renewable energy, with hydro providing about 60 percent, other renewables 27 percent, natural gas 5.3 percent, nuclear and coal around 2 percent each and oil about 1 percent.[1975] Brazil is already a world leader in renewable deployment, besides hydro in which it is the second largest producer (behind China), it is the world's fourth largest producer of wind power and the sixth largest of solar PV (compared to nuclear, where it is the 23rd largest producer, out of the 32 countries that operate commercial reactors)

Going forward, Brazil intends to continue the development of non-hydro renewable energy. Both utility and distributed solar are expected to represent nearly 70 percent of all new power generating capacity connected to the grid in 2024.[1976]

Canada



Canada's reactor fleet consists of 19 CANDU reactors with a total net capacity of 13.6 GW. Three reactors (Darlington-1, Darlington-4, and Bruce-3) are being refurbished since February 2022, July 2023, and March 2023 respectively,[1977] leaving 18 reactors in operation during the 2023-2024 period that is covered here. One of the units under refurbishment has reached LTO status as of mid-2024.

The nuclear fleet produced 84.57 TWh in 2023, which constituted 13.7 percent of the total electricity generated in Canada that year. Both have modestly increased from 2022 figures of 81.72 TWh and 12.9 percent respectively. Eighteen out of the 19 nuclear reactors are located

1974 - Tribunal de Contas da União, "Tribunal analisa processos relacionados à usina termonuclear de Angra 3", Tribunal de Contas da União, 10 April 2024, see https://portal.tcu.gov.br/imprensa/noticias/tcu-analisa-processos-relacionados-a-usina-termonuclear-de-angra-3.htm, accessed 22 August 2024.

1975 - Energy Institute, "Statistical Review of World Energy", 2024.

1976 - International Trade Administration, "Brazil - Renewable Energy Infrastructure", U.S. Government, 4 December 2023, see https://www.trade.gov/country-commercial-guides/brazil-renewable-energy-infrastructure-0, accessed 21 August 2024.

1977 - IESO, "Annual Planning Outlook - Ontario's electricity system needs: 2025-2050", Independent Electricity System Operator, March 2024, see https://www.ieso.ca/-/media/Files/IESO/Document-Library/planning-forecasts/apo/Mar2024/2024-Annual-Planning-Outlook.pdf, accessed 11 April 2024; and Bruce Power, "Bruce Power begins Unit 3 Major Component Replacement outage", 2 March 2023, see https://www.brucepower.com/2023/03/02/bruce-power-begins-unit-3-major-component-replacement-outage/, accessed 13 June 2023.

in the province of Ontario, where nuclear power contributed 53 percent of the electricity generated in 2023, slightly less than the 54 percent in 2022.[1978]

Refurbishment

Canada is in the process of refurbishing many of its ageing CANDU reactors, which "involves replacing core reactor components" such as "fuel channels, feeder pipes, calandria tubes and end fittings".[1979]

As mentioned above, three reactors are currently going through this process. These projects are scheduled for completion by 17 April 2025 (Darlington-1), 1 August 2026 (Darlington-4), and 11 December 2026 (Bruce-3).[1980] Most of these projects were delayed by a few months compared to the schedule laid out in IESO's annual planning document from January 2020. (See Table 16 for details).[1981] So far, Units 2 and 3 of then Darlington nuclear plant and Unit 6 of the Bruce nuclear plant have already been refurbished. Bruce-4 is due to start the refurbishment process on 1 January 2025 according to Ontario's Independent Electricity System Operator (IESO).[1982]

The only nuclear power plant that is not subject of a refurbishment plan so far is the Pickering plant with six operating reactors. However, in January 2024, the Ontario Government announced that it supported refurbishing four of these reactors (Units 5–8).[1983] But it had not estimated how much the refurbishment would cost, though the "Project Initiation Phase" was budgeted at CAD2 billion (US$1.5 billion)—with the province's energy minister claiming that it would be "irresponsible" to put a dollar figure to the refurbishment at this point as there is still a lot of planning to do.[1984]

A feasibility assessment report prepared by OPG and obtained by *CTV News* using the Access to Information Act revealed that the process of refurbishing the Pickering nuclear station would take at least 11 years but "a lack of skilled workers and potential scope adjustments could impact the project".[1985] Despite these problems, OPG unsurprisingly concluded that the project would be economically and technically feasible. In June 2023, OPG submitted "an application to extend commercial operation of Units 5–8 at the Pickering Nuclear Generation Station until December 31, 2026", as the current license "does not allow commercial operation beyond

1978 - IESO, "IESO Year-End Data—2023 Year in Review", Independent Electricity System Operator, 2024, see https://ieso.ca/en/Corporate-IESO/Media/Year-End-Data#yearenddata, accessed 23 June 2024.

1979 - OPG, "Darlington Refurbishment performance update Q1 2024—Frequently asked questions", Ontario Power Generation, 2024, see https://www.opg.com/projects-services/projects/nuclear/darlington-refurbishment/, accessed 23 June 2024.

1980 - IESO, "Annual Planning Outlook - Ontario's electricity system needs: 2025-2050", March 2024, op. cit.

1981 - IESO, "Annual Planning Outlook—A view of Ontario's Electricity System Needs", Independent Electricity System Operator, January 2020, p.11, see http://www.ieso.ca/-/media/Files/IESO/Document-Library/planning-forecasts/apo/Annual-Planning-Outlook-Jan2020.pdf?la=en, accessed 29 July 2023.

1982 - IESO, "Annual Planning Outlook - Ontario's electricity system needs: 2025-2050", March 2024, op. cit.

1983 - Ontario Government, "Ontario Supporting Plan to Refurbish Pickering Nuclear Generating Station", Press Release, 30 January 2024, see https://news.ontario.ca/en/release/1004128/ontario-supporting-plan-to-refurbish-pickering-nuclear-generating-station, accessed 14 April 2024.

1984 - Katherine DeClerq, "Doug Ford government hopes to refurbish Pickering nuclear plant", *CP24.com*, 30 January 2024, see https://www.cp24.com/news/doug-ford-government-hopes-to-refurbish-pickering-nuclear-plant-1.6748136, accessed 23 June 2024.

1985 - Katherine DeClerq, "Lack of skilled workers a risk in Pickering nuclear plant refurbishment, documents show", *CP24.com*, 1 June 2024, see https://www.cp24.com/news/lack-of-skilled-workers-identified-as-risk-in-pickering-nuclear-plant-refurbishment-timeline-documents-show-1.6909799?cache=bubsnwirst%3FclipId%3D89950, accessed 23 June 2024.

December 31, 2024".[1986] The Canadian Nuclear Safety Commission held public hearings on 19 and 20 June 2024 to consider this application.[1987]

Table 16 · Status of Canadian Nuclear Fleet - PLEX and Expected Closures

Reactor	Operator	Grid Connection	Refurbishment[(a)] (Provisional Jan. 2020)[(b)]	Planned Closure	Licensed to[(c)]
Bruce-1	Bruce Power	1977	Restarted in 2012	2064	2028
Bruce-2		1976	Restarted in 2012		
Bruce-3		1977	01/03/23–11/12/26 (01/01/23–30/06/26)		
Bruce-4		1978	01/01/25–31/12/27		
Bruce-5		1984	01/10/26–29/09/29 (01/07/26–30/06/29)		
Bruce-6		1984	17/01/20–08/09/23[(d)] (01/01/20–19/10/23)		
Bruce-7		1986	01/07/28–30/06/31		
Bruce-8		1987	01/10/30–30/09/33 (01/07/30–30/06/33)		
Darlington-1	OPG	1990	15/02/22–17/04/25 (15/10/21–15/12/24)	2055	2025
Darlington-2		1990	10/16–06/20[(e)]		
Darlington-3		1992	30/07/20–07/07/23[(f)] (15/02/20–15/06/23)[(g)]		
Darlington-4		1993	19/07/23–01/08/26 (01/05/23–31/05/26)		
Pickering-1	OPG	1971		End 2024[(h)]	2028[(j)]
Pickering-4		1973		End 2024[(h)]	
Pickering-5		1982		30/09/2026[(i)]	
Pickering-6		1983		30/09/2026[(i)]	
Pickering-7		1984		30/09/2026[(i)]	
Pickering-8		1986		30/09/2026[(i)]	
Point Lepreau	NB Power	1982	03/2008–03/2012 [(k)]	2044–2045[(l)]	2032

Sources: Compiled by WNISR, from IESO, Operators, CNSC, 2024

Notes: **OPG** = Ontario Power Generation.

a - IESO, "Annual Planning Outlook - Ontario's electricity system needs: 2025-2050", March 2024, see https://www.ieso.ca/-/media/Files/IESO/Document-Library/planning-forecasts/apo/Mar2024/2024-Annual-Planning-Outlook.pdf, accessed 11 April 2024.

b - IESO, "Annual Planning Outlook - A view of Ontario's electricity system needs", January 2020, see http://www.ieso.ca/-/media/Files/IESO/Document-Library/planning-forecasts/apo/Annual-Planning-Outlook-Jan2020.pdf?la=en, accessed 1 August 2020.

c - As listed on Canadian Nuclear Safety Commission's (CNSC) website for each station, as of 26 June 2024.

Bruce: https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/nuclear-facilities/bruce-nuclear-generating-station/index.cfm;

Darlington: https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/nuclear-facilities/darlington-nuclear-generating-station/index.cfm;

Pickering: https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/nuclear-facilities/pickering-nuclear-generating-station/index.cfm;

Point Lepreau: https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/nuclear-facilities/point-lepreau-nuclear-generating-station/index.cfm.

1986 - CNSC, "Pickering Nuclear Generating Station", Canadian Nuclear Safety Commission, 27 June 2023, see https://www.nuclearsafety.gc.ca/eng/reactors/power-plants/nuclear-facilities/pickering-nuclear-generating-station/index.cfm, accessed 29 July 2023.

1987 - CNSC, "Watch a public Commission proceeding online—ARCHIVED – June 19-20, 2024 – Pickering (Ontario)", Canadian Nuclear Safety Commission, Government of Canada, Updated 27 June 2024, see https://www.cnsc-ccsn.gc.ca/eng/the-commission/webcasts/archived/20240619-20240620/#CommissionHearing, accessed 11 July 2024.

d - Refurbishment of Bruce-6 was completed in September 2023. See Bruce Power, "Bruce Power's Unit 6 connected to Ontario's electricity grid following Major Component Replacement outage", 8 September 2023, see https://www.brucepower.com/2023/09/08/bruce-powers-unit-6-connected-to-ontarios-electricity-grid-following-major-component-replacement-outage/, accessed 26 June 2024.

e - Refurbishment of Darlington-2 was completed in June 2020, with the reactor being reconnected to the grid on 2 June 2020; see OPG, "Darlington Unit 2 powers on—Refurbishment now complete on first unit", 4 June 2020, see https://www.opg.com/news/darlington-unit-2-powers-on/, accessed 28 July 2020.

f - Refurbishment of Darlington-3 was completed in July 2023, with the reactor being reconnected to the grid on 17 July 2023.

See OPG, "OPG celebrates the early completion of Darlington Unit 3", Press Release, Ontario Power Generation, 18 July 2023, see https://www.opg.com/media_releases/opg-celebrates-the-early-completion-of-darlington-unit-3/, accessed 19 July 2023.

g - In the December 2020 issue of the IESO outlook the dates were changed to 30/07/2020–02/01/2024.

See IESO, "Annual Planning Outlook - Ontario's electricity system needs: 2022-2040", Independent Electricity System Operator, December 2020, see https://www.ieso.ca/-/media/Files/IESO/Document-Library/planning-forecasts/apo/Annual-Planning-Outlook-Dec2020.ashx.

h - OPG, "Pickering Nuclear Station", Undated see https://prdopgv2.wpengine.com/power-generation/our-power/nuclear/pickering-nuclear/, accessed 26 June 2024.

i - OPG, "Pickering Nuclear Generating Station – Power Reactor Operating Licence Amendment Application", Letter to Canadian Nuclear Safety Commission, Ontario Power Generation, 16 June 2023, see https://www.opg.com/documents/letter-to-cnsc-re-pickering-licence-amendment-application-pdf/, accessed 16 July 2023. Potential further lifetime extension under discussion. See Ontario Government, "Ontario Supporting Plan to Refurbish Pickering Nuclear Generating Station", Press Release, 30 January 2024,

j - The current Pickering Power Plan license will expire in 2028 but does not allow operation beyond 2024. OPG's application requires a public hearing and authorization from the Canadian Nuclear Safety Commission (CNSC); the public hearing was held 19–20 June 2024.

See CNSC, "Watch a public Commission proceeding online—ARCHIVED – June 19-20, 2024 – Pickering (Ontario)", Canadian Nuclear Safety Commission, Updated 27 June 2024, see https://www.cnsc-ccsn.gc.ca/eng/the-commission/webcasts/archived/20240619-20240620/#CommissionHearing, accessed 11 July 2024.

k - In 2021, NB Power applied for a 25 year operating license renewal, which was granted for 10 years. Retirement is scheduled for 2044/45. NB Power, "2023 Integrated Resource Plan: Pathways to a Net-Zero Electricity System", 2023, see http://www.nbpower.com/en/about-us/our-energy/integrated-resource-plan/.

l - Point Lepreau: https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/nuclear-facilities/point-lepreau-nuclear-generating-station/index.cfm.

Other Updates

Federal government agencies and some provincial governments have announced initiatives to promote nuclear energy, including Small Modular Reactors (see chapter on SMRs). In June 2024, the Federal Government released a plan "to modernize federal assessment and permitting processes" to accelerate nuclear reactor construction.[1988] Earlier in September 2023, the Federal Government also offered CAD3 billion (US$$_{2023}$2.2 billion) of export financing for the construction of two CANDU-6 reactors at the Cernavoda nuclear power plant, in Romania.[1989]

In July 2023, Ontario's government announced the start of pre-development work to establish the feasibility of building 4.8 GW of new nuclear capacity at the Bruce site.[1990] The announcement did not specify what kind of reactors would be built. Earlier this year, the Federal Government offered CAD50 million (US$36.5 billion) for preliminary work.[1991]

1988 - Ministerial Working Group on Regulatory Efficiency for Clean Growth Projects, "Building Canada's Clean Future—A plan to modernize federal assessment and permitting processes to get clean growth projects built faster", Updated 20 June 2024, Government of Canada, see https://www.canada.ca/en/privy-council/services/clean-growth-getting-major-projects-done/action-plan.html, accessed 25 June 2024.

1989 - Natural Resources Canada, "$3 Billion in Federal Export Finance to Support Canadian Businesses While Providing Clean Energy Security for Romania", Press Release, 19 September 2023, see https://www.canada.ca/en/natural-resources-canada/news/2023/09/3-billion-in-federal-export-finance-to-support-canadian-businesses-while-providing-clean-energy-security-for-romania.html, accessed 11 July 2024.

1990 - Ontario Government, "Province Starts Pre-Development Work for New Nuclear Generation to Power Ontario's Growth", Press Release, 5 July 2023, see https://news.ontario.ca/en/release/1003240/province-starts-pre-development-work-for-new-nuclear-generation-to-power-ontarios-growth, accessed 11 July 2024.

1991 - Kate McKenna, "Ottawa pledging $50M for Bruce Power nuclear plant expansion", *CBC News*, 29 February 2024, see https://www.cbc.ca/news/politics/nuclear-money-bruce-power-expansion-1.7127490, accessed 23 June 2024; and Natural Resources Canada, "Government of Canada Announces $50 million for Ontario's Expansion of Clean, Reliable and Affordable Nuclear Energy", Press Release, 29 February 2024, see https://www.canada.ca/en/natural-resources-canada/news/2024/02/government-of-canada-announces-50-million-for-ontarios-expansion-of-clean-reliable-and-affordable-nuclear-energy.html, accessed 11 July 2024.

In August 2023, Quebec's electricity utility reportedly confirmed it was considering reviving Gentilly-2, the province's only nuclear power plant, which was closed in 2012.[1992] In January 2024, the utility submitted the summary of a report produced by AtkinsRéalis (formerly SNC-Lavalin) that concluded that it had not identified any major barriers to the reactor's restart.[1993] However, this is not envisioned to happen before 2035. In its Action Plan 2035, Hydro Québec mentioned that it would "also examine the potential of the existing Gentilly-2 site for a new nuclear power plant or small modular reactors" but that "these options will be analyzed based on their technological maturity, cost and social acceptability."[1994]

Total renewable energy capacity (incl. hydro) in Canada as of the end of 2023 amounted to 108.8 GW, an increase of 2 percent compared to 2022, growing from 89.5 GW a decade ago (i.e., 2014). The bulk of renewable capacity is hydropower which constituted 83.5 GW in 2023, up from 75.5 GW in 2014; during the same period, wind energy capacity went from 9.7 GW to 17 GW, and solar energy capacity more than tripled from 1.8 GW to a still modest 5.8 GW.[1995] In 2023, wind energy contributed 39.7 TWh and solar energy contributed 4.7 TWh respectively according to data from Statistics Canada.[1996] Together with hydro power, which contributed 359.3 TWh, renewables contributed nearly two thirds of all electrical energy generated in Canada.

Canadian Government targets for reducing carbon dioxide emissions, either for 2030 or 2050, place much emphasis on nuclear power.[1997] These do not envision any expansion of nuclear capacity in the short term. However, the energy regulator's 2023 Canada's Energy Future report did develop scenarios for a path to net zero by 2050 that projected roughly a tripling of nuclear energy generation capacity in Canada.[1998] Nevertheless, these scenarios are based on unrealistic assumptions about costs of future nuclear reactors, typically small modular reactors, that would be 2.5 to 4 times lower than estimated costs of SMRs currently in the planning.[1999]

1992 - Sabrina Jonas and Holly Cabrera, "Hydro-Québec mulls reviving province's nuclear reactor, 10 years after shutdown", *CBC News*, 10 August 2023, see https://www.cbc.ca/news/canada/montreal/quebec-nuclear-reactor-gentilly-2-1.6932355, accessed 15 August 2023.

1993 - Thomas Gerbet, "Hydro-Québec : 'Aucune barrière majeure au redémarrage de Gentilly-2'", *Radio-Canada*, 30 January 2024, see https://ici.radio-canada.ca/nouvelle/2045564/nucleaire-hydro-quebec-etude-snc-gentilly-centrale, accessed 11 July 2024.

1994 - Hydro Québec, "Action Plan 2035 – Towards a Decarbonized and Prosperous Québec", November 2023, see https://www.hydroquebec.com/data/a-propos/pdf/action-plan-2035.pdf, accessed 20 August 2024.

1995 - IRENA, "Renewable Capacity Statistics 2024", International Renewable Energy Agency, March 2024, see https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2024/Mar/IRENA_RE_Capacity_Statistics_2024.pdf?rev=a587503ac9a2435c8d13e40081d2ec34, accessed 17 April 2024.

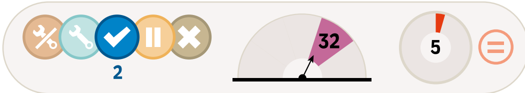
1996 - Statistics Canada, "Electric power generation, monthly generation by type of electricity", Updated 29 June 2024, Government of Canada, see https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510001501, accessed 25 June 2024.

1997 - Environment and Climate Change Canada, "Canada's 2030 Emissions Reduction Plan", Updated 22 June 2022, Government of Canada, see https://publications.gc.ca/collections/collection_2022/eccc/En4-460-2022-eng.pdf, accessed 20 August 2024; Canada Energy Regulator, "Canada's Energy Future 2023—Energy Supply and Demand Projections to 2050", 2023, see https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2023/canada-energy-futures-2023.pdf, accessed 11 August 2023.

1998 - Canada Energy Regulator, "Canada's Energy Future 2023—Energy Supply and Demand Projections to 2050", 2023, op. cit.

1999 - M. V. Ramana and Susan O'Donnell, "Wishful thinking about nuclear energy won't get us to net zero", *The Hill Times*, 3 July 2023, see https://www.hilltimes.com/story/2023/07/03/wishful-thinking-about-nuclear-energy-wont-get-us-to-net-zero/391721/, accessed 5 September 2023.

Mexico



Laguna Verde, located in Alto Lucero, Veracruz, is Mexico's only nuclear power plant. Two General Electric (GE) Boiling Water Reactors (BWRs) operate there, with the first unit connected to the grid in 1989 and the second in 1994. A US$600 million upgrading project was launched in 2007 to increase the output of both units by 20 percent. It was completed in 2011,[2000] bringing the plant's net capacity to 1.55 GW.[2001] The plant is owned and operated by the state utility Comisión Federal de Electricidad (Federal Electricity Commission), commonly referred to as CFE. In 2022, both units underwent refueling outages that caused a drop in nuclear production to 10.5 TWh representing 4.5 percent of the country's total electricity production, down from 11.6 TWh to 5.3 percent in 2021. In 2023, output increased slightly to 12 TWh providing 4.9 percent of the country's power, which was still below the 6.8 percent peak reached in 2015.

In 2015, CFE applied for an unusual 30-year lifetime extension to enable the reactors to operate for 60 years. In most countries, lifetime extensions are either by 10-year periods (like in Belgium or France) or in 20-year periods (like in Japan or the U.S.). In March 2019, the IAEA completed a Safety Aspects of Long-Term Operation (SALTO) review mission at the plant and made recommendations as part of the process to prepare for lifetime extension.[2002] The license renewal was granted in July 2020 to allow for the operation of Unit 1 until July 2050.[2003] The license for Unit 2—initially set to expire in April 2025—was extended in August 2022 by the Ministry of Energy, allowing the reactor to run until April 2055.[2004]

There is no ongoing reactor construction or formal newbuild project in Mexico, though there have been several initiatives and announcements over the years (see previous WNISR editions). However, these have not proceeded, and no serious plans exist to develop additional nuclear.

In a Trend Analysis of Mexico's energy sector published in March 2022, rating agency Fitch labeled the country's nuclear future as "uncertain", mentioning, "we expect no new nuclear capacity additions from 2022 to 2031, with total installed nuclear capacity to remain at 1.6 GW."[2005] Moreover, in July 2022, Moody's downgraded CFE from Baa1 to Baa2 (lower medium grade).[2006] By mid-2024, no rating change had taken place.

2000 - *WNN*, "More capacity for Laguna Verde", *World Nuclear News*, 7 February 2011, see https://www.world-nuclear-news.org/Articles/More-capacity-for-Laguna-Verde, accessed 21 August 2024.

2001 - IAEA, "PRIS - Country Details - Mexico", International Atomic Energy Agency, 20 August 2024, see https://pris.iaea.org/pris/CountryStatistics/CountryDetails.aspx?current=MX, accessed 21 August 2024.

2002 - IAEA, "SALTO Mission to Laguna Verde—Mission Report—Executive Summary", International Atomic Energy Agency, 5 March 2019, see https://www.iaea.org/sites/default/files/documents/review-missions/41_laguna_verde_salto_executive_summary.pdf, accessed 21 August 2024.

2003 - SENER, "La Secretaría de Energía renueva la licencia de operación a Unidad 1 de la Central Nuclear Laguna Verde", Secretaría de Energía/Ministry of Energy, Government of Mexico (in Spanish), 17 July 2020, see http://www.gob.mx/sener/articulos/la-secretaria-de-energia-renueva-la-licencia-de-operacion-a-unidad-1-de-la-central-nuclear-laguna-verde?idiom=es, accessed 7 May 2021.

2004 - CFE, "La Central Nucleoeléctrica Laguna Verde Refrenda Su Compromiso Con el Medio Ambiente y la Seguridad Energética de México, al Obtener la Extensión de Licencia de Operación de su Unidad 2 Por 30 Años Más", Press Release (in Spanish), Comisión Federal de Electricidad/Federal Electricity Commission, 25 August 2022, see https://app.cfe.mx/Aplicaciones/OTROS/Boletines/boletin?i=2634, accessed 28 August 2024.

2005 - Fitch Solutions, "Industry Trend Analysis - Natural Gas Remains Mexico's Dominant Power Type Amid Nuclear And Non-Hydro Uncertainties", Fitch Solutions Industry Research Reports, 15 March 2022.

2006 - *Reuters*, "Moody's downgrades Mexican CFE power utility to Baa2; changes outlook to stable", 12 July 2022, see https://www.reuters.com/article/legal/government/moodys-downgrades-mexican-cfe-power-utility-to-baa2-changes-outlook-to-stable-idUSE1N2U401V /, accessed 21 August 2024.

Even so, in September 2022, CFE Director of Operations, Carlos Andrés Morales Mar stated his company's intention to double the share of nuclear power in the country's electricity mix by 2030, bringing it "from 4 to 8 percent",[2007]and in the 2022 Annual Report that in the "long term", CFE is considering the "incorporation of 5,400 MW of nuclear power plants" to meet the country's rising electricity demand.[2008] The CFE 2023 Annual Report, published in April 2024, does not mention any such long term perspective.[2009]

During a press conference in late July 2023, then President López Obrador said of the prospects for nuclear new build:

> I believe that in order to avoid speculation it would be good to state clearly: we are not going to promote the creation of nuclear plants.[2010]

In the June 2024 elections, Dr. Claudia Sheinbaum was elected president. Not only is she Mexico's first female president, but before being mayor of Mexico City, she was an energy researcher at California's Lawrence Berkeley Laboratory and a lead author of IPCC assessment report.[2011] During her election campaign, she pledged to accelerate the energy transition with new solar, wind, and hydro power, supported by US$13.6 billion in new energy investment by 2030.[2012] However, many commentators noted that Dr. Sheinbaum is the prodigy of former President Obrador, who was a strong supporter of the fossil fuel industry, and oversaw an 11 percent increase in greenhouse gas emissions from the energy sector in 2023,[2013] so how quickly or significantly a shift in energy policy materializes remains to be seen.

Mexico has a power sector dominated by fossil fuels. According to the Energy Institute, natural gas provided 58 percent, oil 9 percent and coal 8 percent. Hydro provides a further 6 percent, other renewables 15 percent, and nuclear 3.5 percent (4.5 percent according to the IAEA).[2014]

Mexico's "Climate Change Mid-Century Strategy", submitted to the United Nations in 2016, set the goal of at least 50-percent clean energy sources of total energy generation by 2050

2007 - Arturo Solís, "CFE duplicará el uso de energía nuclear en México hacia 2030", *Bloomberg Línea*, 8 September 2022 (in Spanish), see https://www.bloomberglinea.com/2022/09/08/cfe-duplicara-el-uso-de-energia-nuclear-en-mexico-hacia-2030/, accessed 21 August 2024.

2008 - CFE, "Informe Anual 2022", Comisión Federal de Electricidad, April 2023, see https://infosen.senado.gob.mx/sgsp/gaceta/65/2/2023-04-28-1/assets/documentos/SEGOB_Informe_Anual_CFE_2022.pdf, accessed 20 October 2023.

2009 - CFE, "Informe Anual 2023", Comisión Federal de Electricidad, April 2024, see https://www.cfe.mx/finanzas/reportes-financieros/Reportes%20Anuales%20Documentos/Informe%20Anual%202023.pdf, accessed 22 August 2024.

2010 - Por César Huerta, "AMLO descarta planes para construir más centrales nucleares en México: 'La que tenemos está funcionando muy bien'", *infobae*, 31 July 2023, see https://www.infobae.com/mexico/2023/07/31/amlo-descarta-planes-para-construir-mas-centrales-nucleares-en-mexico-la-que-tenemos-esta-funcionando-muy-bien/, accessed 21 August 2024.

2011 - Mitchell Beer, "Climate Scientist Sheinbaum Wins Mexico Election, Pledges More Renewables and Gas", *The Energy Mix*, 4 June 2024, see https://www.theenergymix.com/climate-scientist-sheinbaum-wins-mexico-election-pledges-more-renewables-and-gas/, accessed 4 June 2024.

2012 - Rebecca Conan, "Sheinbaum pledges $13bn for Mexican energy transition", *Argus*, 17 April 2024, see https://www.argusmedia.com/en/news-and-insights/latest-market-news/2558850-sheinbaum-pledges-13bn-for-mexican-energy-transition, accessed 21 August 2024.

2013 - Haley Zaremba, "Mexico's President Has Failed to Deliver on Clean Energy Promises", OilPrice.com, 25 February 2024, see https://oilprice.com/Alternative-Energy/Nuclear-Power/Mexicos-President-Has-Failed-to-Deliver-on-Clean-Energy-Promises.html, accessed 21 August 2024.

2014 - Energy Institute, "Statistical Review of World Energy", 2024.

and suggests "to consider, among the plans for diversification of generating facilities, the implementation of a nuclear program as a possible substitute to fossil fuel use".[2015]

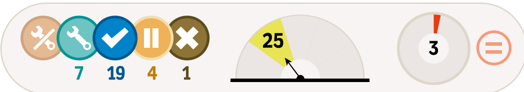
The updated Nationally Determined Contribution (NDC) submitted in November 2022—wherein the country commits to adding 40 GW of clean energy by 2030, but sets no Net Zero target—does not mention nuclear.[2016] For a recent history of Mexico's energy policy, see section on Mexico in WNISR2023.

ASIA

China

See Focus Countries – China Focus.

India



India has 20 operational nuclear power reactors, with a total net generating capacity of 6.9 GW. As of 28 June 2024, the PRIS database listed four reactors under the "suspended operation" category. However, among these, the Rajasthan-1 reactor (RAPS-1) has not generated power since 2004 and is considered permanently closed in WNISR statistics. The other three units, Tarapur-1 (TAPS-1), Tarapur-2 (TAPS-2), and Madras-1 (MAPS-1) fall under the LTO category. Madras-1 has not generated any electricity since 2018, and both Tarapur-1 and -2 since 2020. In a media interview from January 2024, the chairman of NPCIL stated that there were "age-related issues" with MAPS-1 and the reactor needed "upgradation" but that he was expecting it "to come online this financial year."[2017] That has not happened before the financial year ended on 31 March 2024, nor as of mid-2024. He also said that TAPS-1 and TAPS-2 were "undergoing life extension and upgradation works." Subsequently, it was reported that the restart of TAPS-1 and TAPS-2 has been postponed because of "a delay in the delivery" of some special equipment from Italy; and that, as of 9 May 2024, the reactors were expected to "remain offline until

2015 - Secretaría de Medio Ambiente y Recursos Naturales and Instituto Nacional de Ecología y Cambio Climático, "Mexico's Climate Change Mid-Century Strategy.", Government of Mexico, 2016, see https://unfccc.int/files/focus/long-term_strategies/application/pdf/mexico_mcs_final_cop22nov16_red.pdf, accessed 21 August 2024.

2016 - Secretaría de Medio Ambiente y Recursos Naturales and Instituto Nacional de Ecología y Cambio Climático, "Contribución Determinada a Nivel Nacional—Actualización 2022" ((in Spanish)), Government of Mexico, November 2022, see https://unfccc.int/sites/default/files/NDC/2022-11/Mexico_NDC_UNFCCC_update2022_FINAL.pdf, accessed 12 January 2023.

2017 - T. S. Subramanian, "India will 'commission a nuclear power reactor every year': NPCIL chief", *The Hindu*, 18 January 2024, see https://www.thehindu.com/sci-tech/science/npcil-commission-nuclear-power-reactor-every-year-pathak-interview/article67751083.ece, accessed 18 January 2024.

October."[2018] In addition, RAPS-3 has been shut down since 28 October 2022 and was not online as of 1 July 2024,[2019] and thus is also categorized as LTO in WNISR2024.[2020]

The list of operating reactors includes Kakrapar-4, which was first connected to the grid in February 2024, over eight years after the projected startup date December 2015.[2021] Construction had begun in November 2010.

Reactors in India generated a record 44.6 TWh net in 2023, according to IAEA-PRIS. According to the same source, the share of nuclear of all the grid-fed electricity in the country has been slightly declining since 2020, from 3.27 percent to 3.07 in 2023. Nuclear reactors produced more electricity than in 2022, when these reactors put out 42 TWh, but the share remains the same. However, the share calculation is at odds with the Energy Institute, which reports that nuclear reactors generated 48.2 TWh gross, but calculates that the share of all electricity produced is a little under 2.5 percent.[2022] The reason for the difference between the two sources is unclear.

Delays in Construction and Plans

India is building seven more reactors with a combined net capacity of 5.4 GW. The oldest project of these is the Prototype Fast Breeder Reactor (PFBR) that has been under construction for almost two decades, since October 2004. Next are the two Pressurized Heavy Water Reactors (PHWRs), Rajasthan-7 and -8 (being constructed since July and September 2011). Finally, there are four VVER-1000s at Kudankulam, whose construction started in June and October 2017 for the first two units, and June and December 2021 for the second pair.

Most, possibly all, of these are delayed. The 500-MW PFBR is now 14 years past the initially projected commissioning date of September 2010.[2023] The anticipated commissioning date, as of May 2024, was December 2024.[2024] Loading of fuel into the core of the PFBR finally began on 4 March 2024.[2025] Notably, the announcements that accompanied this event did not mention

2018 - *Business Standard*, "Key parts yet to arrive, resumption in operations of TAPS delayed", 10 May 2024, see https://www.business-standard.com/india-news/key-parts-yet-to-arrive-resumption-in-operations-of-taps-delayed-124051000150_1.html, accessed 14 May 2024.

2019 - NPCIL, "Submission of financial results for the quarter and half year ended September 30, 2023", Nuclear Power Corporation of India Limited, 8 November 2023, see https://www.npcil.nic.in/WriteReadData/userfiles/file/Reg_52(4)_08112023_01.pdf, accessed 18 July 2024.

2020 - RAPS-3 was eventually reconnected to the grid in late July; see Department of Atomic Energy, "RAPS-3 comes back online after Renovation & Modernisation", Press Release, as published by the Press Information Bureau, Government of India, 29 July 2024, see https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2038579, accessed 26 August 2024.

2021 - *WNN*, "India's newest nuclear unit connected to grid", *World Nuclear News*, 26 February 2024, see https://www.world-nuclear-news.org/Articles/India-s-newest-nuclear-unit-connected-to-grid, accessed 26 February 2024; and NPCIL, "Project Summary— Kakrapar Atomic Power Project - 3 and 4", 9 July 2024, see http://www.cspm.gov.in/ocmstemp/PROJ_SUMMARY?prcd=N02000010&stat=O, accessed 18 July 2024.

2022 - Energy Institute, "Statistical Review of World Energy 2024", June 2024, see https://www.energyinst.org/__data/assets/pdf_file/0006/1542714/EI_Stats_Review_2024.pdf, accessed 18 July 2024.

2023 - MoSPI, "450th Flash Report on Central Sector Projects (Rs. 150 crore and above)", Ministry of Statistics and Programme Implementation, Government of India, May 2023, see http://www.cspm.gov.in/english/flr/FR_May_2023.pdf, accessed 28 June 2023.

2024 - MoSPI, "463rd Flash Report on Central Sector Infrastructure Projects (Rs. 150 crore & above)—Part - II", Ministry of Statistics and Programme Implementation, Government of India, May 2024, see http://www.cspm.gov.in/english/fr_part/2024-25/May/Part-2.pdf, accessed 18 July 2024.

2025 - IPFM, "India begins loading fuel in Prototype Fast Breeder Reactor", International Panel on Fissile Materials, 4 March 2024, see https://fissilematerials.org/blog/2024/03/india_begins_loading_fuel.html, accessed 10 May 2024.

any plans for building more breeder reactors. In the past, officials had announced plans for building four more fast breeder reactors of 500 MW capacity each, by 2020.[2026] A fast rate of construction of breeder reactors was the basis for projections of rapid growth of nuclear energy in India, although these were never realistic to start with.[2027]

A fast rate of construction of breeder reactors was the basis for projections of rapid growth of nuclear energy in India, although these were never realistic to start with.

The two reactors in Rajasthan are now due to be completed in December 2026, ten years after the original date of December 2016.[2028] A statement from Nuclear Power Corporation of India Limited in November 2023 announced the "successful completion of Hot Conditioning of the Primary Heat Transport (PHT) system" of Rajasthan-7.[2029]

The VVER reactors being imported from Russia are less delayed. Only Kudankulam-5 and -6 are still scheduled to be commissioned by the initially targeted date, in September 2027, although that might well change in the future. Kudankulam-3 and -4 are now expected to be commissioned in November 2026.[2030] When construction started, officials projected that these would start in March 2023 and in 2024.[2031]

Alongside these delays, the estimated costs of these reactors have also gone up. The PFBR's cost has more than doubled from the initially anticipated Rs.34.9 billion to Rs.76.7 billion as of May 2024.[2032] The Kakrapar project is now expected to cost Rs.225.2 billion, up from Rs.114.6 billion; the Rajasthan project was initially estimated at Rs.123.2 billion but the official estimate has gone up to Rs.229.2 billion as of May 2024.[2033] Likewise, Kudankulam-3 and -4 was initially projected to cost Rs.398.5 billion but the revised estimate is Rs.688.9 billion.[2034]

As discussed in detail in earlier volumes of the WNISR, plans for building a large number of PHWRs have been announced by the Indian Government for many years now and have been continuously pushed back. There has been no first pour of concrete for any of these new reactor projects so far. In December 2023, the government announced in parliament that the land for the four-unit Mahi Banswara Rajasthan Atomic Power Project has "been acquired and

2026 - *The Hindu*, "Kalpakkam PFBR to be completed ahead of schedule; 4 more to come up by 2020", 7 September 2005.

2027 - M. V. Ramana and J. Y. Suchitra, "Slow and Stunted: Plutonium Accounting and the Growth of Fast Breeder Reactors", *Energy Policy*, 2009.

2028 - MoSPI, "463rd Flash Report on Central Sector Infrastructure Projects (Rs. 150 crore & above)—Part - II", May 2024, op. cit.

2029 - *The Press Trust of India*, "India's third 700 MW nuclear power reactor completes hot conditioning, says NPCIL", as published by *The Economic Times*, 30 November 2023, see https://economictimes.indiatimes.com/industry/energy/power/indias-third-700-mw-nuclear-power-reactor-completes-hot-conditioning-says-npcil/articleshow/105635137.cms?from=mdr, accessed 29 June 2024.

2030 - MoSPI, "463rd Flash Report on Central Sector Infrastructure Projects (Rs. 150 crore & above)—Part - II", May 2024, op. cit.

2031 - *The Press Trust of India*, "Building of units 3 & 4 of Kudankulam nuke power plant begins", as published in *The Deccan Herald*, 29 June 2017, see https://www.deccanherald.com/content/619873/building-units-3-4-kudankulam.html, accessed 13 July 2021.

2032 - MoSPI, "463rd Flash Report on Central Sector Infrastructure Projects (Rs. 150 crore & above)—Part - II", May 2024, op. cit. As of May 2024, the conversion rate to US dollars is around Rs. 83 per US dollar. However, all of the official costs for Indian nuclear projects are expressed in mixed-year Rupees and so directly converting it into other currencies using one conversion rate is misleading.

2033 - Ibidem.

2034 - Ibidem.

various site investigations have been initiated", and that as of November 2023, Rs. 6.36 billion (US$$_{2023}$77 million) had already been spent on the project.[2035]

There is no concrete progress with India's plans to import reactors from the U.S. and France which has been talked about ever since the U.S.-India nuclear deal was negotiated between 2005 and 2008.[2036] In January 2024, India's Foreign Secretary told journalists that France's EDF and NPCIL were discussing details like financing mechanisms and localization components.[2037] But these elements were part of the Industrial Way Forward Agreement signed by these organizations back in March 2018,[2038] suggesting that differences between the two have not yet been resolved. As of July 2024, EDF's India specific website still features an announcement that a "Techno-Commercial Offer" was "submitted to NCPIL in April 2021" and a promise that "following the target set by the Industrial Way Forward Agreement (IWFA), NPCIL and EDF work alongside in order to reach a General Framework Agreement in the coming months."[2039]

There has been no official updates with the proposal to import Westinghouse AP-1000 reactors since India's Prime Minister Narendra Modi and U.S. President Joseph Biden met in Washington in June 2023, when they announced that there were "intensified consultations between the U.S. DOE [Department of Energy] and India's DAE [Department of Atomic Energy] for facilitating opportunities for WEC [Westinghouse Electric Company] to develop a techno-commercial offer for the Kovvada nuclear project."[2040]

Power Mix

Renewable energy continues to progress rapidly in India. According to the International Renewable Energy Agency (IRENA), total renewable energy capacity (including large hydro plants) grew from 71.9 GW in 2013 to 175.9 GW in 2023.[2041] Of this, solar energy constitutes 73.1 GW (72.8 GW for solar photovoltaics), up from 63.4 GW in 2022 and 3.8 GW in 2013. Wind energy capacity reached 44.7 GW, an increase of 6.7 percent compared to 2022. The latest figures from the Central Electricity Authority, the official source of data on India's electricity

2035 - Lok Sabha, "Starred Question No. 250—Construction of Nuclear Power Plant", Department of Atomic Energy, Government of India, answered by Jitendra Singh, Minister of State for Personnel, Public Grievances and Pensions, and Prime Minister's Office, 20 December 2023, see https://sansad.in/getFile/loksabhaquestions/annex/1714/AS250.pdf?source=pqals, accessed 29 June 2024.

2036 - Prerna Gupta and M. V. Ramana, "A Decade After the Nuclear Deal", *The India Forum*, 3 April 2019, see https://www.theindiaforum.in/article/decade-after-nuclear-deal, accessed 17 May 2020.

2037 - *Press Trust of India*, "India, France in talks for financing mechanism, localisation for Jaitapur n-project", as published by *The Economic Times*, 26 January 2024, see https://economictimes.indiatimes.com/news/india/india-france-in-talks-for-financing-mechanism-localisation-for-jaitapur-n-project/articleshow/107174054.cms?from=mdr, accessed 29 June 2024.

2038 - DAE, "Industrial Way Forward Agreement between NPCIL and Électricité de France S. A. (EDF), France for the implementation of the Jaitapur Nuclear Power Project", Press Release, Department of Atomic Energy, Government of India, 11 March 2018, see https://dae.gov.in/industrial-way-forward-agreement-between-npcil-and-lectricit-de-france-s-a-edf-france-for-the-implementation-of-the-jaitapur-nuclear-power-project/, accessed 29 June 2024.

2039 - EDF India, "JNPP: The Largest Nuclear Power Plant Worldwide", 2024, see https://india.edf.com/en/our-activities/nuclear/jnpp-the-largest-nuclear-power-plant-worldwide, accessed 3 August 2024.

2040 - Government of India and United States Government, "Joint Statement from the United States and India", Press Release, as published by The White House, 22 Jun 2023, see https://www.whitehouse.gov/briefing-room/statements-releases/2023/06/22/joint-statement-from-the-united-states-and-india/, accessed 18 July 2024.

2041 - IRENA, "Renewable Capacity Statistics 2024", International Renewable Energy Agency, March 2024, see https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2024/Mar/IRENA_RE_Capacity_Statistics_2024.pdf?rev=a587503ac9a2435c8d13e40081d2ec34, accessed 17 April 2024.

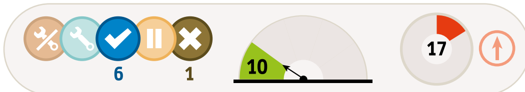
sector, show modern renewables at 144.75 GW and hydropower at 46.9 GW as of April 2024.[2042] Coal continues to dominate with an installed capacity of 210.97 GW whereas the installed capacity of gas is 24.8 GW.

For 2023, the Energy Institute reports the combined output of modern renewables (excluding large hydropower) in India as 232.8 TWh gross—up 14 percent from 203.8 TWh in 2022—representing 12 percent of all the electrical energy.[2043] Of this, wind energy contributed 82.1 TWh and solar energy 113.4 TWh. Nuclear energy contributed 48.2 GWh. In other words, for the year 2023, wind and solar power together produced over four times the amount of electricity that nuclear reactors produced. However, fossil fuels together generated 1,526.7 TWh, nearly 78 percent of all electricity generated in 2023, with coal alone comprising three-quarters of the total.

Japan

See Focus Countries – Japan Focus.

Pakistan



Pakistan operates six nuclear reactors with a combined (net) capacity of 3.3 GW. According to the IAEA's PRIS database, nuclear electricity production in Pakistan has increased from 22.2 TWh in 2022 to an all time high of 22.4 TWh in 2023. The share of electricity from nuclear power plants increased from 16.2 percent in 2022 to a record 17.4 percent in 2023.

Pakistan is the only country outside China where Chinese companies have built nuclear reactors. This includes two Hualong One reactors (Kanupp-2 and Kanupp-3) outside the city of Karachi and four CNP-300 nuclear reactors in Chashma, all from the China National Nuclear Corporation (CNNC). In July 2023, the Pakistani Government formally approved construction of another Hualong One reactor in Chashma (Unit 5),[2044] but an agreement to build this reactor dates back to 2017.[2045]

The Chashma-5 (CHASNUPP-5 or C-5) project is estimated to cost US$4.8 billion.[2046] The majority of the cost is planned to be covered by credit from China.[2047] According to latest estimates from the head of the Pakistan Atomic Energy Commission, the project will be completed by 2030,[2048] while in its ten-year "Transmission System Expansion Plan" filed with

2042 - CEA, "Dashboard", Central Electricity Authority, Ministry of Power, Government of India, as of April 2024, see https://cea.nic.in/dashboard/?lang=en, accessed 3 August 2024.

2043 - Energy Institute, "Statistical Review of World Energy 2024", 2024, op. cit.

2044 - *WNN*, "Pakistan formalises Chashma 5 approval", *World Nuclear News*, 1 August 2023, see https://world-nuclear-news.org/Articles/Pakistan-formalises-Chashma-5-approval, accessed 18 July 2024.

2045 - *WNN*, "Pakistan, China agree to build Chashma 5", 23 November 2017, see https://www.world-nuclear-news.org/Articles/Pakistan,-China-agree-to-build-Chashma-5, accessed 7 May 2022.

2046 - Asif Shahzad, "China and Pakistan sign $4.8 billion nuclear power plant deal", *Reuters*, 20 June 2023, see https://www.reuters.com/business/energy/pakistan-china-sign-48-bln-nuclear-power-plant-deal-2023-06-20/, accessed 18 July 2024.

2047 - *WNN*, "Pakistan formalises Chashma 5 approval", *World Nuclear News*, 1 August 2023, op. cit.

2048 - David Dalton, "Pakistan / Construction Begins Of China-Supplied Hualong One Nuclear Plant At Chasnupp", *NucNet*, 17 July 2023, see https://www.nucnet.org/news/construction-begins-of-china-supplied-hualong-one-nuclear-plant-at-chasnupp-7-1-2023, accessed 31 August 2023.

the regulator in April 2024, the National Transmission & Despatch Company (NTDC) expects Chashma-5 to come online 2030–2031.[2049] The project has been criticized for its high cost of power, and shelving renewable energy projects to make way for it.[2050]

Pakistan's renewable electricity capacity was 14.2 GW in 2023.[2051] The most important component of this capacity is hydropower, with 10.6 GW, which accounts for approximately 75 percent of total installed renewable energy capacity. The total capacities of wind and solar energy are 1.8 GW and 1.2 GW respectively. These figures are the same as what was reported in 2022, an indication of the severe financial troubles in Pakistan. However, the Ministry of Energy has plans for a significant expansion of both wind and solar energy by the end of the decade, and project a capacity increase of 13.4 GW (8.6 GW of solar) by 2031.[2052] Pakistan's National Electric Power Regulatory Authority reports that as of June 2023, the total installed capacity was 45.8 GW, of which fossil fuel sources constituted 28.3 GW.[2053]

Renewable energy sources produced 43.7 TWh gross in 2023, marginally higher than the 2022 figure of 41 TWh; wind and solar energy contributed 4.4 TWh and 1.2 TWh respectively in 2023.[2054]

South Korea

See Focus Countries – South Korea Focus.

Taiwan

See Focus Countries – Taiwan Focus.

2049 - NTDC, "Transmission System Expansion Plan (TSEP 2024-34)", National Transmission & Despatch Company Limited, April 2024, see https://www.nepra.org.pk/Admission%20Notices/2024/05%20May/TSEP%202024-34%20Report.pdf, accessed 18 July 2024.

2050 - Mushtaq Ghumman, "$5bn Chashma-5 N-plant to produce power at Rs20 per unit: Country has swallowed a bitter pill?", *Business Recorder*, 12 July 2023, see https://www.brecorder.com/news/40252138, accessed 29 June 2024.

2051 - IRENA, "Renewable Capacity Statistics 2024", International Renewable Energy Agency, March 2024, op. cit.

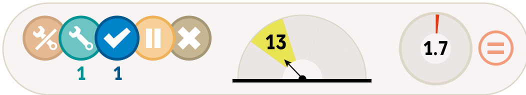
2052 - Power Division, "Year Book 2022-2023", Ministry of Energy, Government of Pakistan, 10 November 2023, see https://power.gov.pk/SiteImage/Publication/YearBook2022-23.pdf, accessed 18 July 2024.

2053 - NEPRA, "State of Industry Report 2023", National Electric Power Regulatory Authority, 2023, see https://nepra.org.pk/publications/State%20of%20Industry%20Reports/State%20of%20Industry%20Report%202023.pdf, accessed 3 August 2024.

2054 - Energy Institute, "Statistical Review of World Energy 2024", 2024, op. cit.

MIDDLE EAST

Iran



Iran has one operational reactor, Bushehr-1—also spelled Busheer-1—with a net capacity of 915 MW and a second unit under construction with a net capacity of 974 MW, both Pressurized Water Reactors (PWRs).[2055] The first reactor was completed by Rosatom in 2011, and the second and third units of the plant are to be completed by Rosatom's subsidiary Atomstroyexport JSC (ASE JSC), which signed an Engineering, Procurement & Construction (EPC) turnkey contract with the Nuclear Power Production and Development Company of Iran (NPPD) back in November 2014.[2056] The contract specified the construction of eight new nuclear reactors, two of which were to be VVER-1000 type reactors built at Bushehr.[2057] Construction on Unit 2 restarted in 2019, and the IAEA has not yet recorded an official start date for the third unit.[2058] At the end of 2023, it was reported that concrete was poured for the new sections of Busehr-2.[2059] Unit 2 had been on the IAEA's "under construction" list for almost 20 years, before it disappeared from the list in 2005. IAEA-PRIS lists it as under construction starting in 27 September 2019, but concrete pour for the foundations of the reactor building that defines the official construction start, only happened in November 2019 according to the Atomic Energy Organization of Iran (AEOI).[2060]

At the end of 2019, these two reactors were expected to be completed in 2024 and 2026, respectively.[2061] While no official date was recorded for the construction start of the third unit, delay is inevitable. The second unit is also likely to miss the 2026 deadline, as the Head of the AEOI Mohammad Eslami was quoted as saying in October 2023, "We hope that the second unit will be completed and inaugurated in less than 5 years and the third unit 1.5 years after that."[2062] On another occasion, Eslami stressed that each power plant would require seven years to construct and hoped that the two 1000-MW reactors still under construction would

2055 - IAEA-PRIS, "Country Statistics—Iran, Islamic Republic of", Power Reactor Information System, International Atomic Energy Agency, Updated 23 July 2024, see https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=IR, accessed 24 July 2024.

2056 - Rosatom, and ASE, "Solemn ground-breaking ceremony for Bushehr-2 NPP construction in Iran", Press Release, Atomstroyexport, Rosatom, 6 September 2016, see https://ase-ec.ru/en/for-journalists/news/2016/sep/news61/; accessed 24 July 2024.

2057 - Rosatom, "Rosatom to Build Eight New Reactors in Iran", Newsletter #64, November 2014, see https://rosatomnewsletter.com/2014/11/12/rosatom-to-build-eight-new-reactors-in-iran/; accessed 24 July 2024.

2058 - WNISR, "Iran: Construction Restart of Busheer-2", 14 November 2019, see https://www.worldnuclearreport.org/Iran-Construction-Restart-of-Busheer-2.html, accessed 14 November 2019; and IAEA-PRIS, "Country Statistics—Iran, Islamic Republic of", Power Reactor Information System, International Atomic Energy Agency, op. cit.

2059 - *Nuclear Engineering International*, "Iran pours concrete for section of second Bushehr reactor", 13 October 2023, see https://www.neimagazine.com/news/iran-pours-concrete-for-section-of-second-bushehr-reactor-11216439/?cf-view, accessed 8 August 2024.

2060 - AEOI, "Concrete pouring of the Second unit of nuclear power plant held in Bushehr", Atomic Energy Organization of Iran, 12 November 2019, see https://aeoi.org.ir/en/portal/home/?news/45799/69280/294254/concrete-pouring-of-the-second-unit-of-nuclear-power-plant-held-in-bushehr, accessed 22 August 2024.

2061 - WNISR, "Iran: Construction Restart of Busheer-2", 14 November 2019, op. cit.

2062 - *Mehr News Agency*, "Iran pours concrete for 2nd Bushehr nuclear reactor", 9 October 2023, see https://en.mehrnews.com/news/206922/Iran-pours-concrete-for-2nd-Bushehr-nuclear-reactor, accessed 30 June 2024.

be inaugurated by 2029.[2063] According to AEOI, the process has recently been fast-tracked with 3,000 people working "round the clock" on the Bushehr-2 and -3 projects.[2064]

Iran generated 1.7 percent of its total electricity from nuclear power in 2023. The country's administration aims to reach 20 GW capacity by 2041.[2065] To reach this target, according to AEOI, the "implementation operation" for the construction of a nuclear power plant, with four units of 1250-MW capacity, commenced in Sirik city of the Hormozgan province in early February 2024.[2066] AEOI has also identified Shiraz as another potential location for a nuclear power plant.[2067]

The number of planned nuclear reactors in Iran is still to be determined, as there are several other issues affecting the country's nuclear development.

Iran also has a project in Darkhovin (Karoon or Karun) with a capacity of 300 MWe, an Iranian-designed reactor as detailed in previous WNISR editions. In February 2024, AEOI announced that the completion of the initial excavation phase, paving the way for the second stage of development "with concrete placement" to begin in fall 2024.[2068]

The number of planned nuclear reactors in Iran is still to be determined, as there are several other issues affecting the country's nuclear development. Iran has a uranium enrichment project, and the 2015 Joint Comprehensive Plan of Action (JCPOA) agreed between Iran, China, France, Germany, Russia, the U.K. and the E.U. was introduced to "ensure that Iran's nuclear programme will be exclusively peaceful."[2069] However, the negotiations have been challenging. The U.S. and E.U. have asserted that the Iranian enrichment program had links to a nuclear weapon development program.[2070] Later, in June 2024, the IAEA's board voted to censure Iran for failing to fully cooperate with the Agency.[2071] Iran's Ambassador and Permanent Representative to the UN, Amir Saeed, responded by stating: "The only viable option for

2063 - *IRNA*, "Raisi administration plans to inaugurate 2 power plants: AEOI chief", *The Islamic Republic News Agency*, 13 March 2024, see https://en.irna.ir/news/85417859/Raisi-administration-plans-to-inaugurate-2-power-plants-AEOI, accessed 22 June 2024.

2064 - AEOI, "Government support for the production of the 20,000 MW goal of nuclear power plants will go on", Atomic Energy Organization of Iran, 29 November 2023, see https://aeoi.org.ir/en/portal/home/?news/45799/69280/355388/government-support-for-the-production-of-the-20-000-mw-goal-of-nuclear-power-plants-will-go-on, accessed 19 April 2024.

2065 - Ibidem; and *The Associated Press*, "Iran begins building 4 more nuclear power plants", 1 February 2024, see https://apnews.com/article/iran-nuclear-power-plant-construction-f96dbdd32426647c2133530cfa3cd6c0, accessed 24 July 2024.

2066 - AEOI, "Construction operation start of 4 nuclear power plants units in the Hormozgan province", Atomic Energy Organization of Iran, 2 February 2024, see https://aeoi.org.ir/en/portal/home/?news/45799/69280/358720/construction-operation-start-of-4-nuclear-power-plants-units-in-the-hormozgan-province, accessed 19 April 2024.

2067 - *IRNA*, "Iran plan to build another reactor in Shiraz: Eslami", *The Islamic Republic News Agency*, 12 May 2024, see https://en.irna.ir/news/85474784/Iran-plans-to-build-new-nuclear-reactor-in-Shiraz-Eslami, accessed 22 June 2024.

2068 - AEOI, "The first stage of excavation of Karun 300 MW nuclear plant has been accomplished", 28 February 2024, see https://aeoi.org.ir/en/portal/home/?news/45799/69280/359541/the-first-stage-of-excavation-of-karun-300-mw%c2%a0-nuclear-plant-has-been-accomplished, accessed 19 April 2024.

2069 - China, France, Germany, Russia, the United Kingdom, Iran, and the European Union, "Joint Comprehensive Plan of Action", 14 July 2015, see https://www.europarl.europa.eu/cmsdata/122460/full-text-of-the-iran-nuclear-deal.pdf, accessed 24 July 2024.

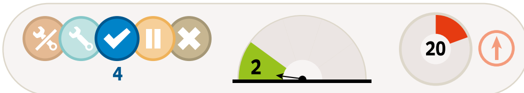
2070 - Patrick Wintour, "Diplomats fear growing power of Iranian factions that want nuclear weapons", *The Guardian*, 10 March 2024, see https://www.theguardian.com/world/2024/mar/10/diplomats-fear-growing-power-of-iranian-factions-that-want-nuclear-weapons, accessed 25 June 2024.

2071 - Patrick Wintour, "Nuclear watchdog votes to censure Iran for non-cooperation with inspectors", *The Guardian*, 5 June 2024, see https://www.theguardian.com/world/article/2024/jun/05/iaea-un-nuclear-watchdog-iran-vote, accessed 30 June 2024.

restoring the JCPOA is sincere dialogue and constructive cooperation."[2072] There is a view that the recent IAEA censure may result in an Iranian escalation, which may lead to an accelerated Iranian nuclear program and a greater conflict in the Middle East.[2073]

Iran is highly reliant on fossil fuels for electricity generation, with renewable energy, including hydro, accounting for only 6.5 percent of the total gross production.[2074] There are plans to increase wind energy capacity by 5.5 times in line with the 7th Development Plan's target of 30 GW by 2028.[2075] Furthermore, Iran is planning to add 15 GW of solar capacity.[2076] While no explicit deadline has been set to achieve this target, in April 2023, the Iranian Ministry of Energy announced that 10 GW of renewable energy capacity would be added by August 2025.[2077]

United Arab Emirates



The fourth and last APR-1400 reactor at the Barakah nuclear project was connected to the grid on 23 March 2024.[2078] The earlier three units were declared entering commercial operation in April 2021, March 2022, and February 2023 respectively.[2079] The initial timeline laid out in 2014 by the Emirates Nuclear Energy Corporation (ENEC), projected that Unit 1 would "enter commercial operation in 2017, Unit 2 in 2018, Unit 3 in 2019 and the final Unit 4 in 2020",[2080] these were all delayed by several years. According to media reports from April 2024, the United Arab Emirates (UAE) might be planning a second nuclear power plant, but few details are known with any degree of reliability.[2081] In November 2023, ENEC launched the

2072 - *IRNA*, "Only viable option for restoring JCPOA is sincere dialogue", *The Islamic Republic News Agency*, 25 June 2024, see https://en.irna.ir/news/85519594/Only-viable-option-for-restoring-JCPOA-is-sincere-dialogue, accessed 30 June 2024.

2073 - Simon Henderson, "IAEA Censure Risks Iranian Escalation", The Washington Institute, 10 June 2024, see https://www.washingtoninstitute.org/policy-analysis/iaea-censure-risks-iranian-escalation; and *Bulletin of the Atomic Scientists*, "Why Iran may accelerate its nuclear program, and Israel may be tempted to attack it", 26 April 2024, see https://thebulletin.org/2024/04/why-iran-may-accelerate-its-nuclear-program-and-israel-may-be-tempted-to-attack-it/?, accessed 30 June 2024.

2074 - Energy Institute, "Statistical Review of World Energy 2024 - Consolidated Dataset", 2024, see https://www.energyinst.org/__data/assets/excel_doc/0004/1540552/merged_narrow.xlsx, accessed 24 June 2024.

2075 - *IRNA*, "Capacity of Iran's wind power plants to increase by 5.5 times", *The Islamic Republic News Agency*, 12 June 2024, see https://en.irna.ir/news/85506434/Capacity-of-Iran-s-wind-power-plants-to-increase-by-5-5-times, 30 June 2024.

2076 - *IRNA*, "Iran finalizes plan for construction of 15 GW solar power plants", *The Islamic Republic News Agency*, 4 October 2023, see https://en.irna.ir/news/85247625/Iran-finalizes-plan-for-construction-of-15-GW-solar-power-plants, accessed 30 June 2024.

2077 - Enterprise Climate, "Iran breaks ground on the second phase of the Bushehr nuclear power plant", 10 October 2023, see https://climate.enterprise.press/stories/2023/10/10/iran-breaks-ground-on-the-second-phase-of-the-bushehr-nuclear-power-plant-102883/; and *Tehran Times*, "Capacity of Iran's renewable power plants rises 0.9% in a month", 17 April 2023, see https://www.tehrantimes.com/news/483751/Capacity-of-Iran-s-renewable-power-plants-rises-0-9-in-a-month; both accessed 9 August 2024.

2078 - ENEC, "Unit 4 of Barakah Nuclear Energy Plant successfully connected to UAE grid", Press Release, Emirates Nuclear Energy Corporation, 23 March 2024, see https://www.enec.gov.ae/news/latest-news/unit-4-of-barakah-nuclear-energy-plant-successfully-connected-to-uae-grid/, accessed 25 March 2024.

2079 - ENEC, "The UAE's sustainable powerhouse: Barakah Nuclear Energy Plant doubles clean electricity generation with start of Commercial Operations at Unit 2", 24 March 2022, see https://www.enec.gov.ae/news/latest-news/barakah-plant-doubles-clean-electricity-generation-with-start-of-commercial-operations-at-unit-2/; and ENEC, "In the Year of Sustainability UAE Takes Significant Leap towards Net Zero 2050 as Unit 3 of Barakah Nuclear Energy Plant Starts Commercial Operations", Press Release, 24 February 2024, see https://www.enec.gov.ae/news/latest-news/uae-takes-leap-towards-net-zero-2050-as-unit-3-plant-starts-commercial-operations/; both accessed 28 August 2024.

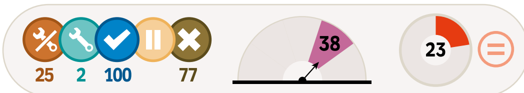
2080 - ENEC, "Unit 1 of power plant more than 57% complete", Press Release, 17 September 2014, see https://www.enec.gov.ae/news/latest-news/unit-1-of-enecs-barakah-power-plant-now-more-than-57-complete/, accessed 10 June 2022.

2081 - Alexander Cornwell and Maha El Dahan, "Exclusive: UAE planning second nuclear power plant, sources say", *Reuters*, 26 April 2024, see https://www.reuters.com/business/energy/uae-planning-second-nuclear-power-plant-sources-say-2024-04-26/, accessed 27 May 2024.

ADVANCE Program intended to "evaluate the latest technologies in the advanced, Small Modular Reactor (SMR) and microreactor categories," and "in doing so, (...) work with national stakeholders to determine deployment pathways, and with international partners for both technology and project collaboration opportunities."[2082] It has since been contracting preliminary agreements with a long list of potential vendors and national entities, including to jointly explore deployment of their technology in the UAE, but also in other countries.

In 2023, nuclear reactors contributed 31.2 TWh of electricity to the UAE's grid representing 19.7 percent of total electrical energy, its highest to date by both metrics. The corresponding figures for 2022 are 19.3 TWh and 12.4 percent. Natural gas remains the main source of electricity generation in the country, contributing 72 percent of the total.[2083] Renewables contributed 13.8 TWh (gross), or 8.4 percent of all electricity supplied to UAE's grid.[2084] However, their installed capacity continues to increase rapidly. The total capacity as of 2023 is 6.1 GW, a 67-percent increase over the 2022 capacity of 3.6 GW.[2085] Practically all of this is solar energy (5.9 GW), including photovoltaics (5.3 GW) and concentrated solar power (600 MW). The UAE plans to "triple the share of renewable energy by 2030" and reach 19.8 GW of clean energy by 2030 according to the 2023 update of its energy strategy.[2086]

EUROPEAN UNION (EU27)



The EU27 member states have gone through three nuclear construction waves (see Figure 70)—two small ones in the 1960s and the 1970s and a larger one in the 1980s (mainly in France). But over the past 30 years since 1994 only 12 reactors were connected to the grid in current EU27 Member States, five of them in Western Europe—four in France and one in Finland—and seven in Eastern and Central Europe—three in Slovakia, and two each in the Czech Republic and Romania. Only three reactors started up since 2003: after Cernavoda-2 was connected to the grid in Romania in 2007, the following reactor—the long-awaited, many times delayed Olkiluto-3 in Finland—produced its first kilowatt-hours in March 2022, and Mochovce-3 in Slovakia, where construction first started in 1985, was finally connected to the grid in January 2023.

2082 - ENEC, "ENEC launches ADVANCE Program to accelerate decarbonization through advanced nuclear technologies" Press Release, 29 November 2023, see https://www.enec.gov.ae/news/latest-news/enec-launches-advance-program-to-accelerate-decarbonization-through-advanced-nuclear-technologies/, 29 August 2024.

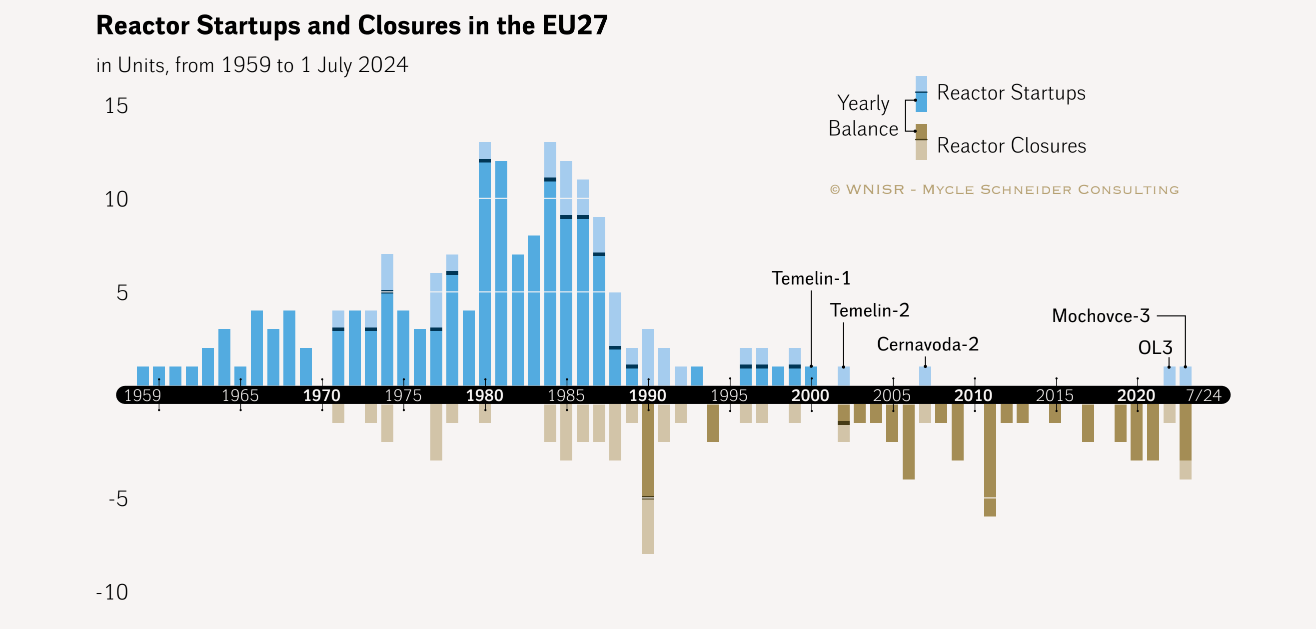
2083 - Energy Institute, "Statistical Review of World Energy 2024 - Data", June 2024, see https://www.energyinst.org/__data/assets/excel_doc/0020/1540550/EI-Stats-Review-All-Data.xlsx, accessed June 2024 .

2084 - Energy Institute, "Statistical Review of World Energy 2024 – Data", June 2024, op. cit.

2085 - IRENA, "Renewable Energy Statistics", 2024, see https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/Jul/IRENA_Renewable_Energy_Statistics_2024.pdf, accessed 1 August 2024.

2086 - Ministry of Energy & Infrastructure, "UAE Energy Strategy 2050", United Arab Emirates Government, 14 August 2023, see https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/strategies-plans-and-visions/environment-and-energy/uae-energy-strategy-2050, accessed 27 August 2023.

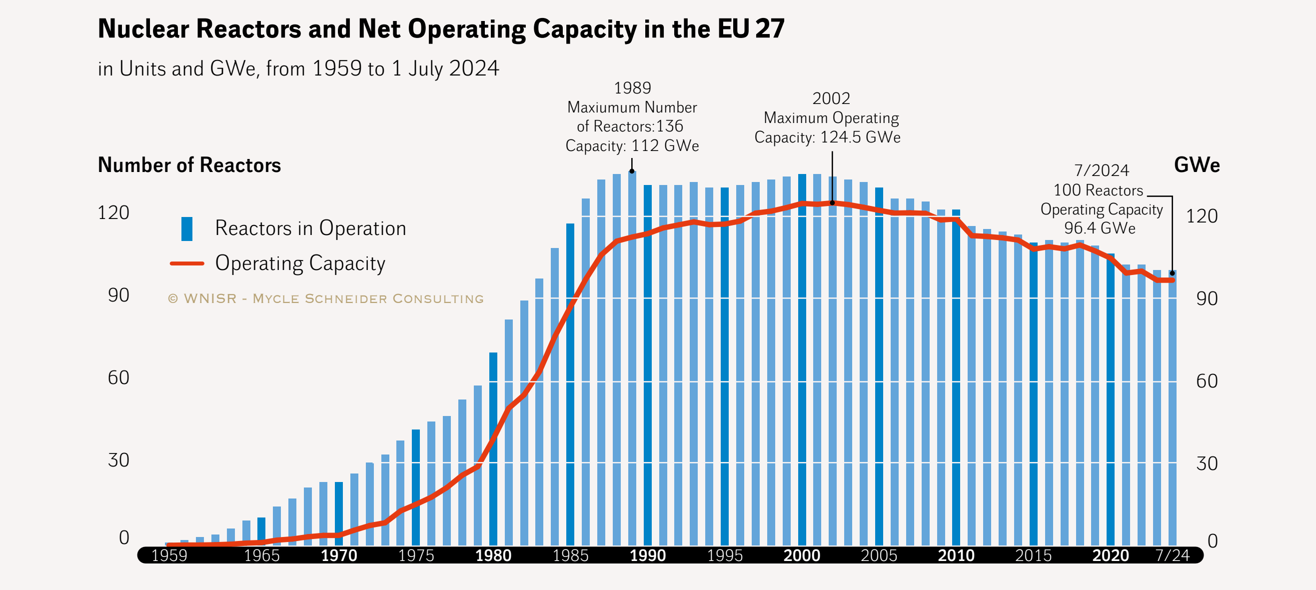
Figure 70 • Nuclear Reactors Startups and Closures in the EU27, 1959–1 July 2024



Sources: WNISR, with IAEA-PRIS, 2024

As Figure 71 shows, 100 reactors are operating in the EU27 as of mid-2024, 36 less than the historic maximum of 136 units in 1989, a drop by over one quarter. Eighty percent of the operating plants are located in six of the western countries—with 56 units in France alone—and only 20 in six newer member states.

Figure 71 • Nuclear Reactors and Net Operating Capacity in the EU27



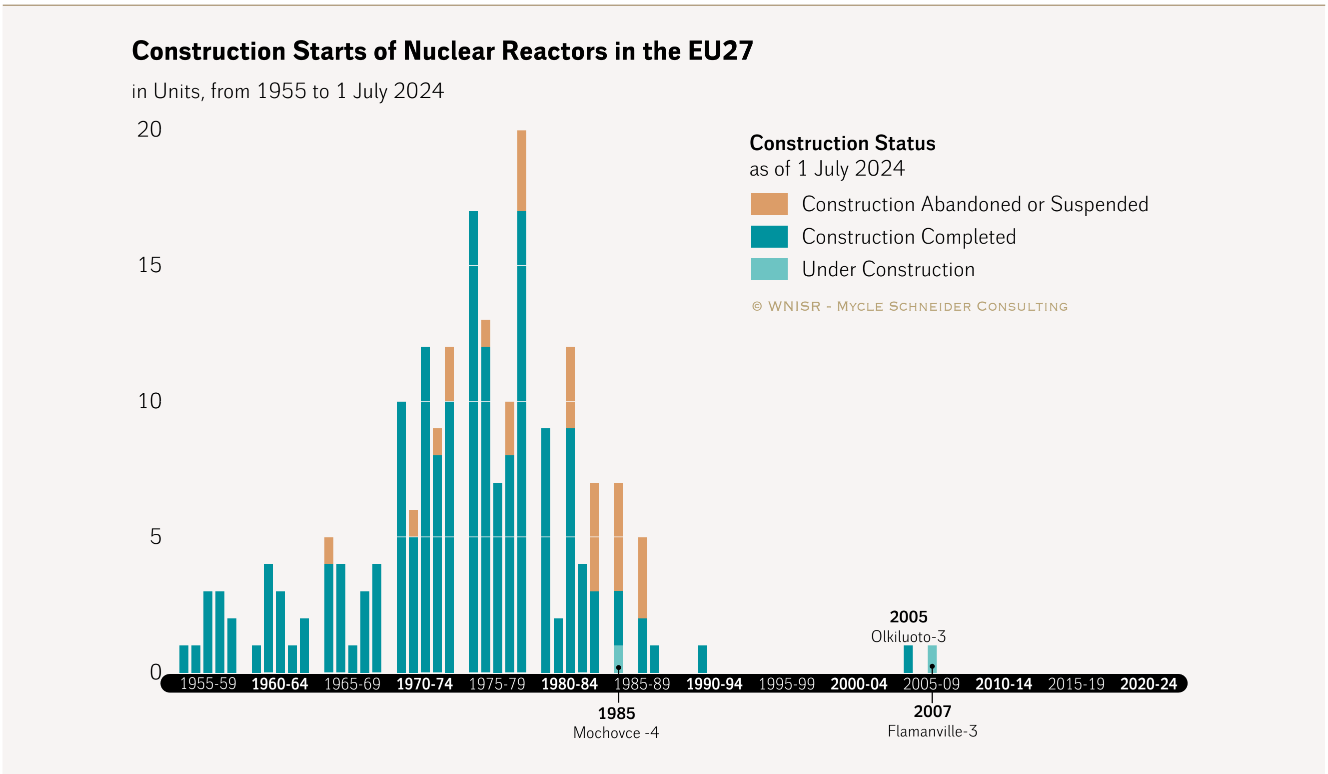
Sources: WNISR, with IAEA-PRIS, 2024

The closures of Tihange-2 in February 2023 in Belgium, and Emsland, Isar-2 and Neckarwestheim-2, all in Germany, in April 2023, brought the number of permanently closed reactors in the EU27 to 77 (68 in Western Europe, over half of which in Germany). Thirty-six units were closed over the past 20 years from 2004 to mid-2024.

In the EU27, in 2023, nuclear plants have generated net 591.3 TWh, an increase of almost 2 percent, compared to the previous year, following a significant percent decrease of 17 percent in 2022.[2087] The Statistical Review of World Energy indicates a 22.6 percent share in gross generation, a slight increase of one percentage point compared to 2022 (21.6 percent).[2088]

Without any significant delivering newbuild program (see Figure 72), the average age of nuclear power plants has increased since the mid-80s and at mid-2024 is 38.2 years (see Figure 73 and Figure 74). Grid connection of Olkiluoto-3 in 2022, and Mochovce-3 in 2023, as well as the two reactors under construction, one in Slovakia (since 1985) and one in France (since 2007), will not significantly impact this evolution.

Figure 72 • Construction Starts of Nuclear Reactors in the EU27



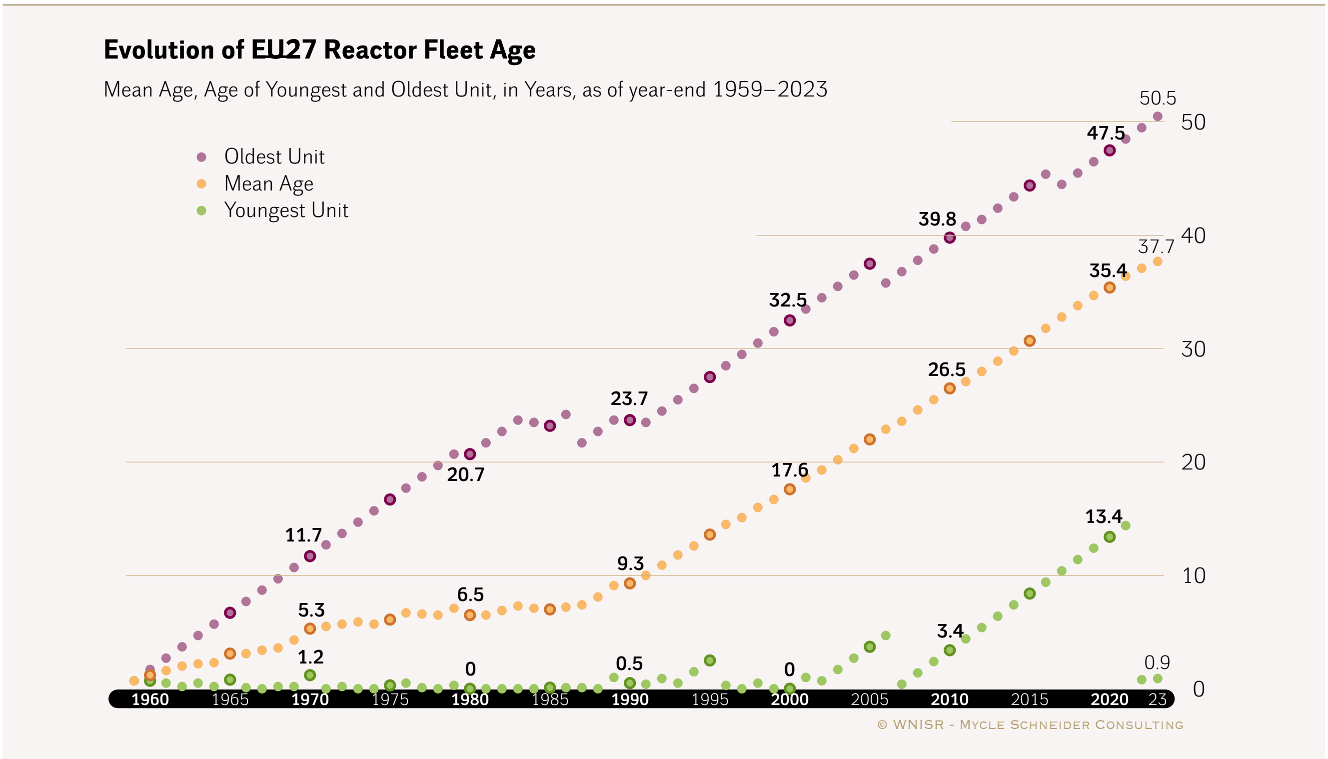
Sources: WNISR, with IAEA-PRIS, 2024

Note: Construction start of Mochovce-3 and -4 was first introduced as of 1985 in IAEA-PRIS, "Nuclear Power Reactors in the World – April 1986 Edition", 1986. Their construction was later suspended. See Slovakia in Annex 1.

2087 - IAEA-PRIS data.

2088 - Energy Institute, "Statistical Review of World Energy – Statistical Workbook", June 2024, op. cit.

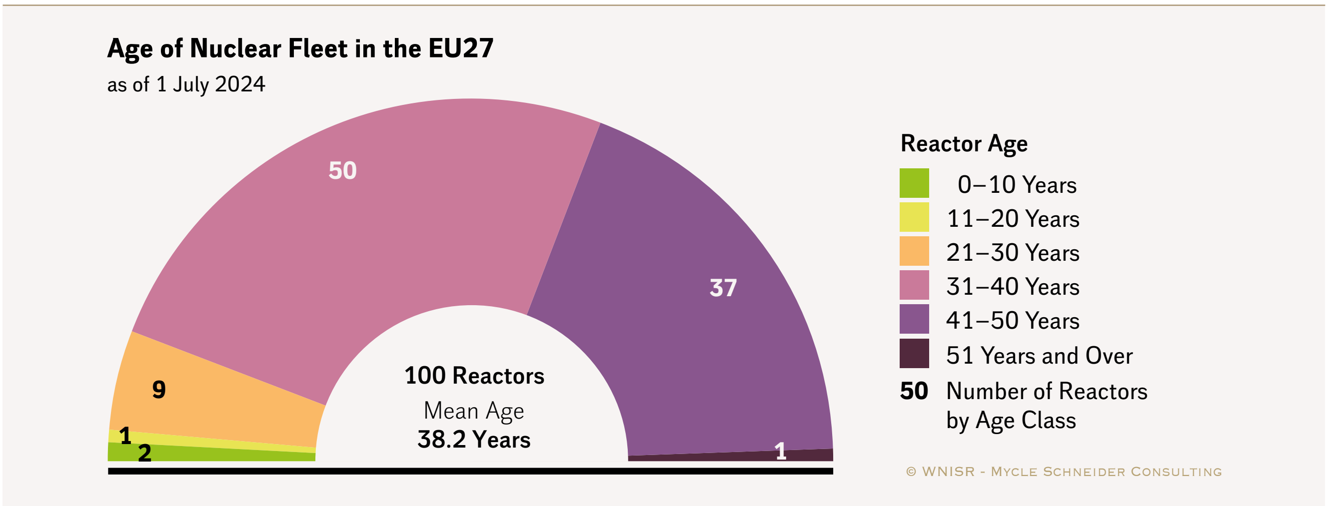
Figure 73 • Age Evolution of EU27 Reactor Fleet, 1959–2023



Sources: WNISR, with IAEA-PRIS, 2024

The age distribution shows that now over 85 percent—88 of 100—of the E.U.'s operating nuclear reactors have been in operation for 31 years and beyond of which 38 have been on the grid for 41 years and more. One reactor, Borssele in the Netherlands, reached 51 years of operation in July 2024.

Figure 74 • Age Distribution of the EU27 Reactor Fleet



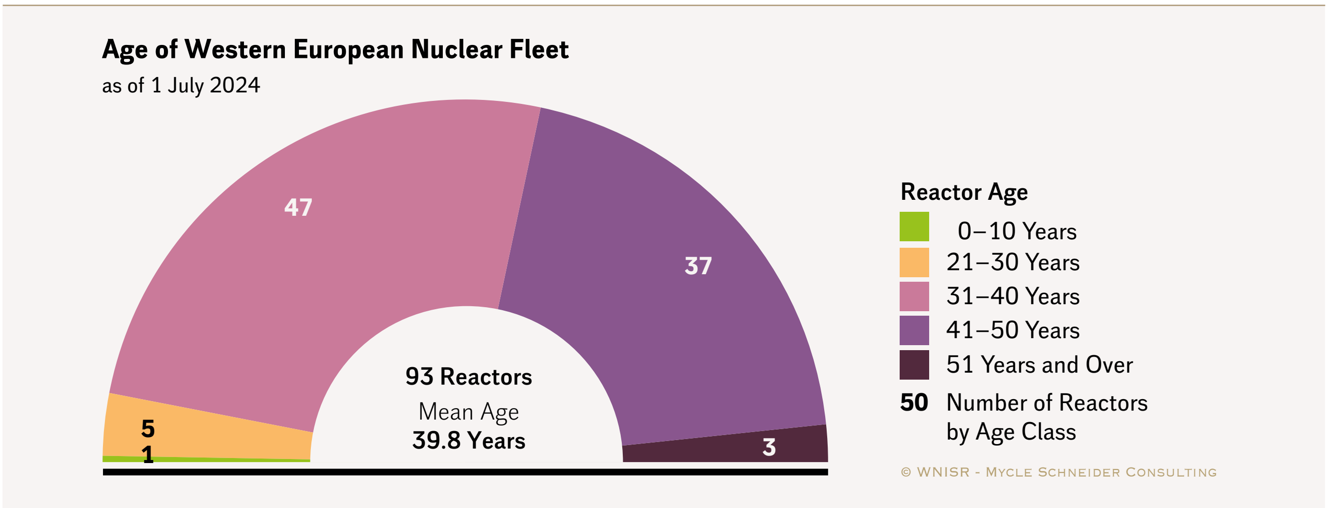
Sources: WNISR, with IAEA-PRIS, 2024

WESTERN EUROPE

As of mid-2024, 93 nuclear power reactors operated in Western Europe (including U.K. and Switzerland), 67 units fewer than in the peak years 1988–89, a 42-percent decline. One reactor was restarted after LTO (Penly-1 in France).

With Switzerland operating two reactors for over 50 years—Beznau-1 (55), Beznau-2 (close to 53)—the average age of operating reactors in Western Europe reaches 39.8 years (see Figure 75).

Figure 75 · Age Distribution of the Western European Reactor Fleet (incl. Switzerland and the U.K.)



Sources: WNISR, with IAEA-PRIS, 2024

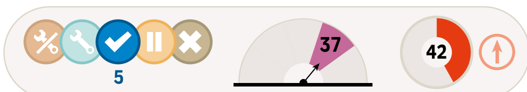
Three reactors are currently under construction, two in the U.K. (Hinkley Point C-1 and C-2) and one in France (Flamanville-3). All are European Pressurized Water Reactors (EPR) and are many years behind their initial schedule and billions of Euros over budget (details are discussed in other chapters of the report).

The mean-age evolution of the nuclear reactor fleet in Western Europe follows the same pattern as the EU27, constantly increasing since the middle of the 1980s. The eventual startup of the three reactors currently under construction will not modify the picture significantly.

Belgium

See Focus Countries – Belgium Focus.

Finland



Nuclear reactors supplied a new record of 32.8 TWh of electricity in Finland. The nuclear share represented 42 percent in 2023, topping the previous peak of 38.4 percent in 1986. Finland has adopted different nuclear technologies and suppliers, as two of its operating reactors are modified VVER-V213 built by Russian contractors at Loviisa, while two others are AAIII, BWR-2500 built by Asea Brown Boveri (ABB) at Olkiluoto. A third technology was recently deployed at the same site, the OL3 European Pressurized Water Reactor (EPR). The original contractor thereof was AREVA-Siemens. AREVA went technically bankrupt, and its reactor construction branch AREVA NP was absorbed by French state-utility EDF.[2089] However, AREVA SA was kept as a state-owned empty shell to deal with the financial liabilities of the project. Siemens quit the nuclear sector in 2011 but remains jointly liable until the end of the guarantee period.

This 1600-MW EPR at Olkiluoto (OL3)—which had been under construction since August 2005 and had originally been scheduled to begin operations in 2009—was finally connected to the grid on 12 March 2022.[2090] Several "unexpected events" during 2022 led to operator TVO (Teollisuuden Voima Oyj) delaying the commercial startup from September to December 2022,[2091] then to February 2023,[2092] until, after more delays, OL3 generated electricity at full capacity for the first time on 16 April 2023, 17.5 years after construction began.[2093] In 2023, OL3 represented about one third of the Finnish nuclear power generation. Refer to previous WNISR editions for a more detailed account of the OL3 construction project.

Europe's largest reactor continued to be pained by technical challenges. For example, the first annual outage in early 2024 was scheduled to last 37 days but, following repeated delays, took twice as long with "about 74 days and 9 hours". The reasons included the "shutdown process and preparations for refueling taking longer than expected" and the identification of several technical issues along the process, such as "foreign material in the fuel elements" requiring further inspection.[2094] Just two weeks after restarting, in June 2024, electricity production was halted again, albeit only for a few hours, because of a turbine malfunction.[2095]

The average age of the other four operating reactors is 45.3 years. In January 2017, operator TVO filed an application for a 20-year license extension for Olkiluoto-1 and -2 (OL1 and OL2), which were connected to the grid in 1978 and 1980 respectively.[2096] In 2018, the government

2089 - Framatome, "Framatome marks the start of operations of the first EPR nuclear reactor in Europe, Olkiluoto 3 operated by TVO", Press Release, 21 December 2021, see https://www.framatome.com/medias/download/?id=6989&n=Framatome-marks-the-start-of-operations-the-first-EPR-nuclear-reactor-Europe-Olkiluoto3-operated-by-TVO-pdf, accessed 4 June 2024.

2090 - WNISR, "Europe's First EPR: 13 Years Behind Schedule, Olkiluoto-3 in Finland Starts Up", World Nuclear Industry Status Report, 25 March 2022, see https://www.worldnuclearreport.org/Europe-s-First-EPR-13-Years-Behind-Schedule-Olkiluoto-3-in-Finland-Starts-Up.html, accessed 27 July 2023.

2091 - TVO, "TVO - Olkiluoto 3 EPR's test production will continue in the end of July", Press Release, Teollisuuden Voima Oyj, 15 June 2022, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2022/olkiluoto3epr8217stestproductionwillcontinueintheendofjuly.html, accessed 22 August 2022.

2092 - TVO, "Olkiluoto 3 EPR's electricity production will continue at the end of December at the earliest", Press Release, 9 December 2022, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2022/olkiluoto3epr8217selectricityproductionwillcontinueattheendofdecemberattheearliest.html, accessed 4 November 2023.

2093 - TVO, "Regular electricity production has started at Olkiluoto 3 EPR", Press Release, 16 April 2023, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2023/regularelectricityproductionhasstartedatolkiluoto3epr.html, accessed 27 July 2023.

2094 - David Dalton, "Finland / Olkiluoto-3 Back Online After Longer Than Scheduled First Outage", *NucNet*, 16 May 2024, see https://www.nucnet.org/news/olkiluoto-3-back-online-after-longer-than-scheduled-first-outage-5-4-2024, accessed 4 June 2024; and TVO, "Olkiluoto 3 annual outage completed", Press Release, 16 May 2024, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2024/4824555.html, accessed 16 June 2024.

2095 - TVO, "Electricity production at Olkiluoto 3 will resume next night", 3 June 2024, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2024/electricityproductionatolkiluoto3willresumenextnight.html, accessed 4 June 2024.

2096 - TVO, "New operating license applied for Olkiluoto 1 and 2 plant units", Press Release, 26 January 2017, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2017/hNRykwgEO.html, accessed 27 July 2023.

approved the lifetime extension for both units to operate until 2038.[2097] While OL2 completed its latest annual maintenance outage with no complications, OL1 experienced delays when the outage was extended from 15 to at least 35 days due to a detected fault in the generator.[2098] Operations finally resumed on 19 June 2024.[2099]

Current contracts with TVEL were set to expire in accordance with former operating licenses, and Fortum had originally planned on continuing to purchase fuel from Russia.

In February 2023, both 507 MW Russian-built reactors at the Loviisa plant were granted operational lifetime extensions until the end of 2050, resulting in 73 and 70 years of planned operation, respectively.[2100] Beginning in 2026, work on the modernization of the low-pressure turbines shall increase the total plant capacity by around 38 MW.[2101] In February 2023, the company indicated that after having already invested €300 million (US$$_{2023}$324 million) into refurbishment over the past five years, it estimates that by 2050, another €1 billion (US$$_{2023}$1.1 billion) will have become necessary for continued operation.[2102]

Fuel for Loviisa has been provided by Russian supplier TVEL (formerly Technopromexport) since the start of operations, with a brief interruption, when British Nuclear Fuel Limited (then the owner of Westinghouse[2103]) supplied fuel for seven reloads from 2001 to 2007.[2104] Current contracts with TVEL were set to expire in accordance with former operating licenses (2027 and 2030, respectively), and Fortum had originally planned on continuing to purchase fuel from Russia. Early November 2022, Matti Kattainen, Fortum's Head of Nuclear Power, said that they would "look at who's the most suitable fuel supplier at the latest when the current contract expires."[2105] A few weeks later, Fortum announced that an agreement had been signed with Westinghouse "for the design, licensing, and supply of a new fuel type" for Loviisa, but

2097 - TVO, "Finnish Government approves extension of operating licences for OL1 and OL2 plant units", Press Release, 20 September 2018, see https://www.tvo.fi/news/2043, accessed 25 October 2018.

2098 - TVO, "Annual outages progress at Olkiluoto plant units – maintenance starts at Olkiluoto 2 on Sunday", Press Release, 26 April 2024, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2024/4806181.html; and TVO, "Annual outage of Olkiluoto 1 extended due to fault detected in generator", Press Release, 25 May 2024, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2024/4832086.html, accessed 4 June 2024.

2099 - TVO, "Olkiluoto 1 returns to electricity production upon completion of annual outages", Press Release, 19 June 2024, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2024/4853399.html, accessed 2 July 2024.

2100 - Ministry of Economic Affairs and Employment, "Fortum granted licence to operate Loviisa power plant units until end of 2050", Press Release, Government of Finland, 16 February 2023, see https://valtioneuvosto.fi/en/-/1410877/fortum-granted-licence-to-operate-loviisa-power-plant-units-until-end-of-2050, accessed 16 June 2024.

2101 - Aaron Larson, "Upgrades Planned at Loviisa Nuclear Power Plant as Part of Life Extension", *POWER Magazine*, 29 May 2024, see https://www.powermag.com/upgrades-planned-at-loviisa-nuclear-power-plant-as-part-of-life-extension/, accessed 4 June 2024.

2102 - Fortum, "The Finnish Government has granted a new operating licence for Fortum's Loviisa nuclear power plant", 16 February 2023, see https://www.fortum.com/media/2023/02/finnish-government-has-granted-new-operating-licence-fortums-loviisa-nuclear-power-plant, accessed 27 July 2023.

2103 - Christopher Rhodes, David Hough and Louise Butcher, "Privatisation", Research Paper 14/61, House of Commons Library, UK Parliament, November 2014, see https://commonslibrary.parliament.uk/research-briefings/rp14-61/, accessed 4 November 2023.

2104 - Heidi Lindroth, "Operational experience of Loviisa Nuclear Fuel and Long-term refuelling strategy", Fortum Power and Heat Oy, presented at the 10th International conference on WWER fuel performance, modelling and experimental support, 7–14 September 2013, 11 January 2013, see https://inis.iaea.org/collection/NCLCollectionStore/_Public/44/122/44122435.pdf, accessed 3 August 2023.

2105 - *NEI Magazine*, "Fortum will use Russian nuclear fuel until 2030", 10 November 2022, see https://www.neimagazine.com/news/newsfortum-will-use-russian-nuclear-fuel-until-2030-10284929, accessed 3 January 2023.

reiterated that a tendering process for the fuel supply succeeding the current contract with TVEL would be launched at a later stage.[2106]

Fortum proceeded to pull out of the Russian market, and attempted to sell its Russian assets, but had to write off a total of US$1.9 billion in May 2023 after the assets had been seized by Russian authorities.[2107]

Lifetime extension at Loviisa was granted under the condition that Fortum reports on its "procurement arrangements for the new nuclear fuel" by 31 December 2023.[2108] In January 2024, Finnish Environment and Climate Minister Kai Mykkänen said that Fortum was going to use up its Russian-delivered fuel stock at Loviisa prior to switching to a western supplier,[2109] and Fortum indicated it was planning a tender for fuel production for when the delivery contracts with TVEL ended, i.e. 2027 and 2030.[2110] Meanwhile, Fortum loaded a Westinghouse test fuel element into one of the reactors in 2023.[2111] In January 2024, Fortum said it was also "explor[ing] the capabilities of another [W]estern fuel supplier."[2112]

The Cancelled Hanhikivi Project

In 2013, Finnish company Fennovoima, of which Rosatom holds a 34 percent stake via its subsidiary company RAOS Voima Oy,[2113] announced the construction plan of a 1200 MW AES-2006 reactor for the Hanhikivi plant in Pyhäjoki with first grid connection envisioned for 2024.[2114] One year later, a "binding decision to construct" the Hanhikivi-1 reactor was announced.[2115] It took until 2021 for a construction license to be filed, according to which work was planned to begin in 2023, with commercial operation expected by 2029.[2116] However, following Russia's full-scale invasion of Ukraine, Fennovoima announced on 2 May 2022 that the contract of plant delivery and cooperation for Hanhikivi-1 had been terminated "with

2106 - Fortum, "Fortum and Westinghouse Electric Company sign an agreement for the design and supply of a new fuel type for the Loviisa power plant", Press Release, 22 November 2022, see https://www.fortum.com/media/2022/11/fortum-and-westinghouse-electric-company-sign-agreement-design-and-supply-new-fuel-type-loviisa-power-plant, accessed 27 July 2023.

2107 - Louise Breusch Rasmussen, "Fortum to write off $1.9 billion after Russia seized assets", *Reuters*, 11 May 2023, see https://www.reuters.com/business/energy/fortums-q1-core-profit-beats-estimates-2023-05-11/, accessed 3 August 2023.

2108 - Ministry of Economic Affairs and Employment, "Fortum granted licence to operate Loviisa power plant units until end of 2050", 16 February 2023, op. cit.

2109 - *YLE News*, "Minister: Loviisa plant cuts dependence on Russian nuclear fuel", 13 January 2024, see https://yle.fi/a/74-20069301, accessed 4 June 2024.

2110 - *NEI Magazine*, "Fortum plans tender for Loviisa fuel supplier", *Nuclear Engineering International*, 3 January 2024, see https://www.neimagazine.com/news/fortum-plans-tender-for-loviisa-fuel-supplier-11409055/, accessed 4 June 2024.

2111 - Fortum, "Fortum's Loviisa nuclear power plant generated 8.09 terawatt-hours of carbon-free electricity in 2023", Press Release, 4 January 2024, see https://www.fortum.com/media/2024/01/fortums-loviisa-nuclear-power-plant-generated-809-terawatt-hours-carbon-free-electricity-2023, accessed 4 June 2024.

2112 - Fortum, "Fortum's Loviisa nuclear power plant generated 8.09 terawatt-hours of carbon-free electricity in 2023", Press Release, 4 January 2024, see https://www.fortum.com/media/2024/01/fortums-loviisa-nuclear-power-plant-generated-809-terawatt-hours-carbon-free-electricity-2023, accessed 4 June 2024.

2113 - Fennovoima, "Rosatom Acquired 34% Share of Fennovoima", Press Release, 27 March 2014.

2114 - *NEI Magazine*, "Fennovoima/Rosatom target 2024 start-up for Hanhikivi", *Nuclear Engineering International*, 3 September 2013, see https://www.neimagazine.com/news/fennovoimarosatom-target-2024-start-up-for-hanhikivi/, accessed 4 June 2024.

2115 - David Dalton, "Fennovoima Owners Make Binding Decision To Proceed With Hanhikivi-1", *NucNet*, 15 April 2014, see https://www.nucnet.org/news/fennovoima-owners-make-binding-decision-to-proceed-with-hanhikivi-1, accessed 25 May 2022.

2116 - Fennovoima, "Fennovoima updates the Construction License Application", Press Release, 28 April 2021.

immediate effect".[2117] The contract cancellation will no doubt lead to a lengthy legal battle between stakeholders. Head of Rosatom, Alexey Likhachev, said that "all the money that was spent in Finland will be billed" and that Rosatom "will take legal steps."[2118] By August 2022, Rosatom said it had filed six lawsuits totaling US$3 billion, and Fennovoima had countered with several filings adding up to €2 billion (US$$_{2022}$2.1 billion).[2119] In December 2022, an independent dispute review board—a standard element of contracts for large-scale projects—concluded that contract termination had been unlawful. Fennovoima acknowledged the board's recommendation but emphasized that it was "neither final nor binding."[2120]

Over the course of 2023, Fennovoima wrote-off the value of the land that had been dedicated to the project and reported a loss of €800 million (US$$_{2023}$865 million) for the financial year. Most of the staff was terminated. In early 2024, Fennovoima acquired RAOS' shares in the property and plans to sell it off.[2121] Furthermore, an additional lawsuit was filed to the District Court of Helsinki regarding the reduction of Rosatom's stake to only 2 percent of the company's share via capital stock increase.[2122] In February 2024, Likhachev was quoted by Russian news agencies *Interfax* and *TASS* announcing that an arbitration board in Paris had sided with Rosatom, which was promptly countered by Fennovoima CEO Matti Suurnäkki who said that there was no litigation happening in Paris, and that the case of the Hanhikivi project was being disputed before the International Chamber of Commerce in Stockholm. A final ruling was not to be expected for another six months.[2123] The exact nature of the current litigation remains opaque, as such boards normally operate behind closed doors.

New Projects, SMRs – An Avalanche of MoUs, No Binding Contracts

Despite the challenges of the OL3 and Hanhikivi-1 projects, some Finnish utilities are envisioning further nuclear power expansions. In 2022 and 2023, a flurry of studies were initiated and numerous MoUs signed (see section on Finland in WNISR2023). A further MoU was signed in November 2023 between Fortum and Swedish nuclear technology company Studsvik to "assess the potential to construct small modular reactors (SMR) or conventional

2117 - Fennovoima, "Fennovoima has terminated the contract for the delivery of the Hanhikivi 1 nuclear power plant with Rosatom", Press Release, 2 May 2022.

2118 - Thomas Nilsen, "Rosatom wants to get back its investment in Finnish not-to-be-built NPP", *The Barents Observer*, 24 June 2022, see https://thebarentsobserver.com/en/nuclear-safety/2022/06/rosatom-wants-get-back-its-investment-finnish-not-be-built-npp, accessed 27 June 2023.

2119 - Anne Kauranen, "UPDATE 2-Rosatom and Finnish partner in dispute for damages for nuclear project", *Reuters*, 23 August 2022, see https://www.reuters.com/article/finland-russia-nuclearpower-idUSL8N2ZZ177, accessed 27 July 2023.

2120 - David Dalton, "Contract Cancellation Was Unlawful, Says Independent Review Board", *NucNet*, 16 December 2022, see https://www.nucnet.org/news/contract-cancellation-was-unlawful-says-independent-review-board-12-5-2022, accessed 3 August 2023.

2121 - Risto Degerman and Essi Markkula, "Yhteistyö venäläisrakentajan kanssa päättyi Hanhikivellä, ja nyt Fennovoima valmistautuu myymään alueen", *Yle*, 31 May 2024 (in Finnish), see https://yle.fi/a/74-20091664, accessed 17 June 2024.

2122 - Markku Uhari, "Fennovoima halusi Rosatomilta ydinvoimalan mutta sai miljardien oikeussotkut – nyt voimalan alueelle nousee vain heinää", *Helsingin Sanomat*, 14 October 2023 (in Finnish), see https://www.hs.fi/talous/art-2000009923118.html, accessed 4 June 2024.

2123 - *TASS*, "Paris Arbitration considers Finland's rejection of Hanhikivi project ungrounded — Rosatom", 26 February 2024, see https://tass.com/economy/1751823, accessed 17 June 2024; and Liisa Niemi, "Fennovoima kiistää Rosatomin väitteet Hanhikivi-ratkaisusta – 'ei ole olemassa minkäänlaista päätöstä'", *Helsingin Sanomat*, 27 February 2024 (in Finnish), see https://www.hs.fi/talous/art-2000010256328.html, accessed 4 June 2024.

large reactors at the Studsvik site outside Nyköping in Sweden."[2124] None of these MoUs are binding, and no indications until when potential investment decisions are to be expected have been specified.

In early 2024, Fortum launched a pre-licensing dialogue with the Finnish nuclear safety authority while it was reviewing the potential of several sites for new nuclear capacity, both "small and large". However, Fortum Vice-President Laurent Leveugle pointed out that the company was "unlikely to embark on a first-of-a-kind facility".[2125] This statement places doubts on Finnish SMR construction to begin anytime soon, as most companies with whom MoUs have been signed remain far from building their first reactors and none have any operational experience (see chapter on SMRs).

Since the Russian invasion of Ukraine, Finland has been under increased pressure regarding power and gas supply.

In February 2024, Fortum and TVO announced that under a two-year framework agreement, they were going to support Polish state-owned company PEJ in the "development of operation and maintenance processes" for the planned Westinghouse project in Pomerania (see Poland Focus).[2126]

Since the Russian invasion of Ukraine, Finland has been under increased pressure regarding power and gas supply. In May 2022, Russia cut power exports to Finland because Finnish utilities had not paid for delivery after sanctions put restrictions on payment methods. This led to drastic wholesale price increases in the short term.[2127] Russia also cut natural gas flows in the same month.[2128] In October 2023, it was revealed that the Baltic-connector pipeline, Finland's only gas connection to the European mainland via Estonia, had been damaged by "mechanical force". Suspicion amounted that this might have been caused by Russia as "retribution for Finland joining NATO" in April 2023.[2129] The pipeline was repaired in Spring 2024, and Finland has replaced its gas supply with mostly Western LNG deliveries. However, as of June 2024, two terminals were still receiving LNG deliveries from Russia.[2130] The long-awaited operation of

2124 - Fortum "Fortum and Studsvik partner to explore possibilities for new nuclear in Sweden", Press Release, 17 November 2023, see https://www.fortum.com/media/2023/11/fortum-and-studsvik-partner-explore-possibilities-new-nuclear-sweden, accessed 17 June 2024.

2125 - Anne Kauranen, "Fortum considers Nordic sites for new nuclear power", *Reuters*, 22 January 2024, see https://www.reuters.com/business/energy/fortum-considers-nordic-sites-new-nuclear-power-2024-01-22/, accessed 1 February 2024.

2126 - Fortum, "Fortum and TVO to provide expert services for Poland's nuclear power program", Press Release, 13 February 2024, see https://www.fortum.com/media/2024/02/fortum-and-tvo-provide-expert-services-polands-nuclear-power-program; and TVO, "TVO and Fortum to provide expert services for Poland's nuclear power program", Press Release, 13 February 2024, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2024/4748865.html; both accessed 17 June 2024.

2127 - Gwladys Fouche and Nora Buli, "Russia cuts power exports to Finland over failed payments", *Reuters*, 16 May 2022, see https://www.reuters.com/markets/europe/russia-cuts-power-exports-finland-over-failed-payments-2022-05-16/, accessed 27 July 2023.

2128 - Terje Solsvik, "Russia stops gas flows to Finland over payments dispute", *Reuters*, 21 May 2022, see https://www.reuters.com/business/energy/russia-stops-finland-gas-flow-over-payments-dispute-2022-05-21/, accessed 27 July 2023.

2129 - *BBC*, "Putin denies Russia behind Finland gas pipeline damage", 13 October 2023, see https://www.bbc.com/news/world-europe-67106799, accessed 4 June 2024.

2130 - Riku Huttunen, "Phasing out Russian gas will continue – EU prepares for the coming winter", Director General, Energy Department, Ministry of Economic Affairs and Employment, Government of Finland, 7 June 2024, see https://valtioneuvosto.fi/en/-/1410877/phasing-out-russian-gas-will-continue-eu-prepares-for-the-coming-winter, accessed 2 July 2024.

OL3 has relieved Finnish power supply from some of this external pressure,[2131] with electricity prices having returned to pre-pandemic levels.[2132]

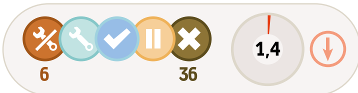
Finland produced a total of 79.8 TWh (gross) of electricity in 2023. Nuclear power had the highest share at 42.5 percent, followed by hydro (18.9 percent), wind (18.3 percent), biomass (13.9 percent), coal (2 percent), and other fossil fuels (2.9 percent). Solar had overtaken gas, with 0.81 and 0.66 percent, respectively.[2133]

In the past, Finland was a net importer of electricity, mainly from Russia and Sweden, and now plans to become a net exporter by 2030.[2134] Electricity imports have already substantially dropped from 12.5 TWh in 2022 to 1.8 TWh in 2023. The development of wind power capacity has had a substantial part in Finnish renewables capacity expansion, growing 15-fold over the past decade from 453 MW to nearly 7 GW in 2023.[2135] Finland plans to fully decarbonize its energy system by 2035, aiming for significantly increased renewable power generation.[2136] Compared to 2020 values, by 2035 wind power generation is to increase more than 5-fold, from 8.2 TWh to over 46 TWh, and solar generation shall rise to roughly 7 TWh from only 0.2 TWh. For 2040, the plan envisions a nuclear share of around 30 percent, with absolute electricity generation increasing to close to 37 TWh in 2025 and then remaining roughly the same, compared to 23 TWh in 2020. Wind power is to cover roughly 40 percent. Biomass and hydro shall account for 10 and 12 percent, respectively, the remainder covered mostly by solar PV.[2137]

France

See Focus Countries – France Focus.

Germany



On 15 April 2023, Germany's last three nuclear power reactors Emsland, Neckarwestheim-2, and Isar-2 were disconnected from the grid after their lifetime had been extended by three months via a so-called "stretch mode operation" ("Streckbetrieb") in the wake of the energy crisis that had been caused by Russia's invasion of Ukraine and an unprecedented drop in French nuclear output. This decision had followed a controversial and heated political debate

2131 - TVO, "Reasons why Olkiluoto 3 is so significant", Press Release, Teollisuuden Voima Oyj, 8 May 2023, see https://www.tvo.fi/en/index/news/pressreleasesstockexchangereleases/2023/reasonswhyolkiluoto3issosignificant.html, accessed 3 August 2023.

2132 - Finnish Energy, "Energy Year 2023 - Electricity", January 2024, Updated 22 February 2024, see https://energia.fi/wp-content/uploads/2024/02/Electricity-Year-2023_updated-22022024.pdf, accessed 4 June 2024.

2133 - Ember, "Electricity Data Explorer—Finland electricity generation by source", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 4 June 2024.

2134 - IEA, "Finland 2023 Energy Policy Review", International Energy Agency, 2023, see https://www.oecd-ilibrary.org/energy/finland-2023-energy-policy-review_d435fa51-en, accessed 27 July 2023.

2135 - Finnish Energy, "Energy Year 2023 - Electricity", January 2024, Updated 22 February 2024, op. cit.

2136 - Ministry of Economic Affairs and Employment, "Finland's Integrated National Energy and Climate Plan Update", Government of Finland, June 2024, see https://commission.europa.eu/document/download/069886e9-7a50-4df1-b523-9eb7bf7308c3_en?filename=FI_FINAL%20UPDATED%20NECP%202021-2030%20%28English%29.pdf, accessed 2 July 2024.

2137 - Ministry of Economic Affairs and Employment, "Finland's Integrated National Energy and Climate Plan Update—Annex 1—Reporting of used parameters and variables included in Annex 1, part 2, of the Energy Union Governance as agreed in trilogue", Government of Finland, 2024, see https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/165742/Annex_02_Finland_NECP_2024_parameters.xlsx?sequence=3&isAllowed=y, accessed 2 July 2024.

over the course of 2022 (see Germany Focus—An Unexpected Debate Over Potential Lifetime Extensions in WNISR2023 for details).[2138] The closure means that Germany has ceased the commercial operation of nuclear power plants (see Table 17) and will now have to deal with the decommissioning of its reactor fleet. An overview of currently ongoing decommissioning work in Germany is provided in the Decommissioning Status Report.

After Germany's withdrawal from commercial nuclear power plant operations, the debate on nuclear power is still ongoing. Over the course of the year 2023, conservatives such as Christian Democrat Jens Spahn (CDU) claimed that due to the closure of the three plants, Germany would now have to bring multiple coal power plants back to the grid, and that the current "traffic light" (Ampel) coalition, consisting of Social Democrats (SPD, red), liberals (FDP, yellow), and the Green Party, would now be a "coal-coalition" instead of working to combat climate change.[2139] Additionally, commentators said that Germany would now be importing electricity produced from nuclear power plants in France, implying that nothing had been gained (in terms of reducing "nuclear power production") by taking the German plants off the grid.[2140] In its new program, the Christian Democrats (CDU) party, currently in opposition, says (twice) that Germany "presently cannot afford to abstain from the nuclear power option". However, they do not allude to current reactor designs but "nuclear power plants of the fourth and fifth generation", and state "we want to build the world's first fusion reactor", all in the framework of "technology openness".[2141]

In reality, German lignite power plant production had indeed temporarily increased after the Russian invasion of Ukraine (+6 percent in 2022), also due to the strongly reduced production from French nuclear power plants and increased exports to France[2142] (see France Focus in WNISR2023), but it has fallen in 2023 by 27 percent year-on-year to levels last seen in 1963. Electricity generation from hard coal fell by 35 percent to 1955-levels, while natural gas consumption for electricity production fell by 1.7 percent year-on-year.[2143] Renewables are now providing more than half of German electricity production[2144] (see Figure 76).

2138 - Laura Bisch, "Wo Deutschland nach einem Jahr ohne Atomkraft steht", *tagesschau.de*, 15 April 2024, see https://www.tagesschau.de/faktenfinder/ein-jahr-atomausstieg-deutschland-100.html, accessed 5 June 2024.

2139 - Jens Spahn, Member of the German Bundestag, on X (formerly Twitter), 19 June 2023, see https://x.com/jensspahn/status/1670747460174598146, accessed 5 June 2024.

2140 - Sarah Vojta, "Energie: Deutschland muss nach Atomausstieg mehr Strom zukaufen", *Die Zeit* with *dpa*, 6 September 2023 (in German), see https://www.zeit.de/wirtschaft/2023-09/atomausstieg-energiemix-importueberschuss; and Ellie Harmsworth, "France Is Europe's Top Power Exporter as Germany Turns Importer", *Bloomberg.com*, 7 August 2023, see https://www.bloomberg.com/news/articles/2023-08-07/france-is-europe-s-top-power-exporter-as-germany-turns-importer; both accessed 5 June 2024.

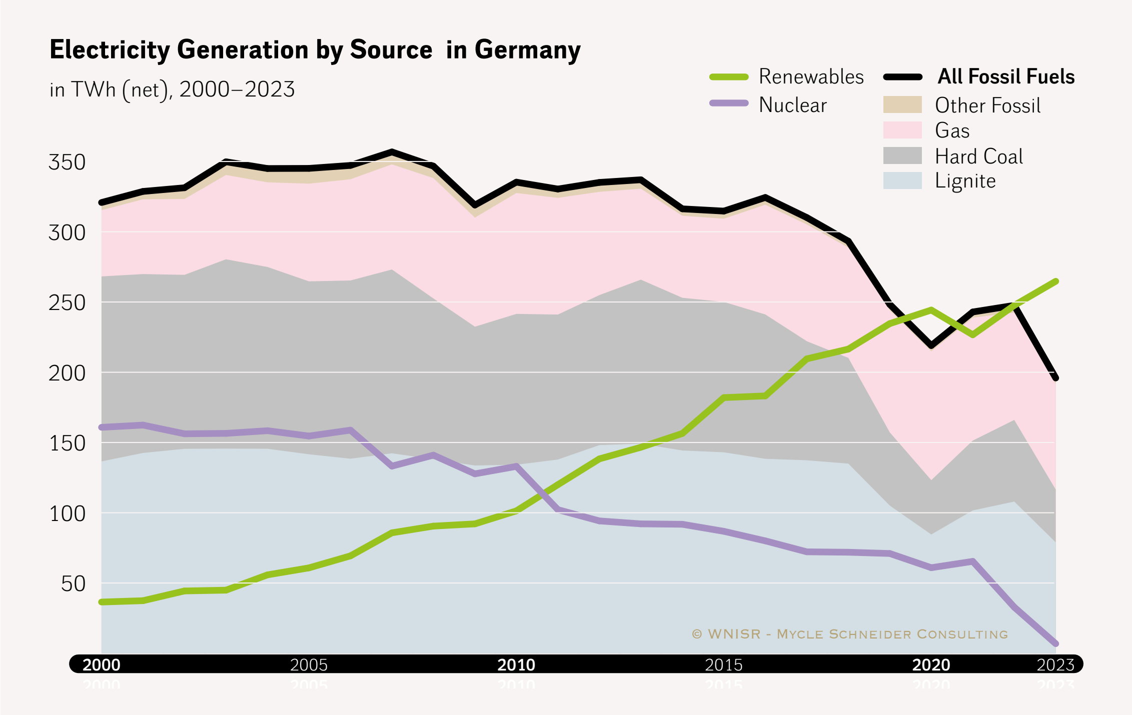
2141 - CDU, "In Freiheit leben—Deutschland sicher in die Zukunft führen—Grundsatzprogramm der CDU Deutschlands", Manifesto, Christlich Demokratische Union Deutschlands/Christian Democratic Union of Germany, adopted 7 May 2024, see https://assets.ctfassets.net/nwwnl7ifahow/5CgMnK71ags88lqIxtkCB5/66e14b4cc6a1207a4a5e4da169e46a33/240507_CDU_GSP_2024_Beschluss_Parteitag_FINAL.pdf, accessed 19 July 2024.

2142 - Vera Eckert and Tom Sims, "Even in crisis, Germany extends power exports to neighbours", *Reuters*, 5 January 2023, see https://www.reuters.com/business/energy/even-crisis-germany-extends-power-exports-neighbours-2023-01-05/; and Bruno Burger, "Stromerzeugung in Deutschland im Jahr 2023", Fraunhofer ISE, 2 January 2024, Updated 22 February 2024 (in German), see https://www.energy-charts.info/downloads/Stromerzeugung_2023.pdf; both accessed 5 June 2024.

2143 - Bruno Burger, "Stromerzeugung in Deutschland im Jahr 2023", Fraunhofer ISE, Updated 22 February 2024, op. cit.

2144 - AGEB, "Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2023 (in TWh), Deutschland insgesamt", AG Energiebilanzen e.V., February 2024 (in German), see https://ag-energiebilanzen.de/wp-content/uploads/2024/04/STRERZ_Abg_02_2024_korr.pdf, accessed 5 June 2024.

Figure 76 · Electricity Generation by Source in Germany, 2000–2023



Source: AGEB, 2024

Increased electricity imports from France are not a sign of a lack of capacity in Germany. They are rather a sign that the European energy market is functioning as intended, i.e., in the most cost-efficient manner. In 2023, electricity imports occurred mainly during the summer months, when overall electricity demand is lower than in winter, supply from renewables is high, and non-fossil generation technologies are cheaper than German fossil power plants.[2145] Additionally, Federal grid regulator Bundesnetzagentur said in a statement to German news agency *tagesschau.de* that installed reserve capacity would suffice and could cover domestic supply without imports at any given time.[2146]

In April 2024, conservative media outlet *Cicero* published an article in which accusations were made against Energy and Climate Minister Robert Habeck of the Green party, alleging that he had "imposed" the closure of the three remaining plants against internal opinions in the ministry itself, that all three plants could have been kept on the grid, and that experts had been ignored. The publication, pointing to internal documents, accused green officials from various ministries of deception, manipulation and falsification to withhold information from Habeck.[2147] In a first parliamentary hearing held the next day by the Climate Protection and Energy Committee, Habeck referred to the operator's notices of lack of fuel and challenges related to the short-term acquisition thereof to justify the decision to phaseout, and dismissed

2145 - Agora Energiewende, "Die Energiewende in Deutschland: Stand der Dinge 2023—Rückblick auf die wesentlichen Entwicklungen sowie Ausblick auf 2024", January 2024 (in German), see https://www.agora-energiewende.de/fileadmin/Projekte/2023/2023-35_DE_JAW23/A-EW_317_JAW23_WEB.pdf, accessed 5 June 2024.

2146 - Laura Bisch, "Wo Deutschland nach einem Jahr ohne Atomkraft steht", *tagesschau.de*, 15 April 2024, op. cit.

2147 - Daniel Gräber, "Wie die Grünen beim Atomausstieg getäuscht haben", *Cicero*, 25 April 2024 (in German), see https://www.cicero.de/innenpolitik/robert-habeck-akten-atomkraftwerke-kernkraftwerke-klage-akw-laufzeit-atomausstieg, accessed 5 June 2024.

any claims of public deception.[2148] At least two of the three operators confirmed their initial statements of "judicial and economic risks" and that the restart of either reactor was no option under the given conditions.[2149] Conservative opposition parties CDU and CSU (Christian Social Union), which in 2011 had initiated the phaseout policy together with the liberal party FDP, said that Habeck had followed "Green party logic" (implicitly against better judgement) instead of pursuing public interest[2150] and formally requested a parliamentary inquiry on the matter in June 2024,[2151] for which a committee was formed in early July 2024.[2152] All relevant documents are to be provided to the committee.[2153] Early on, upon scrutiny of the material released by *Cicero*, some voices emerged claiming the issue to be a fabricated "right-wing pseudo-scandal".[2154]

CDU party leader Friedrich Merz appears to have led the entire episode ad absurdum stating at a conference held at the German Association of the Water and Energy Industry (BDEW) in June 2024 that the party would no longer attempt to reignite a "nuclear renaissance" in Germany.[2155]

Nuclear Power, Renewables, Fossil Fuels, and Efficiency

In 2023, the "stretch mode operation" resulted in a total of 6.8 TWh of electricity being produced from nuclear until mid-April. In 2022, the same fleet had generated 32.8 TWh, a fraction of the peak generation of 162.4 TWh in 2001. Nuclear plants provided 1.4 percent of Germany's gross electricity production in 2023, compared to the historic maximum of 35.6 percent in 1999.[2156]

In 2023, renewables–including hydro–generated a record 264.8 TWh (net), a significant 6.9 percent-increase over the previous year. Solar and wind alone produced 199 TWh. The share of renewables now lies well above half of gross electricity generation at 54.8 percent.[2157] Some

2148 - *Heute im bundestag*, "Habeck: 'Vermerke wurden nicht ins Gegenteil verkehrt'", Deutscher Bundestag, 26 April 2024 (in German), see https://www.bundestag.de/presse/hib/kurzmeldungen-1000520, accessed 21 July 2024.

2149 - *Süddeutsche Zeitung*, "Betreiber meldet endgültiges Aus für die Anlage", 26 October 2023 (in German), see https://www.sueddeutsche.de/bayern/essenbach-atomkraftwerk-isar-2-atomausstieg-1.6293926; and Sebastian Scheffel, "Habeck kontert Vorwürfe zu Atom-Akten: „Es ist nichts verheimlicht worden"", *FOCUS online*, 26 April 2024 (in German), see https://www.focus.de/politik/deutschland/cdu-mann-zu-atom-akten-jetzt-muessen-wir-den-akw-rueckbau-stoppen_id_259886215.html; both accessed 5 June 2024.

2150 - *Tagesschau*, "Union will Atomausstieg in U-Ausschuss aufarbeiten", *tagesschau.de*, 4 June 2024 (in German), see https://www.tagesschau.de/inland/innenpolitik/atomausstieg-u-ausschuss-beantragt-100.html, accessed 5 June 2024.

2151 - Friedrich Merz, Alexander Dobrindt et al., "Drucksache 20/11731—Antrag—Einsetzung des 2. Untersuchungsausschusses der 20. Wahlperiode", 11 June 2024 (in German), see https://dserver.bundestag.de/btd/20/117/2011731.pdf, accessed 21 July 2024.

2152 - Deutscher Bundestag, "Untersuchungsausschuss zum Atomausstieg hat sich konstituiert", July 2024 (in German), see https://www.bundestag.de/dokumente/textarchiv/2024/kw27-pa-2-untersuchungsausschuss-1011506, accessed 21 July 2024.

2153 - *Der Spiegel*, "Habeck will Akten zum Atomausstieg herausgeben", 1 May 2024 (in German), see https://www.spiegel.de/politik/deutschland/robert-habeck-akten-zum-atomausstieg-sollen-dem-bundestagsausschuss-zur-verfuegung-gestellt-werden-a-558eaf2d-485c-449c-a96f-3cdd9dc24475, accessed 5 June 2024.

2154 - Thomas Laschyk and Philip Kreißel, "Habeck hat nichts falsch gemacht: Der rechte Pseudo-Skandal 'AKW-Files'", *Volksverpetzer*, 26 April 2024 (in German), see https://www.volksverpetzer.de/faktencheck/habeck-rechte-pseudo-skandal-akw-files/, accessed 5 June 2024.

2155 - Horand Knaup, "Kernkraft: Auch die CDU verabschiedet sich", *Table Briefings*, 6 June 2024 (in German), see https://table.media/berlin/news/kernkraft-auch-die-cdu-verabschiedet-sich/, accessed 21 July 2024.

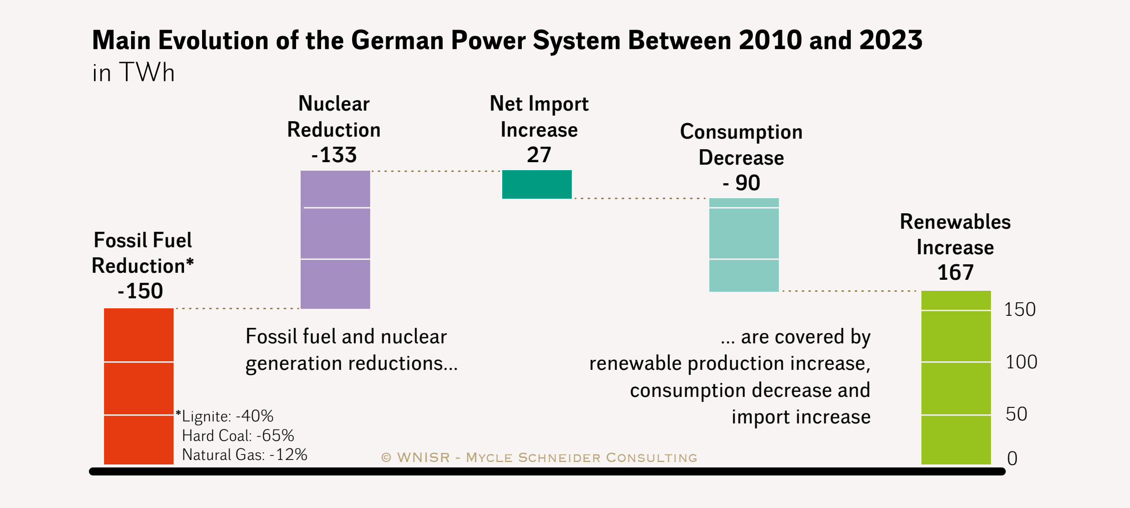
2156 - AGEB, "Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2023 (in TWh), Deutschland insgesamt", February 2024, op. cit.

2157 - Ibidem.

references even claim a higher share of over 60 percent in public power generation (net).[2158] Regulatory changes to the installation of solar panels that can be installed on balconies (hence the German term "Balkonkraftwerk" meaning "balcony power plant") have led to a boom of such privately installed, "plug-in" solar panels. By mid-2024, over half a million of such systems, generally consisting of multiple panels, had been installed by households all over the country.[2159]

Figure 77 summarizes the main developments of the German power system between 2010—the year prior to the post-3/11 closure of the eight oldest nuclear reactors and the nuclear phaseout decision in 2011—and 2023. The increase in renewables (+167 TWh) and the decline in consumption (-90 TWh) as well as an increase in imports (+27 TWh) compensate the decline in fossil fuel (-150 TWh) and nuclear generation (-133 TWh).

Figure 77 · Main Developments of the German Power System Between 2010 and 2023



Sources: WNISR, based on AGEB, 2024

Developments within the fossil-fuel generating segment:

- Lignite peaked in 2013 and then declined until 2020. A short-term increase in 2021–2022 was reversed with 2023-production dropping by 29 TWh (25 percent). The cumulated decline 2010–2023 reached 40 percent.
- After declining constantly between 2013 and 2019, hard coal electricity generation increased in 2021 and 2022, to 63.7 TWh, about 46 percent below the 2010-level. In 2023, hard coal generation dropped to its lowest level since 1990 at 40.6 TWh. This represents a 36 percent decline from the previous year and a 65 percent drop from 2010.
- Natural gas consumption for electricity in 2022 declined by 12.4 percent compared to 2021 to 79.1 TWh, the lowest value since 2016. In 2023, natural gas-based generation dropped again by 1.3 TWh or 1.7 percent to reach a level 12 percent below the 2010 value.

2158 - Bruno Burger, "Stromerzeugung in Deutschland im Jahr 2023", Fraunhofer ISE, Updated 22 February 2024, op. cit.

2159 - Federal Government of Germany, "Mehr Solarstrom, weniger Bürokratie", 5 July 2024 (in German), see https://www.bundesregierung.de/breg-de/themen/tipps-fuer-verbraucher/solarpaket-photovoltaik-balkonkraftwerke-2213726; and Bundesnetzagentur, "Zubau Erneuerbarer Energien im ersten Halbjahr 2024", Press Release (in German), The Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway, 19 July 2024, see https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2024/20240719_EEZubauHJ1.html?nn=660040; both accessed 21 July 2024.

In addition to renewables expansion, efficiency gains have played a significant role in compensating fossil fuel and nuclear power generation reductions in Germany. From 1991 to 2022, the economy-wide energy efficiency increased by 43 percent. Energy productivity has increased substantially, while per capita demand has dropped from 190.7 gigajoule (GJ) in 1990 to 139.3 GJ in 2022. This results from efficiency gains in fossil power plants, such as the introduction of Combined Heat and Power (CHP) technologies, and, amongst other factors, the overall economic shift from an energy-intensive manufacturing focus to more service oriented one.[2160]

However, independent think-tank Agora Energiewende noted that "most of the emissions cuts in 2023 are not sustainable from an industrial or climate policy perspective—for example, if emissions rise again as the economy picks up or if a share of Germany's industrial production is permanently moved abroad."[2161]

Table 17 · Legal Closure Dates for German Nuclear Reactors, 2011–2023

Reactor Name (Type, Net Capacity)	Owner/Operator	First Grid Connection	End of License (latest closure date)
Biblis-A (PWR, 1167 MW) **Biblis-B** (PWR, 1240 MW) **Brunsbüttel** (BWR, 771 MW) **Isar-1** (BWR, 878 MW) **Krümmel** (BWR, 1346 MW) **Neckarwestheim-1** (PWR, 785 MW) **Philippsburg-1** (BWR, 890 MW) **Unterweser** (BWR, 1345 MW)	RWE RWE KKW Brunsbüttel [a] PreussenElektra KKW Krümmel [b] EnBW EnBW PreussenElektra	1974 1976 1976 1977 1983 1976 1979 1978	6 August 2011
Grafenrheinfeld (PWR, 1275 MW)	PreussenElektra	1981	31 December 2015 (closed 27 June 2015)
Gundremmingen-B (BWR, 1284 MW)	KKW Gundremmingen [c]	1984	31 December 2017
Philippsburg-2 (PWR, 1402 MW)	EnBW	1984	31 December 2019
Brokdorf (PWR, 1410 MW) **Grohnde** (PWR, 1360 MW) **Gundremmingen-C** (BWR, 1288 MW)	PreussenElektra/Vattenfall [d] PreussenElektra KKW Gundremmingen	1986 1984 1984	31 December 2021
Isar-2 (PWR, 1410 MW) **Emsland** (PWR, 1329 MW) **Neckarwestheim-2** (PWR, 1310 MW)	PreussenElektra KKW Lippe-Ems [e] EnBW	1988 1988 1989	15 April 2023

Sources: WNISR with IAEA-PRIS, July 2023

Notes: Krümmel and Brunsbüttel were officially closed in 2011 but had not been providing electricity to the grid since 2009 and 2007 respectively.

PWR: Pressurized Water Reactor; **BWR:** Boiling Water Reactor; **KKW:** Nuclear Power Plant (Kernkraftwerk); **RWE:** Rheinisch-Westfälisches Elektrizitätswerk Power AG; **EnBW:** Energie Baden-Württemberg AG.

a - Vattenfall 66.67%, E.ON 33.33%

b - Vattenfall 50%, E.ON 50%.

c - RWE 75%, E.ON 25%.

d - E.ON 80%, Vattenfall 20%.

e - RWE 87.5%, E.ON 12.5%.

2160 - AGEB, "Ausgewählte Effizienzindikatoren zur Energiebilanz Deutschland. Daten für die Jahre von 1990 bis 2022", AG Energiebilanzen e.V, November 2023 (in German), see https://ag-energiebilanzen.de/wp-content/uploads/2022/09/Effizienzindikatoren_2022_V1-1.pdf, accessed 29 July 2024.

2161 - Agora Energiewende, "Germany's CO_2 emissions drop to record low but reveal gaps in country's climate policies", Press Release, 4 January 2024, see https://www.agora-energiewende.org/news-events/germanys-co2-emissions-drop-to-record-low-but-reveal-gaps-in-countrys-climate-policies, accessed 29 August 2024.

Other nuclear developments in Germany

The closure of the commercial nuclear power plants has not led to the end of industrial activities in the sector in Germany, in particular considering the nuclear fuel manufacturing facility in Lingen and the uranium enrichment plant in Gronau.

The facility at Lingen is operated by Advanced Nuclear Fuels GmbH (ANF), a subsidiary of French state-owned company Framatome.[2162] ANF is awaiting the approval of an operating license to produce Soviet-designed VVER reactor fuel assemblies together with Russian state-owned company Rosatom.[2163] Apparently, Rosatom employees have been sighted at the factory, where they are supposedly conducting test operations for VVER fuel operations.[2164] See Framatome and the Lingen VVER Fuel Manufacturing Plant Project for an analysis of the developments in Lingen.

In the past, depleted uranium hexafluoride had been transported from the Gronau enrichment facility to Russia where it had been re-enriched[2165], but these deliveries ceased in 2021; before the Russian attack on Ukraine.[2166] Dutch Urenco shareholders indicated it has since cut all ties with an unnamed Russian supplier.[2167] However, in February 2024, Dutch authorities authorized the transport of enriched uranium from Russia to Urenco's facility in Almelo, Netherlands,[2168] meaning that Urenco is "back in business with Russia."[2169]

The Netherlands

See Focus Countries – The Netherlands Focus.

2162 - Framatome, "Lingen, ANF", Undated, see https://www.framatome.com/en/implantations/lingen/, accessed 29 July 2023.

2163 - Grace Symes, "Fuel Fabrication: Framatome Awaiting German Authorization to Produce VVER Fuel", *Energy Intelligence*, 1 March 2024, see https://www.energyintel.com/0000018d-fodd-d9ab-adff-f2fd0d950000, accessed 31 May 2024.

2164 - Michael Bauchmüller and Georg Mascolo, "Lingen: Französischer Konzern will Brennelemente für russische Reaktoren herstellen - Kritik", *Süddeutsche Zeitung*, 8 May 2024 (in German), see https://www.sueddeutsche.de/politik/brennelemente-herstellung-deutschland-russland-reaktoren-kritik-1.7043300, accessed 5 June 2024.

2165 - Matthias Eickhoff, "Stellungnahme zur schriftlichen Anhörung des Ausschusses für Wirtschaft, Energie und Landesplanung des NRW-Landtags zum Antrag der Fraktion BÜNDNIS 90/DIE GRÜNEN 'Urananreicherung in NRW beenden, illegale Urantransporte stoppen!'", Sofortiger Atomausstieg Münster, commissioned by the Green Party, submitted to the State Parliament of North Rhine-Westphalia, 17 February 2021 (in German), see https://www.landtag.nrw.de/portal/WWW/dokumentenarchiv/Dokument/MMST17-3624.pdf, accessed 31 July 2024; and *BBC*, "Nuclear shipment leaves Germany for Russia", *BBC News*, 24 June 2020, see https://www.bbc.com/news/world-europe-53156266, accessed 1 August 2023.

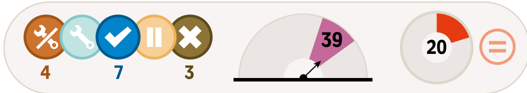
2166 - Government of North Rhine-Westphalia, "Antwort der Landesregierung auf die Kleine Anfrage 6409 vom 9. Februar 2022 der Abgeordneten Wibke Brems BÜNDNIS 90/DIE GRÜNEN", March 2022 (in German), see https://gruene-fraktion-nrw.de/wp-content/uploads/2022/02/Antwort-17-16784-Atomtransporte-2021.pdf, accessed 31 July 2024; and *dpa*, "Landesregierung: Keine Transporte von Gronau nach Russland", as published in *Süddeutsche Zeitung* (in German), 21 March 2022, see https://www.sueddeutsche.de/wirtschaft/atomkraft-gronau-westfalen-landesregierung-keine-transporte-von-gronau-nach-russland-dpa.urn-newsml-dpa-com-20090101-220321-99-615154, accessed 1 August 2023.

2167 - Urenco, "Annual Report and Accounts 2022", March 2023, see https://www.urenco.com/cdn/uploads/supporting-files/Urenco_AR2022.pdf, accessed 1 August 2023.

2168 - ANVS, "Kernenergiewetvergunning verleend aan Transrad NV/SA voor het binnen Nederland grondgebied (DOEN) brenen en het vervoeren op Nederlands grondgebied van splijtstoffen", Autoriteit Nucleaire Veilighheid en Stralingsbescherming/Authority for Nuclear Safety and Radiation Protection of the Netherlands, February 2024 (in Dutch), see https://puc.overheid.nl/anvs/doc/PUC_758468_32/1/, accessed 31 July 2024.

2169 - Ecodefense Russia, Stichting Laka/Laka Foundation Netherlands, Aktionsbündnis Münsterland gegen Atomanlagen Germany and Bündnis AtomkraftgegnerInnen im Emsland, "Urenco is back in business with Russia – despite of war in Ukraine: International NGOs reject uranium deliveries from Russia to Almelo", Press Release, 22 February 2024, see https://www.laka.org/info/urenco/2024-02-22-press-release-Urenco-EDF-rosatom.pdf, accessed 31 July 2024.

Spain



As of 1 July 2024, Spain operated seven reactors with about 7 GW capacity that provided 54.4 TWh in 2023, compared to 56. 15 TWh in 2022, representing 20.3 percent of the country's electricity generation—18.1 percentage points below the historic maximum of 38.4 percent in 1989. Spain's reactors have a mean operating age of 39.4 years as of mid-2024.

Spanish nuclear ownership is concentrated with the utilities Iberdrola and Endesa. Both utilities have shared ownership of Asco-2 and Vandellos-2, with Naturgy at Almaraz-1 & -2, and with Naturgy and EDP at Trillo. Endesa is the sole owner of Asco-1, and Iberdrola fully owns Cofrentes.[2170]

In January 2019, Spain's coalition government agreed a nuclear phaseout plan with utilities Endesa, Iberdrola and Naturgy as part of the overall Integrated National Energy and Climate Plan (INECP).[2171] All of Spain's reactors are scheduled to be closed by 2035; however, the policy also secured the possibility for all reactors to apply for lifetime extensions beyond 40 years, in contrast to the previously governing Socialist Party's (PSOE) policy.[2172] This plan was confirmed in the latest draft of the country's NECP published in June 2023.[2173]

Asociación Nuclear Ascó-Vandellós II, known as ANAV, the operator of Vandellós-2, applied for a 10-year license renewal in 2019 for which it received approval in 2020.[2174] Under current planning, Vandellós-2 is scheduled to operate until February 2035, offering the possibility to request an additional extension upon expiration of the current license in 2030.[2175]

The Cofrentes reactor, Spain's last operational BWR, was granted a license extension to 30 November 2030 in 2021.[2176]

In September 2021, license renewals of nine and ten years were issued for both PWRs at the Ascó plant, respectively, allowing for the operation of Unit 1 to 2030 and Unit 2 to 2031.[2177] An IAEA mission to assess the long-term safety at the plant concluded in September 2023 that most recommendations that had been made in a previous review in 2021 had been met, and

2170 - Foro Nuclear, "Nuclear power in Spain", Undated, see https://www.foronuclear.org/en/nuclear-power/nuclear-power-in-spain/, accessed 6 June 2024.

2171 - Carmen Monforte, "El Gobierno cierra el calendario con las fechas de clausura de cada central nuclear", *CincoDías*, *El País Economía*, 11 February 2019 (in Spanish), see https://cincodias.elpais.com/cincodias/2019/02/08/companias/1549647160_807281.html, accessed 8 July 2021.

2172 - *Público*, "La ministra Ribera afirma que es necesario prolongar la vida de las centrales nucleares", 3 March 2019 (in Spanish), see https://www.publico.es/politica/energia-nuclear-prolonga-vida-centrales-nucleares.html, accessed 8 July 2021.

2173 - Government of Spain, "Draft Update of the Plan Integrated National Energy and Climate 2023-2030", June 2023, see https://commission.europa.eu/system/files/2023-07/EN_SPAIN%20DRAFT%20UPDATED%20NECP.pdf, accessed 22 July 2023.

2174 - MITECO, "Orden TED/774/2020, de 23 de julio, por la que concede la renovación de la autorización de explotación de la Central Nuclear de Vandellós II.", Ministerio para la Transición Ecológica y el Reto Demográfico/Ministry for the Ecological Transition and Demographic Challenge, *Boletín Oficial del Estado*, Government of Spain, No. 212, issued 23 July 2020, promulgated 6 August 2020 (in Spanish), see https://www.boe.es/boe/dias/2020/08/06/pdfs/BOE-A-2020-9329.pdf, accessed 25 July 2024.

2175 - MITECO, "7° Plan General de Residuos Radioactivos", Government of Spain, 27 December 2023 (in Spanish), see https://www.miteco.gob.es/content/dam/miteco/es/energia/files-1/nuclear/Residuos/Documents/20231227%20PGRR%207_Version%2027%20diciembre%202023.pdf, accessed 25 July 2024.

2176 - MITECO, "Orden Ministerial— El MITECO aprueba la orden que extiende la autorización de explotación de la central nuclear de Cofrentes y establece el cierre en 2030", Press Release (in Spanish), Government of Spain, 18 March 2021, see https://www.miteco.gob.es/content/dam/miteco/es/prensa/210318renovacionautorizaciondeexplotacionlacentraldecofrentes_tcm30-524154.pdf, accessed 25 July 2024.

2177 - ANAV, "anav 2022—energía positiva", Asociación Nuclear Ascó-Vandellós II, 2022, see https://www.anav.es/app/uploads/2022/06/ANAV_MemoriaAnual2021.pdf, accessed 11 July 2022.

that the few remaining issues for safe operation of the plants beyond their 40-year design lifetime were already being addressed by the operator.[2178]

The Almaraz plant is located adjacent to the Tagus River in an area of significant seismic risk and 110 kilometers from the Portuguese border, resulting in strong opposition from stakeholders and the government in Portugal.

On 22 March 2019, Iberdrola confirmed that an agreement had been reached for the extension of the Almaraz-1 and -2 reactors to operate until 2027 and 2028 instead of May 2021 and October 2023, respectively, and that it had applied for corresponding license extensions.[2179] The agreement is based on the condition that Iberdrola will spend no more than €600 million (US$$_{2019}$672 million) during the remaining operational life of the reactors.[2180] In May 2020, the Spanish Nuclear Safety Council (El Consejo de Seguridad Nuclear or CSN) delivered a favorable report, and the license application received final governmental approval in July 2020.[2181] This extended operational lifetimes of Almaraz-1 and -2, then 41 and 39 years old, to 1 November 2027 and 31 October 2028, respectively. The CSN approval sets various safety and compliance conditions, including the requirement, as noted above, for significant investment.[2182] The license of the units had already been extended by 10 years in 2010.[2183]

The Almaraz plant is located adjacent to the Tagus River in an area of significant seismic risk and 110 kilometers from the Portuguese border, resulting in strong opposition from stakeholders and the Government in Portugal.[2184] The latest dispute arose with the CSN decision of May 2020, prompting the Portuguese Government to demand that Almaraz be subject to an environmental impact assessment (EIA).[2185] In July 2020, after the Spanish

2178 - IAEA, "IAEA Concludes Long Term Operational Safety Review of Spain's Ascó Nuclear Power Plant", Press Release 90/2023, 11 September 2023, see https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-of-spains-asco-nuclear-power-plant-0; and IAEA, "IAEA Concludes Long Term Operational Safety Review of Spain's Ascó Nuclear Power Plant", Press Release 43/2021, 30 July 2021, see https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-of-spains-asco-nuclear-power-plant; both accessed 25 July 2024.

2179 - Iberdrola, "Iberdrola finalises the Almaraz renewal agreement, which guarantees economic activity and employment at the plant for the next 25 years", Press Release, 22 March 2019, see https://www.iberdrola.com/press-room/news/detail/iberdrola-finalises-almaraz-renewal-agreement-which-guarantees-economic-activity-employment-plant-next-years, accessed 8 July 2021.

2180 - Isla Binnie, "Power firms agree on route to close Spain's oldest nuclear plant", *Reuters*, 22 March 2019, see https://www.reuters.com/article/us-spain-energy-nuclearpower/power-firms-agree-on-route-to-close-spains-oldest-nuclear-plant-idUSKCN1R325G, accessed 8 July 2021.

2181 - MITECO, "Orden TED-773-2020 , de 23 de julio, por la que concede la renovación de la autorización de explotación de la Central Nuclear de Almaraz, Unidades I y II", Government of Spain, *Boletín Oficial del Estado*, 6 August 2020 (in Spanish), see https://www.csn.es/documents/10182/27922/Orden%20TED-773-2020%20,%20de%2023%20de%20julio,%20por%20la%20que%20concede%20la%20renovaci%C3%B3n%20de%20la%20autorizaci%C3%B3n%20de%20explotaci%C3%B3n%20de%20la%20Central%20Nuclear%20de%20Almaraz,%20Unidades%20I%20y%20II, accessed 11 August 2020.

2182 - *elEleconomista*, "El CSN autoriza a la central nuclear de Almaraz a operar hasta octubre de 2028", 7 May 2020 (in Spanish), see https://www.eleconomista.es/empresas-finanzas/noticias/10529185/05/20/El-CSN-autoriza-a-la-central-nuclear-de-Almaraz-a-operar-hasta-octubre-de-2028.html, accessed 8 July 2021.

2183 - MITECO, "Orden ITC/158812010, de 7 de junio, por la que se concede renovación de la autorización de explotación a la Central Nuclear Almaraz, Unidades 1 y 11.", Government of Spain, *Boletin Oficial del Estado*, No. 146, Sec. III, P. 51616 (in Spanish), 16 June 2010, see https://www.csn.es/documents/10182/27922/Orden%20ITC-1588-2010,%20de%207%20de%20junio,%20por%20la%20que%20se%20concede%20renovaci%C3%B3n%20de%20la%20autorizaci%C3%B3n%20de%20explotaci%C3%B3n%20a%20la%20Central%20Nuclear%20Almaraz,%20Unidades%20I%20y%20II, accessed 15 August 2022.

2184 - *Jornal Económico*, "Spanish nuclear power plant in Almaraz authorized to operate until 2028", 8 May 2020.

2185 - *LUSA*, "Governo quer que extensão de funcionamento de Almaraz seja avaliada", as published in *Notícias ao Minuto,* 5 May 2020 (in Portuguese), see https://www.noticiasaominuto.com/pais/1483078/governo-quer-que-extensao-de-funcionamento-de-almaraz-seja-avaliada, accessed 8 July 2021

Government approved the plant's lifetime extension, the Pessoas-Animais-Natureza (PAN) party requested an investigation into potential violations of the procedure regarding both the Convention on Environmental Impact Assessment in a Transboundary Context (also known as "Espoo Convention") and the Aarhus Convention,[2186] and filed complaints with the United Nations Economic Commission for Europe (UNECE) in October 2020.[2187] In October 2022, the Implementation Committee of the Espoo Convention reached the agreement to close the case, as no information gave rise to a "profound suspicion of non-compliance by Spain" or indicated "major change" at the site.[2188] On 28 May 2024, a letter was issued by the Secretary of the Aarhus Convention Compliance Committee stating that it was "of the view that it is in a position to commence deliberations […] without holding a hearing," requesting a response from both parties on this procedural decision.[2189] It remains unclear when the matter might be resolved.

The last reactor to apply for license renewal was Trillo. This plant is currently operating under a ten-year license valid until November 2024.[2190] In the first quarter of 2023, an application for a ten-year license renewal was submitted to the regulator.[2191] As of June 2024, it had not been fully approved.[2192]

Spanish plans to end commercial operation of nuclear power plants are facing increasing opposition as the promotion of nuclear power as a necessary technology for a carbon neutral energy system in Spain has been gaining traction.[2193] To reverse the planned closure of Almaraz I in 2027, all necessary licenses would have to be applied for three years prior to the

2186 - *Portugal Resident*, "Almaraz nuclear risks: PAN lodges complaint against Spain to UN", 30 July 2020, see https://www.portugalresident.com/almaraz-nuclear-risks-pan-lodges-complaint-against-spain-to-un/, accessed 7 July 2021; and Implementation Committee, "EIA/IC/INFO/34—Correspondence as a result of information provided to the Committee from other sources", United Nations Economic Commission for Europe, 30 July 2020, see https://unece.org/eiaicinfo34, accessed 18 August 2022.

2187 - André Silva, "Non-compliance of the Espoo Convention by the Member State Spain", Pessoas-Animais-Natureza, addressed to the Implementation Committee, Convention on Environmental Impact Assessment in a Transboundary Context, UNECE, United Nations, 9 October 2020, see https://unece.org/DAM/env/pp/compliance/C2020-183_Spain/Att1_Complaint_to_Espoo_Convention_Imp_Committee.pdf, accessed 18 August 2022; and André Silva, "Communication on non-compliance by Spain with the Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters", addressed to the Secretariat of the Arrhus Convention Compliance Committee, Environment Division, United Nations Economic Division for Europe, see https://unece.org/DAM/env/pp/compliance/C2020-183_Spain/Communication_Spain_PAN_09.10.2020_Redacted.pdf, accessed 25 July 2024.

2188 - Implementation Committee, "Report of the Implementation Committee on its fifty-fourth session", ECE/MP.EIA/IC/2022/7, Meeting of the Parties to the Convention on Environmental Impact Assessment in a Transboundary Context serving as the Meeting of the Parties to the Protocol on Strategic Environmental Assessment, United Nations, 21 October 2022, see https://unece.org/sites/default/files/2022-11/ece_mp.eia_ic_2022_7_advance_edited.pdf, accessed 5 September 2023.

2189 - Aarhus Convention Compliance Committee, "RE: Communication to the Aarhus Convention Compliance Committee concerning compliance by Spain in connection with the lifetime extension of the Almaraz nuclear power plant (ACCC/C/2020/183)", addressed to the Spanish Ministry for Ecological Transition and the Demographic Challenge and Pessoas – Animais – Natureza, 28 May 2024, see https://unece.org/sites/default/files/2024-05/toPartiesC183_28.05.2024.pdf, accessed 6 June 2024.

2190 - CNAT, "CNAT 2023-Informe Medioambiental", May 2024, see https://www.cnat.es/publipdf/INFORME-AMBIENTAL-CNAT23.pdf, accessed 25 July 2024.

2191 - CNAT, "CNAT solicitará la renovación de la Autorización de Explotación de CN Trillo por diez años", 27 March 2023 (in Spanish), see https://www.cnat.es/notpdf/270323Nota%20Informativa%20AEX%20CN%20Trillo.pdf, accessed 25 July 2024.

2192 - On 24 July 2024, the regulator issued a favorable decision to the license extension, which now requires the final Ministerial approval; see CSN, "El CSN informa favorablemente la renovación de la autorización de explotación de la central nuclear Trillo para diez años más", 24 July 2024 (in Spanish), see https://www.csn.es/en/noticias-csn/2024/-/asset_publisher/zfXTQAgA3izm/content/el-csn-informa-favorablemente-la-renovacion-de-la-autorizacion-de-explotacion-de-la-central-nuclear-trillo-para-diez-anos-mas, accessed 25 July 2024.

2193 - *WNN*, "Nuclear plants vital for Spain, manifesto says", 10 March 2023, see https://www.world-nuclear-news.org/Articles/Nuclear-plants-vital-for-Spain,-manifesto-says, accessed 7 September 2023.

scheduled closure, i.e. by November 2024. Some experts assumed that this was not possible given the amount of necessary work.[2194]

The snap elections called by Prime Minister Pedro Sánchez in July 2023 led to the conservative party Partido Popular (PP)—which had run its election campaign on reversing the nuclear phaseout plan[2195]—winning the majority of seats in Parliament. But after several failed attempts of the PP to form a government, Sánchez was nominated by King Felipe VI to form a government in October 2023.[2196] This led to the formation of an "awkward coalition that includes two Catalan separatist parties".[2197] As of writing in June 2024, the Spanish Government under Sánchez was still functioning.

Despite opposition from industry lobby groups such as Circulo de Empresarios,[2198] Sanchéz confirmed Spanish phaseout plans by 2035, beginning with the closure of Almaraz-1 in 2027, in December 2023. Additionally, a cost estimate of €20.2 billion (US$$_{2023}$22 billion) for radioactive waste management and decommissioning was published, to be paid by the operators via an external fund.[2199] This fund is expected to last until the year 2100.[2200] The government plans are once again facing opposition, mostly by opposition parties, utility executives, and nuclear lobbyists.[2201]

In order to limit the impact of high energy prices on households, Spain introduced a windfall-profit tax of 1.2 percent on power utilities' sales in 2023 and 2024.[2202] In its 2022-Annual Report,

2194 - Laura Ojea, "El plan de cierre de nucleares no se puede cambiar aunque haya vuelco electoral en las próximas elecciones generals", *El Español* (in Spanish), 8 May 2023, see https://www.elespanol.com/invertia/empresas/energia/20230508/nucleares-no-cambiar-electoral-proximas-elecciones-generales/761923816_0.html, accessed 7 September 2023.

2195 - Pietro Lombardi, "Spain's election frontrunners plan U-turn in nuclear power phase-out", *Reuters*, 26 June 2023, see https://www.reuters.com/world/europe/spains-election-frontrunners-plan-u-turn-nuclear-power-phase-out-2023-06-26/, accessed 27 June 2023.

2196 - *Agencia EFE*, "Spain King appoints Socialist Sánchez to form government", 3 October 2023, see https://efe.com/en/latest-news/2023-10-03/spain-king-appoints-socialist-sanchez-to-form-government/, accessed 6 June 2024.

2197 - Laura Gozzi, "Spain's Prime Minister Pedro Sánchez will not resign after allegations against wife", *BBC*, 29 April 2024, see https://www.bbc.com/news/world-europe-68919354, accessed 6 June 2024.

2198 - Pietro Lombardi, "Spain's business lobby calls for extension of nuclear power", *Reuters*, 3 November 2023, see https://www.reuters.com/business/energy/spains-business-lobby-calls-extension-nuclear-power-2023-11-03/, accessed 6 June 2024.

2199 - Pietro Lombardi, "Spain confirms nuclear power phase-out, extends renewable projects deadlines", *Reuters*, 27 December 2023, see https://www.reuters.com/business/energy/spain-confirms-nuclear-power-phase-out-extends-renewable-projects-deadlines-2023-12-27/, accessed 6 June 2024; and MITECO, "7° Plan General de Residuos Radioactivos", Government of Spain, 27 December 2023, op. cit.

2200 - Manuel Planelles, "Felipe González carga contra las renovables para defender la energía nuclear", *El País*, 29 January 2024 (in Spanish), see https://elpais.com/clima-y-medio-ambiente/2024-01-29/felipe-gonzalez-carga-contra-las-renovables-para-defender-la-energia-nuclear.html, accessed 6 June 2024.

2201 - Ibidem; and Elena Sánchez Laso, "Emilio Mínguez (Sociedad Nuclear): 'El plan de cierre de reactores deja a España muy sola'", *EFE Noticias*, 2 March 2024 (in Spanish), see https://efe.com/economia/2024-03-02/emilio-minguez-sociedad-nuclear-plan-cierre-reactores-deja-espana-sola/; also *Europa Press*, "El PP pedirá la continuidad de la vida útil de la central nuclear de Trillo en el pleno de la Diputación de Guadalajara", 12 March 2024 (in Spanish), see https://www.europapress.es/castilla-lamancha/noticia-pp-pedira-continuidad-vida-util-central-nuclear-trillo-pleno-diputacion-guadalajara-20240312130049.html; both accessed 6 June 2024.

2202 - Belén Carreño, "Spain seeks to set nuclear, hydro power prices to curb profits", *Reuters*, 10 January 2023, see https://www.reuters.com/business/energy/spain-seeks-set-nuclear-hydro-prices-end-windfall-profits-2023-01-10/; and *Montel*, "Spain approves 1.2% windfall tax on energy companies", 22 December 2022, see https://www.montelnews.com/news/1391799/spain-approves-12-windfall-tax-on-energy-companies; both accessed 4 September 2023; also Barney Jopson, "Spain extends windfall tax on banks and energy companies", *The Financial Times*, 27 December 2023, see https://www.ft.com/content/8b89d457-4783-4025-bc76-1b77135d99ac, accessed 25 July 2024.

industry lobby group Foro Nuclear "insists that the economic viability of Spanish nuclear reactors be guaranteed for as long as they remain in operation."[2203]

Energy and Climate Change Policy

In July 2023, the country submitted a 580-page draft of its updated NECP aligned with E.U. legislation setting more ambitious emission reduction targets.[2204] The proposed plan expects 214 GW of installed power capacity by 2030, including 160 GW of renewables and 22 GW of storage, while maintaining its projection of 3 GW of nuclear power, reducing its contribution in overall installed capacity to 1.4 percent. Further indicative technology distribution entails 76 GW of solar PV (of which 19 GW would be small-scale self-consumption), 62 GW of wind, 26.6 GW in combined cycle gas and 14.5 GW of hydro. The final version of the plan, implementing recommendations issued by the European Commission in December 2023, was to be submitted by 30 June 2024, but had not yet been made public as of mid-July 2024.[2205]

In 2023, solar and wind combined delivered over 40 percent of Spain's total gross electricity generation of around 270 TWh, followed by 23.4 percent from natural gas, about 21 percent nuclear power, 7.4 percent hydro, and bioenergy, oil and coal remaining in low single digit percentages.[2206] According to the grid operator Red Eléctrica, 2023 solar capacities alone grew by 28 percent year-on-year, to over 25.5 GW.[2207] The country's 2050 objectives stipulate renewables to deliver an ambitious 100 percent of electricity production and 97 percent of final energy consumption.[2208]

Sweden

See Focus Countries – Sweden Focus.

2203 - Foro Nuclear, "Nuclear Results in 2022 and Future Perspectives—Executive Summary", April 2023, see https://www.foronuclear.org/wp-content/uploads/2023/04/Nuclear-results-in-2022-executive-summary.pdf?x67659, accessed 4 September 2023.

2204 - Government of Spain, "Draft Update of the Plan Integrated National Energy and Climate 2023-2030", European Commission, July 2023, see https://commission.europa.eu/system/files/2023-07/EN_SPAIN%20DRAFT%20UPDATED%20NECP.pdf, accessed 4 September 2023.

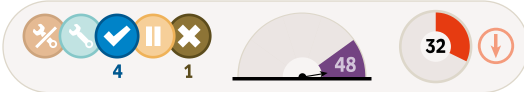
2205 - European Commission, "National energy and climate plans", 2024, see https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en#the-process, accessed 25 July 2024.

2206 - Ember, "Electricity Data Explorer—Spain electricity generation by source", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 6 June 2024.

2207 - Red Eléctrica, "In 2023, Spain implemented the largest installed solar photovoltaic power system in its history", Press Release, Red Eléctrica, 21 March 2024, see https://www.ree.es/en/press-office/news/press-release/2024/03/in-2023-spaim-implemented-the-largest-installed-solar-photovoltaic-power-system-in-its-history, accessed 6 June 2024.

2208 - Government of Spain, "España 2050: Fundamentos y propuestas para una Estrategia Nacional de Largo Plazo", May 2021 (in Spanish), see https://www.lamoncloa.gob.es/presidente/actividades/Documents/2021/200521-Estrategia_Espana_2050.pdf; and EIA, "Spain 2021—Energy Policy Review", International Energy Agency, May 2021, see https://iea.blob.core.windows.net/assets/2f405ae0-4617-4e16-884c-7956d1945f64/Spain2021.pdf, accessed 16 August 2022.

Switzerland

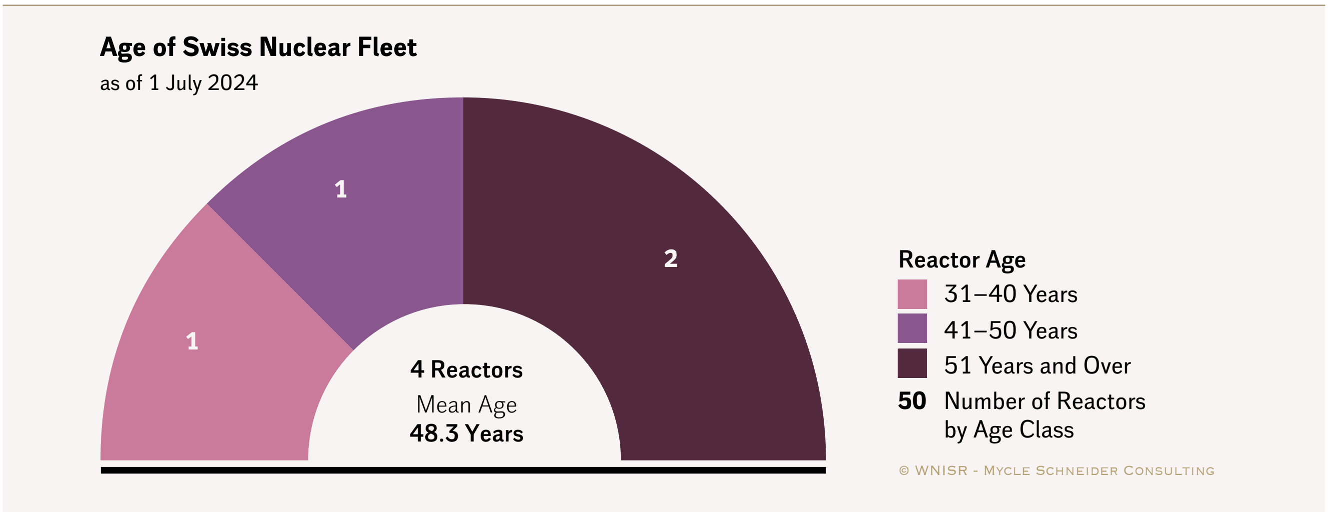


Swiss gross nuclear power production increased slightly by 1 percent year-on-year to 23.3 TWh in 2023. This corresponded to 32.4 percent of gross power production which reached a record level of 72.1 TWh, up 13.5 percent compared to 2022, fueled mainly by a 22 percent increase in hydro output.[2209] The historic maximum nuclear share of 43 percent was achieved in 1996.

With an average age of 48.3 years (see Figure 78), Switzerland operates the second oldest nuclear fleet in the world behind the Netherlands (that operates only one 51-year old unit), of which Beznau-1, age 55, is the oldest commercially operating reactor in the world. Beznau-2 is almost 53 years old.

The safety assessments of the old plants remain controversial. In November 2021, the Swiss Federal Nuclear Safety Inspectorate (ENSI) concluded in a 404-page safety assessment report covering the evaluation period 2012–2016 that some improvements were needed in the "assessment and maintenance of the quality" of the spent fuel pools and that an increased surveillance of the material ageing of certain components was necessary. The report included a list of over 30 required measures to be implemented with individually specified timelines, starting in 2022 with the last item to be completed by the end of 2024.[2210]

Figure 78 · Age Distribution of the Swiss Nuclear Fleet



Sources: WNISR with IAEA-PRIS, 2024

An independent study completed in February 2022 evaluated the 2015 AREVA "fractographic investigation", forming the basis for the operator's conclusion that any defaults at the reactor pressure vessel of Beznau-1—already subject to a series of contradictory evaluations in the past

2209 - OFEN/BFE/SFOE, "Schweizerische Elektrizitätsstatistik 2023 / Statistique suisse de l'électricité 2023", Office fédérale de l'énergie/Bundesamt für Energie/Swiss Federal Office of Energy, April 2023 (in French and German), see https://www.bfe.admin.ch/bfe/en/home/versorgung/statistik-und-geodaten/energiestatistiken/elektrizitaetsstatistik.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvMTE3Njk=.html, accessed 30 July 2024.

2210 - ENSI/IFSN, "Sicherheitstechnische Stellungnahme zur Periodischen Sicherheitsüberprüfung 2017 des Kernkraftwerks Beznau", ENSI 14/3025, Eidgenössisches Nuklearsicherheitsinspektorat/Swiss Federal Nuclear Safety Inspectorate, 16 November 2021 (in German), see https://www.ensi.ch/de/dokumente/sicherheitstechnische-stellungnahme-zur-periodischen-sicherheitsueberpruefung-2017-des-kernkraftwerks-beznau/, accessed 20 August 2022.

(see previous WNISR editions)—were non-evolutive. The expertise concluded that the AREVA analysis provided "a superficial exemplary examination of different microstructural features" and appears to be "incomplete".[2211]

Another independent report on the Leibstadt plant listed numerous deficiencies of the safety standards including insufficient protection against airplane crashes and the penetration of the concrete foundation in case of a core-melt accident. The assessment concludes that a lifetime extension would not be feasible under current safety standards as certain critical components cannot be replaced or appropriately retrofitted.[2212]

Regardless, in early July 2021, it was reported that the Federal Office of Energy had engaged in talks with the operators of four operational reactors about a potential lifetime extension to 60 years. In Switzerland, there is no specific time limit on nuclear operational licenses. Thus, nuclear reactors can operate as long as they are deemed safe by the authorities.[2213] The Swiss Energy Foundation has called lifetime extensions "an unnecessary and dangerous game to gain time",[2214] but work and assessments for continued operation is ongoing at most operational plants.[2215] However, long-term operation brings more than just technical challenges; currently, Swiss nuclear operators are struggling to recruit qualified personnel for their reactors and this shortfall might intensify in the coming years.[2216]

As of 2024, substantial investments have been made towards Swiss nuclear power plant modernization. At the Beznau plant, combined investment has surpassed CHF2.5 billion (US$2.8 billion), and at Gösgen, a 45-year-old PWR, CHF700 million (US$772 million) are planned to be invested until 2029. At Leibstadt, CHF1 billion (US$1.1 billion) are expected to be spent over the next decade.[2217]

In 2024, based on a 2018-safety report covering the 2008–2017 operating years, ENSI concluded that while the Gösgen plant had good safety standards in general, several improvements were necessary for continued operation.[2218] Another ENSI assessment concluded that both Leibstadt

2211 - Kim Wallin, "Assessment of Fractographic Investigation Report and Applicability of the Master Curve Method", kw-solutions, commissioned by Schweizerische Energiestiftung/Swiss Energy Foundation, 14 February 2022, see https://energiestiftung.ch/files/energiestiftung/Studien/2022_Wallin_RDB/KW-2022-01.pdf, accessed 10 September 2023.

2212 - Manfred Mertins, "Studie zu den Sicherheitsdefiziten des Schweizer AKW Leibstadt (Defizit-Studie KKL)", TH Brandenburg, commissioned by Schweizerische Energiestifung/Swiss Energy Foundation, August 2021 (in German), see https://energiestiftung.ch/files/energiestiftung/publikationen/pdf/20210829_Studie%20zu%20den%20Sicherheitsdefiziten%20des%20Schweizer%20AKW%20Leibstadt_final.pdf, accessed 10 September 2023.

2213 - Rebekka Bärenbold, "Nuclear Decommissioning Profile Switzerland", University of Basel, January 2023, see https://fonew.unibas.ch/fileadmin/user_upload/fonew/Reports/2023_01_NucDecom_Switzerland.pdf, accessed 10 November 2023.

2214 - Michel Sutter, "Laufzeitverlängerung der Kernkraftwerke sorgt für Diskussionen", *energate messenger*, 7 May 2021 (in German), see https://www.energate-messenger.ch/news/213514/laufzeitverlaengerung-der-kernkraftwerke-sorgt-fuer-diskussionen, accessed 5 July 2021.

2215 - Jürg Meier, "So bereiten sich die Schweizer AKW darauf vor, länger zu laufen", *Neue Zürcher Zeitung*, 20 April 2024 (in German), see https://www.nzz.ch/wirtschaft/die-schweizer-kernkraftwerke-sollen-deutlich-laenger-laufen-doch-wie-renoviert-man-eigentlich-ein-akw-ld.1826541, accessed 13 June 2024.

2216 - Jürg Meier, "Personalmangel bedroht Langzeitbetrieb der Kernkraftwerke", *Neue Zürcher Zeitung*, 3 December 2023 (in German), see https://www.nzz.ch/wirtschaft/personalmangel-bedroht-langzeitbetrieb-der-kernkraftwerke-ld.1768521, accessed 30 July 2024.

2217 - swissnuclear, "23,467 TWh of electricity produced by Swiss nuclear power stations in 2023", Press Release, 23 February 2024, see https://swissnuclear.ch/wp-content/uploads/2024/03/20240223_MM_Produktionszahlen-2023-en-Versand.pdf, accessed 12 June 2024.

2218 - ENSI, "KKW Gösgen: ENSI fordert Verbesserungen für den Langzeitbetrieb" Eidgenössisches Nuklearsicherheitsinspektorat/Swiss Federal Nuclear Safety Inspectorate, 17 January 2024 (in German), see https://www.ensi.ch/de/2024/01/17/kkw-goesgen-ensi-fordert-verbesserungen-fuer-den-langzeitbetrieb/, accessed 12 June 2024.

and Beznau would be able to withstand "very severe earthquakes, as are expected to occur every 1,000 or 10,000 years."[2219]

In 2016, Swiss utility Alpiq, majority-owner of both Gösgen (40 percent)[2220] and Leibstadt (27.4 percent)[2221], had, due to unfavorable economic prospects, considered transferring the ownership of both plants to foreign operators (EDF) for free. This did not happen because no one would take on the financial responsibility coming with the inevitable decommissioning of the plants.[2222] Instead, by November 2023, Alpiq said that it had begun to "[study] the impacts of a [lifetime extension to] 80 years." According to *Bloomberg*, the operator claimed that the extension of the operational lifetime to more than 60 years would be "economically feasible without support from the Government."[2223] Utility Axpo, responsible for Beznau, followed in March 2024 with an announcement that a feasibility assessment of operating both reactors for more than 60 years had been launched.[2224]

Developments in Swiss Energy Policy

On 21 May 2017, 58 percent of Swiss voters agreed to the Energy Strategy 2050[2225] that provides a long-term policy framework based on the dynamic development of energy efficiency and renewable energies. The strategy does not fix any closure dates for the nuclear power plants and aims to keep the existing reactors operating "as long as they are safe". However, it prohibits the construction of new nuclear power plants, "fundamental changes" to operating reactors, and the reprocessing of spent fuel. This "totally revised energy legislation" entered into force on 1 January 2018.[2226]

The legislation was comprehensive and exhaustive, providing a framework for the development of grid regulation, renewable energy incentives, auto-consumption, energy efficiency, and the "organic phaseout" of nuclear power. The efficiency targets were ambitious; the per-capita energy consumption levels were to be reduced—compared to the 2000 baseline—by 16 percent by 2020 and 43 percent by 2035, while per-capita electricity consumption was to decrease

2219 - ENSI, "Leibstadt and Beznau nuclear power plants can withstand infrequent severe earthquakes", 8 April 2024, see https://www.ensi.ch/en/2024/04/08/leibstadt-and-beznau-nuclear-power-plants-can-withstand-infrequent-severe-earthquakes/, accessed 9 April 2024.

2220 - KKG, "Über uns", Kernkraftwerk Gösgen-Däniken AG/Nuclear Power Plant Gösgen, 2024 (in German), see https://www.kkg.ch/de/uns.html, accessed 12 June 2024.

2221 - KKL, "Über uns—Organisation", Kernkraftwerk Leibstadt/Nuclear Power Plant Leibstadt, 2024 (in German), see https://www.kkl.ch/unternehmen/ueber-uns/organisation, accessed 12 June 2024.

2222 - *Aargauer Zeitung*, "Atomausstieg - Alpiq will AKW Leibstadt und Gösgen verschenken", 6 November 2016 (in German), see https://www.aargauerzeitung.ch/wirtschaft/alpiq-will-akw-leibstadt-und-gosgen-verschenken-ld.1592229, accessed 12 June 2024.

2223 - Bastian Benrath, "Switzerland to Use Nuclear Energy Longer Than Expected", *Bloomberg.com*, 7 November 2023, see https://www.bloomberg.com/news/articles/2023-11-07/switzerland-to-keep-using-nuclear-energy-longer-than-expected, accessed 7 November 2023.

2224 - Axpo Group, "Strengthening security of supply: Axpo is giving a clear Yes to the new electricity law, assessing the potential of operating Beznau for longer, and is prepared to construct a reserve power plant", Press Release, 28 March 2024, see https://www.axpo.com/group/en/news-and-stories/media-releases.detail.html/news-and-stories/media-releases/2024/strengthening-security-of-supply--axpo-is-giving-a-clear-yes-to-.html, accessed 28 August 2024.

2225 - Federal Chancellery, "Volksabstimmung vom 21.05.2017", Updated 18 July 2024 (in German), see https://www.bk.admin.ch/ch/d/pore/va/20170521/index.html, accessed 30 July 2024.

2226 - UVEK, "Wichtigste Neuerungen im Energierecht ab 2018", Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation/Federal Department of the Environment, Transport, Energy and Communications, Swiss Federal Office of Energy, 2 November 2017 (in German), see https://www.newsd.admin.ch/newsd/message/attachments/50166.pdf, accessed 13 July 2018.

by 3 percent by the end of 2020 and 13 percent by 2035.[2227] The 2020 target was surpassed by 4.8 percentage points, resulting in a reduction of per-capita end-energy consumption by 20.8 percent compared to 2000. While the COVID-19 pandemic played a major role in the decline that year, the Swiss Federal Office of Energy notes that the target had already been "undercut in the last three years prior to the COVID-19 pandemic", concluding that it was "highly likely that the applicable target in the Energy Act for 2020 would also have been achieved without the influence of the pandemic."[2228]

In April 2024, the European Court of Human Rights ruled that Switzerland was failing "to comply with positive obligation to implement sufficient measures to combat climate change"

Since then, legislation has further solidified Swiss commitment to climate neutrality by 2050. The nationally determined Swiss contribution, submitted in 2022 under the Paris Agreement, now envisions a reduction of greenhouse gas emissions by "at least 50 percent" by 2030, compared to 1990 levels, while this target had previously been set as an upper limit.[2229] In 2023, the new Climate and Innovation Act was accepted in a referendum with a 59.1-percent majority. The act aims at reducing the consumption of oil and gas solely by implementing incentives and avoids the banning of any technologies. Rather, funding is provided for "climate friendly heating" and "innovative technologies and processes" are to be supported. Further, state-owned assets, in their function as role models, shall reduce their emissions to zero by 2040, while private actors shall do so by 2050.[2230] In April 2024, the European Court of Human Rights ruled that Switzerland was failing "to comply with positive obligation to implement sufficient measures to combat climate change" after the Swiss association of Elders for Climate Protection ("*Verein Klimaseniorinnen Schweiz*") had brought the case forward. The ruling is based on Article 8 of the European Convention on Human Rights that includes "an obligation to maintain a healthy environment".[2231] The Court had already ruled on this basis in earlier cases relating to industrial environmental pollution and issues of waste management.[2232] The ruling was rejected by the relevant Swiss parliamentary committee in May 2024,[2233] followed by a vote to reject the ruling in the lower house of Parliament in June 2024 during which the ruling was

2227 - SFOE, "Energy Strategy 2050 Once the New Energy Act is in Force", Swiss Federal Office of Energy, 18 January 2018, see https://www.bfe.admin.ch/bfe/en/home/politik/energiestrategie-2050/dokumentation.exturl.html, accessed 10 September 2023.

2228 - SFOE, "Energy Strategy 2050 - Monitoring Report 2021", Swiss Federal Office of Energy, December 2021, see https://www.bfe.admin.ch/bfe/en/home/versorgung/statistik-und-geodaten/monitoring-energiestrategie-2050.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZW4vcHVibGljYX/Rpb24vZG93bmxvYWQvMTA3NzM=.html, accessed 14 September 2023.

2229 - FOEN, "Switzerland's submissions within the framework of international climate negotiations (UNFCCC): 2022", Federal Office for the Environment, Updated 8 May 2023, see https://www.bafu.admin.ch/bafu/en/home/themen/thema-klima/klimawandel-stoppen-und-folgen-meistern/klima--internationales/eingaben-der-schweiz-im-rahmen-der-internationalen-klimaverhandl/eingaben-der-schweiz-im-rahmen-der-internationalen-klimaverhandlungen-unfccc-2021.html, accessed 10 September 2023.

2230 - UVEK/DETEC, "Klima- und Innovationsgesetz", Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikatoin/Federal Department of the Environment, Transport and Communications, 18 June 2023 (in German), see https://www.uvek.admin.ch/uvek/de/home/uvek/abstimmungen/klima-und-innovationsgesetz.html, accessed 14 September 2023.

2231 - European Court of Human Rights, "Judgement on the Case of Verein Klimaseniorinnen and Others v. Switzerland", Application no. 53600/20, 9 April 2024, see https://hudoc.echr.coe.int/eng#_Toc162522507, accessed 13 August 2024.

2232 - *AFP*, "Climate justice: Top European rights court condemns Switzerland in landmark ruling", *Le Monde*, 9 April 2024, see https://www.lemonde.fr/en/europe/article/2024/04/09/climate-justice-top-european-rights-court-condemns-switzerland-in-landmark-ruling_6667858_143.html, accessed 12 August 2024.

2233 - Dave Graham and Emma Farge, "Swiss parliamentary committee rejects European climate ruling", *Reuters*, 21 May 2024, see https://www.reuters.com/world/europe/swiss-parliamentary-committee-rejects-european-climate-ruling-2024-05-21/, accessed 12 August 2024.

decried as "judicial activism". According to *Reuters*, this vote "could encourage others to resist the influence of international courts" regarding climate action, especially under the pressure of far-right electorates.[2234]

The Swiss' perception of the necessity of nuclear power appears to be highly volatile. While in August 2022, a poll found a 52-percent majority approving lifetime extensions and opposing the ban on newbuilds,[2235] a 2023-survey found that support for nuclear had dropped to less than a third of the people polled.[2236]

In February 2024, an initiative called "Electricity for all at all times (stop the blackout)" submitted their application to be considered for a referendum (so-called *Volksinitiative* or *Initiative Populaire* that can be brought to referendum by members of the population) after having gathered the necessary number of 100,000 signatures.[2237] The initiative is supported by Swiss center-right parties and envisions the removal of the existing ban on nuclear power plant expansions.[2238]

In June 2024, a referendum on a new electricity-expansion law that intends to boost renewables expansion, i.e. wind, solar, and hydro, was held, and around 69 percent of Swiss voters approved the legislative initiative against right-wing and small-scale environmentalist opposition.[2239] Subsequently, a new debate on nuclear power began, with Member of Parliament Roger Nordmann of the Social Democrats hailing the results as "the final nail in the coffin of nuclear power", and conservative party leader of the SVP (Swiss People's Party) Marcel Dettling calling for "cheap and reliable energy" that could supposedly only be achieved with nuclear.[2240]

Environment Minister Albert Rösti, who had supported the June-2024 referendum for renewables against his own party (SVP), said shortly after the results were announced, that he now planned to work towards the removal of the ban on nuclear newbuilds from legislation.[2241] Rather surprisingly, the move met no opposition from Green Party members such as Martin Neukom, who in his role as head of the Zürich Construction Department and member of the Government of the Canton of Zürich, said that such a ban was unnecessary anyway,

2234 - Emma Farge and Gloria Dickie, "Swiss parliament snubs European court climate ruling", *Reuters*, 12 June 2024, see https://www.reuters.com/world/europe/swiss-parliament-considers-snubbing-european-court-climate-ruling-2024-06-12/, accessed 12 August 2024.

2235 - Stefan Diepenbrock and Matthias Rey, "Mehrheit der Schweizer Bevölkerung für weitere Nutzung der Kernenergie", Nuklearforum Schweiz, 11 August 2022 (in German), see https://www.nuklearforum.ch/de/medienmitteilung/mehrheit-der-schweizer-bevoelkerung-fuer-weitere-nutzung-der-kernenergie, accessed 12 June 2024.

2236 - Keystone-SDA, "Fewer than third of Swiss back nuclear power", *SWI*, 20 December 2023, see https://www.swissinfo.ch/eng/politics/fewer-than-third-of-swiss-back-nuclear-power/49074064, accessed 12 June 2024.

2237 - Federal Chancellery, "Eidgenössische Volksinitiative 'Jederzeit Strom für alle (Blackout stoppen)'", Government of Switzerland, 24 July 2024 (in German), see https://www.bk.admin.ch/bk/de/home/politische-rechte/pore-referenzseite.html, accessed 30 July 2024.

2238 - Julien Furrer, "Return to nuclear power: problematic or a pragmatic solution?", *SWI swissinfo.ch*, 11 April 2024, see https://www.swissinfo.ch/eng/swiss-politics/return-to-nuclear-power-problematic-or-a-pragmatic-solution/75469944, accessed 12 June 2024.

2239 - Agnes Pedrero, "Swiss approve law boosting renewable energy generation", *TechXplore*, 10 June 2024, see https://techxplore.com/news/2024-06-swiss-law-boosting-renewable-energy.html, accessed 12 June 2024; and Federal Council of Switzerland, "Federal Act on a Secure Electricity Supply from Renewable Energy Sources", Updated 9 June 2024, see https://www.admin.ch/gov/en/start/documentation/votes/20240609/federal-act-on-a-secure-electricity-supply-from-renewable-energy-sources.html, accessed 9 June 2024.

2240 - *SRF*, "Atomenergie-Debatte in der Schweiz geht weiter", *Schweizer Radio und Fernsehen*, 10 June 2024 (in German), see https://www.srf.ch/news/schweiz/nach-ja-zu-stromgesetz-die-atomenergie-frage-kommt-wieder-aufs-tapet, accessed 12 June 2024.

2241 - Tobias Bruggmann, Sermîn Faki and Ruedi Studer, "Albert Rösti veut faire sauter l'interdiction des centrales nucléaires", *Blick*, 10 June 2024, see https://www.blick.ch/fr/news/suisse/apres-son-succes-sur-lelectricite-albert-roesti-veut-faire-sauter-linterdiction-des-centrales-nucleaires-id19830015.html, accessed 10 June 2024.

because "nobody would make investments into a [new] nuclear power plant".[2242] However, MP Nordmann said the removal would be "devastating" because it would shift the focus away from implementing the necessary renewables expansions and entrap it in a "false debate".[2243]

The major goal of the new referendum was to cover the so-called "winter shortage" entirely with renewables, as Switzerland turns into a net-power-importer in winter.

Domestic production of non-hydro renewable-energy based electricity covered only 8.7 percent of the country's electricity generation in 2023. In total, 72.1 TWh had been produced. The bulk was covered by hydro at 56.6 percent, followed by nuclear at 32.4 percent.[2244] With the acceptance of the June-2024 referendum, Swiss efforts to boost solar PV and wind power expansion, such as the "Alpine Solar Initiative", can proceed. This initiative was introduced in late 2022 to speed up approval processes of alpine solar farms,[2245] and individual projects may now advance—as long as they manage to produce first electricity in 2025.[2246] The major goal of the new referendum was to cover the so-called "winter shortage" entirely with renewables, as Switzerland turns into a net-power-importer in winter. The plan is to increase renewable energy production during these winter months by 6 TWh by 2040.[2247]

Switzerland is strongly reliant on Russia's Rosatom for its enriched uranium. Half of the fuel material for Leibstadt and all of it for Beznau is of Russian origin. Since Russia's attack on Ukraine, Axpo, the operator at both plants, has been facing criticism regarding its continued cooperation with Rosatom.[2248] Axpo said that it would honor the contracts for Beznau (until 2030) and Leibstadt (until 2025), but will not extend cooperation.[2249]

Nonetheless, in August 2022, the utility claimed that there would be no Russian uranium coming to Europe due to blocked trade routes.[2250] However, reports suggest that in November 2022, Russian ship "Mikhail Dudin" set sail to transport uranium to Rotterdam, which would be

2242 - Malte Aeberli and Stefan Häne, "Interview mit Zürcher Regierungsrat – «Ich persönlich finde ein Windrad in der Landschaft schön»" (in German), *Tages-Anzeiger*, 13 May 2024, see https://www.tagesanzeiger.ch/martin-neukom-zum-stromgesetz-wir-brauchen-kein-akw-verbot-354164959950 accessed 12 June 2024.

2243 - Tobias Bruggmann, Sermîn Faki and Ruedi Studer, "Albert Rösti veut faire sauter l'interdiction des centrales nucléaires", *Blick*, 10 June 2024, see https://www.blick.ch/fr/news/suisse/apres-son-succes-sur-lelectricite-albert-roesti-veut-faire-sauter-linterdiction-des-centrales-nucleaires-id19830015.html, accessed 10 June 2024.

2244 - OFEN/BFE/SFOE, "Schweizerische Elektrizitätsstatistik 2023 / Statistique suisse de l'électricité 2023", Office fédérale de l'énergie/Bundesamt für Energie/Swiss Federal Office of Energy, April 2023, op. cit.

2245 - Bundesversammlung, "Parlament einigt sich auf Details der Solaroffensive", Swiss Parliament, 27 September 2022 (in German), see https://www.parlament.ch/de/services/news/Seiten/2022/20220927111913386194158159038_bsd064.aspx, accessed 12 August 2024.

2246 - *SRF*, "Alp Morgeten - Erste alpine Gross-Solaranlage in der Schweiz bewilligt", *Schweizer Radio und Fernsehen*, 3 May 2024 (in German), see https://www.srf.ch/news/schweiz/alp-morgeten-erste-alpine-gross-solaranlage-in-der-schweiz-bewilligt, accessed 12 August 2024.

2247 - IEA, "Switzerland 2023 - Energy Policy Review", International Energy Agency, September 2023, see https://iea.blob.core.windows.net/assets/b6451900-e6ef-45a8-922d-117520e09a82/Switzerland2023.pdf, accessed 12 June 2024.

2248 - Res Gehringer and Sascha Buchbinder, "Russische Brennstäbe für Schweizer AKW", *SRF Rundschau*, 31 March 2022 (in German), see https://www.srf.ch/news/international/axpo-in-der-kritik-russische-brennstaebe-fuer-schweizer-akw, accessed 10 September 2023; and Stefan Häne, "Axpo bleibt bis 2030 von Uran aus Russland abhängig", *Tagesanzeiger*, 11 September 2023 (in German), see https://www.tagesanzeiger.ch/trotz-ukraine-krieg-axpo-bleibt-bis-2030-von-uran-aus-russland-abhaengig-667105390358, accessed 30 July 2024.

2249 - Fabian Hägler, "Russisches Atomschiff unterwegs – mit Uran für Aargauer Kernkraftwerke?" *Aargauer Zeitung*, 11 November 2022 (in German), see https://www.aargauerzeitung.ch/aargau/kanton-aargau/uran-doch-wieder-russisches-uran-fuer-aargauer-atomkraftwerke-axpo-kann-umstrittene-lieferung-nicht-ausschliessen-ld.2371501?, accessed 10 September 2023.

2250 - Stefan Häne, "Axpo will neue Partner, ohne Russland zu vergraulen", *Tages-Anzeiger*, 11 August 2022 (in German), see https://www.tagesanzeiger.ch/axpo-will-neue-partner-ohne-russland-zu-vergraulen-669252921640, accessed 10 September 2023.

transported to the fuel plant in Lingen, Germany, from where 44 fuel assemblies were to be transported to Beznau and 80 fuel assemblies to Leibstadt. Reportedly, this is confirmed by German export documents. Axpo neither confirmed nor denied these reports.[2251] At Lingen, French company Framatome and Rosatom are planning to cooperate via a French joint venture company after withdrawing—a few days prior to the invasion of Ukraine—a previous application for setting up a joint venture filed with the German authorities (see Framatome and the Lingen VVER Fuel Manufacturing Plant Project).[2252] As of 2022, Axpo itself said that it had enough fuel reserves to operate its plants for several years.[2253] As of April 2024, the situation had not changed, and a cancelation of delivery contracts by Axpo was, according to André Hunziker, chief operator of the Leibstadt NPP, not possible (without contract violation) because Russian uranium did not fall under any sanctions.[2254] If Axpo left the contract, the company might be liable for compensation payments to Russian suppliers amounting to CHF150–200 million (US$165.4–220.5 million). Further, it is argued that Russian suppliers would "profit in two ways" because they could then sell the reserved uranium to other buyers.[2255] However, Axpo noted that there were developments in finding a replacement for future supply.[2256]

On 10 September 2022, Switzerland concluded a major step in developing a final nuclear waste depository when the National Cooperative for the Disposal of Radioactive Waste (Nagra) announced the proposed location for the site at Northern Lägern, close to the German border. The application for the construction of the repository is to be submitted by the end of 2024, while the final governmental decision is not expected before 2029 (and will probably have to be validated through public consensus, anticipated for 2031). Current plans envision initial construction work for underground geological investigation to start in 2034, actual repository construction to begin in 2045, and the first disposal of waste around 2050–2060.[2257] As of early 2024, the acceptance for the site is high both nationwide and locally, a potentially positive signal for the planned referendum in the 2030s.[2258]

2251 - Stefan Häne, "Importiert die Axpo doch wieder russisches Uran?", *Tages-Anzeiger*, 11 November 2022 (in German), see https://www.tagesanzeiger.ch/importiert-axpo-doch-wieder-russisches-uran-724530496073, accessed 10 September 2023.

2252 - *dpa*, "Joint Venture stellt Brennelemente her", *Deutsche Presse-Agentur*, as published in *Süddeutsche Zeitung* (in German), 30 March 2023, see https://www.sueddeutsche.de/wissen/atom-lingen-ems-joint-venture-stellt-brennelemente-her-dpa.urn-newsml-dpa-com-20090101-230330-99-142358, accessed 10 September 2023.

2253 - Fabian Hägler, "Russisches Atomschiff unterwegs – mit Uran für Aargauer Kernkraftwerke?", *Aargauer Zeitung*, November 2022, op. cit.; and Stefan Häne, "Schweizer Kernkraftwerke beziehen Uran aus Russland", *Der Bund*, 1 March 2022 (in German), see https://www.derbund.ch/schweizer-kernkraftwerke-beziehen-uran-aus-russland-917246134946, accessed 10 September 2023.

2254 - Fabian Hägler, "Aargauer AKW: Wann endet der Bezug von russischem Uran?", *Aargauer Zeitung*, 22 April 2024 (in German), see https://www.aargauerzeitung.ch/aargau/kanton-aargau/atomenergie-ausstieg-in-sicht-wie-lange-setzen-die-aargauer-atomkraftwerke-noch-auf-russisches-uran-ld.2609663?reduced=true, accessed 12 June 2024.

2255 - Stefan Häne, "Axpo ersetzt Uran aus Russland – aber die Sache hat einen Haken", *Tages-Anzeiger*, 19 January 2024 (in German), see https://www.tagesanzeiger.ch/axpo-ersetzt-uran-aus-russland-kritik-reisst-nicht-ab-779682064474, accessed 12 August 2024.

2256 - Fabian Hägler, "Aargauer AKW: Wann endet der Bezug von russischem Uran?", *Aargauer Zeitung*, 22 April 2024, op. cit.

2257 - Nagra, "The Site for the Deep Geological Repository—Nagra's Proposal", Nationale Genossenschaft für die Lagerung radioaktiver Abfälle/National Cooperative for the Disposal of Radioactive Waste, September 2022, see https://nagra.ch/wp-content/uploads/2022/09/Report-the-site-for-the-deep-geological-repository-Nagras-proposal.pdf; and *SWI swissinfo.ch*, "Site in northern Switzerland chosen for nuclear waste storage", 10 September 2022, see https://www.swissinfo.ch/eng/sci-tech/site-in-northern-switzerland-chosen-for-nuclear-waste-storage-/47890816; both accessed 10 September 2023; also Nagra, "Angepasster Zeitplan im Sachplanverfahren", 14 April 2014 (in German), see https://nagra.ch/aktuelles/angepasster-zeitplan-im-sachplanverfahren/; and Nagra, "Standortsuche", Nagra, Undated (in German), see https://nagra.ch/wissensforum/standortsuche/, both accessed 12 August 2024.

2258 - Francesca Prader, "Nagra-Standort Nördlich Längern: Erstmals zeigt Umfrage, was Bevölkerung denkt", *Neue Zürcher Zeitung*, 6 February 2024 (in German), see https://www.nzz.ch/zuerich/nagra-standort-noerdlich-laengern-erstmals-zeigt-umfrage-was-bevoelkerung-denkt-ld.1775729, accessed 12 June 2024; and Nagra,

United Kingdom

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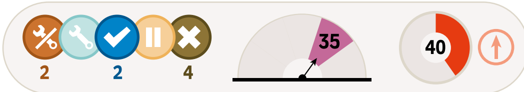
CENTRAL AND EASTERN EUROPE

Bulgaria



Bulgaria's two operating VVER-1000 reactors at Kozloduy provided 15.5 TWh of electricity in 2023 down from 15.8 TWh in 2022, thereby unintuitively bringing the share of electricity generated from nuclear power up from 32.6 percent in 2022 to 40.4 percent, still well below a maximum share of 47.3 percent in 2002.

In recent years, the country has been plagued by an unstable political situation due to a splintered parliament that has led to several hung governments and a series of general elections. In June 2023, Parliament approved a new coalition government, which conservative Citizens for European Development of Bulgaria (GERB) and liberal We Continue the Change (PP) parties had formed based on the agreement to alternate leadership every nine months.[2259] The first power transfer failed in March 2024, leading to a breakdown of the coalition.[2260] An interim government was put in place in April 2024, and a snap election was called for 9 June 2024, the same day as the European Parliament elections. This election marks the sixth general election since April 2021.[2261] GERB gained the most seats and was formally tasked to form a new government by President Rumen Radev. However, whether this can be achieved is uncertain considering that, according to *Reuters*, the party "is yet to secure the support of at least two other political parties that it would need to command a majority".[2262]

Against this political uncertainty stands a Bulgarian energy sector historically dependent on Russian imports, and with ambitious nuclear new build plans. In the wake of the Russian attack on Ukraine, this dependence has been drastically reduced. Russian natural gas imports, amounting to more than 90 percent of total supply before the war, have been completely halted by Russia.[2263] Demand in 2023 was covered via Greek[2264] and Turkish LNG terminals, and Bulgaria has signed long-term contracts with Turkish company BOTAŞ for access to

2259 - *AFP*, "Bulgaria breaks two-year deadlock with power sharing govt", as published by *France 24*, 22 May 2023, see https://www.france24.com/en/live-news/20230522-bulgaria-breaks-two-year-deadlock-with-power-sharing-govt, accessed 28 May 2024; and RFE/RL, "Bulgarian Parliament Approves Coalition Government After Five Elections In Two Years", RadioFreeEurope/RadioLiberty, 6 June 2023, see https://www.rferl.org/a/bulgaria-parliament-approves-new-government-denkov/32447233.html, accessed 31 July 2024.

2260 - Henry Foy, "What Bulgaria's government collapse means for the rest of the EU", *The Financial Times*, 27 March 2024, see https://www.ft.com/content/670818b4-1c2c-4188-b362-6b7a1816cfde, accessed 28 May 2024.

2261 - *The Associated Press*, "Bulgarian parliament formally approves caretaker government to run country until June 9 elections", 9 April 2024, see https://apnews.com/article/bulgaria-interim-government-elections-420c9287382ee4bf93c8463842554617, accessed 28 May 2024.

2262 - Stoyan Nenov and Ivana Sekularac, "Bulgaria's centre-right GERB party to try to form minority government", *Reuters*, 1 July 2024, see https://www.reuters.com/world/europe/bulgarias-centre-right-gerb-party-try-form-minority-government-2024-07-01/, accessed 31 July 2024.

2263 - Andrew Higgins, "Bulgarian Distrust of Russia Simmers Over a Black Sea Oil Terminal", *The New York Times*, 1 May 2024, see https://www.nytimes.com/2024/05/01/world/europe/bulgaria-russia-oil-ukraine.html, accessed 28 May 2024.

2264 - *CE Energy News*, "Over 15.5 million MWh transported via the Greece-Bulgaria interconnector in 2023", 8 January 2024, see https://ceenergynews.com/oil-gas/over-15-5-million-mwh-transported-via-the-greece-bulgaria-interconnector-in-2023/, accessed 28 May 2024.

its terminals and pipelines.[2265] The country's only oil refinery is owned by Russian company Lukoil and as of May 2022, about 50 percent of the processed crude oil was of Russian origin.[2266] Although the E.U. banned oil imports from Russia, in June 2022 Bulgaria received a temporary exemption valid until December 2024[2267], and proceeded to process only Russian crude. Legislation enabling to take control of the refinery (for a limited period) if necessary was approved in January 2023[2268] and in November 2023, the government announced that it would end Russian sea-born oil imports by March 2024 cutting off a significant Russian income stream[2269]. Oil imports indeed ceased on 1 March 2024.[2270] Concrete plans have been made to take over full control of Lukoil to further reduce Russian influence, contrasted by fears of job losses from the region's largest employer in one of the E.U.'s poorest countries.[2271]

Bulgaria is also dependent on Russian deliveries of equipment and fuel for its only operational nuclear power plant at Kozloduy. Consequently, Bulgaria is seeking to diversify its nuclear fuel supply. In November 2022, Parliament voted to shift nuclear fuel supply away from Russian sources with a three-quarter majority,[2272] although a delivery contract had been signed with Russian fuel company TVEL in December 2019 for both operational units at Kozloduy for fuel provision until 2025.[2273] In 2021, in a step to implement the E.U.'s Energy Security Strategy that demands the diversification of nuclear supplies and services, Westinghouse and Kozloduy's operator had signed a licensing contract for fuel to be used at Unit 5[2274], and following the above-mentioned vote in the Bulgarian parliament, a ten-year contract with Westinghouse was signed in December 2022 to begin supplying fuel to Unit 5 by 2024.[2275] Loading of the first fuel that arrived at the site in April 2024, began in May.[2276] On 10 June 2024, the operator

2265 - Tsvetelia Tsolova, "Bulgaria signs long-term gas deal with Turkey", *Reuters*, 3 January 2023, see https://www.reuters.com/business/energy/bulgaria-signs-deal-access-turkeys-lng-terminals-gas-network-2023-01-03/, accessed 31 July 2024.

2266 - Tsvetelia Tsolova, "Bulgaria to seek exemption from EU oil embargo on Russia if possible, deputy PM says", *Reuters*, 4 May 2022, see https://www.reuters.com/business/energy/bulgaria-seek-exemption-any-eu-embargo-russian-oil-deputy-pm-says-2022-05-04/, accessed 4 August 2023.

2267 - European Commission, "Russia's war on Ukraine: EU adopts sixth package of sanctions against Russia", Press Release, 3 June 2022, see https://ec.europa.eu/commission/presscorner/detail/en/IP_22_2802, accessed 4 November 2023.

2268 - Tsvetelia Tsolova, "Bulgaria clears way to take control of Lukoil oil refinery if needed", *Reuters*, 13 January 2023, see https://www.reuters.com/business/energy/bulgaria-clears-way-take-control-lukoil-oil-refinery-if-needed-2023-01-13/, accessed 4 August 2023.

2269 - Victor Jack, "Bulgaria accelerates end of sanctions loophole that earned Russia €1B", *Politico*, 17 November 2023, see https://www.politico.eu/article/bulgaria-accelerates-end-of-sanctions-loophole-that-earned-russia-e1b/, accessed 28 May 2024.

2270 - *Novinite*, "Bulgaria Ceases Russian Oil Imports: Parliament's Decision Marks End of Derogation", 1 March 2024, see https://www.novinite.com/articles/224553/Bulgaria+Ceases+Russian+Oil+Imports%3A+Parliament%27s+Decision+Marks+End+of+Derogation, accessed 7 August 2024.

2271 - Andrew Higgins, "Bulgarian Distrust of Russia Simmers Over a Black Sea Oil Terminal", *The New York Times*, 1 May 2024, op. cit.

2272 - *WNN*, "Bulgarian parliament votes to switch from Russian nuclear fuel", 10 November 2022, see https://www.world-nuclear-news.org/Articles/Bulgarian-parliament-votes-to-switch-from-Russian, accessed 26 July 2023.

2273 - TVEL, "TVEL and Kozloduy NPP have contracted supplies of Russian nuclear fuel to Bulgaria through 2025", 19 December 2019, see https://www.tvel.ru/en/press-center/news/?ELEMENT_ID=8140, accessed 19 July 2023.

2274 - Kozloduy NPP, "Press Release", 4 February 2021, see https://www.kznpp.org/en/news/474-PRESS-RELEASE, accessed 31 July 2024.

2275 - Westinghouse, "Westinghouse's VVER-1000 Nuclear Fuel Fabrication Agreement Helps Cement Bulgaria's Energy Security", Press Release, 22 December 2022, see https://info.westinghousenuclear.com/uk/news-insights/westinghouse-vver-1000-nuclear-fuel-fabrication-agreement-helps-cement-bulgarias-energy, accessed 4 November 2023.

2276 - Westinghouse, "Westinghouse Delivers First VVER-1000 Fuel Reload to Bulgaria", Press Release, 29 May 2024, see https://info.westinghousenuclear.com/news/westinghouse-delivers-first-vver-1000-fuel-reload-to-bulgaria, accessed 26 June 2024.

indicated that Unit 5 was back on the grid, operating with 43 cartridges manufactured by Westinghouse.[2277]

Further it was announced on 30 December 2022 that Unit 6 was to be supplied with Framatome fuel from 2025 to 2034.[2278] According to the press release, the agreement "sets out the schedule for future negotiations and the conclusion of a contract."[2279] Although in May 2024 the company indicated it had "recently signed a contract to supply fuel to Kozloduy 6" [2280], as of writing in mid-2024, additional details had not been disclosed. Instead, the Bulgarian Government reiterated with conflicting statements regarding the timeline of signature.[2281] As Framatome currently lacks production capacities for VVER fuel, it remains unclear how it would be provided (see Russia Nuclear Dependencies), and WNISR will continue to monitor the situation and update information once it becomes more reliable. In March 2023, the acting Bulgarian Government passed a derogation from E.U. import sanctions to allow for Russian parts and materials to be brought into the country for the annual maintenance of Kozloduy.[2282]

The Kozloduy site originally consisted of six reactors, of which the oldest four (VVER-440/v230) were closed as part of an agreement by the G7 in Munich in 1992—as they were considered impossible to be "economically upgraded to a required level of safety"—and implemented through the agreement for Bulgaria to join the E.U. in 2007.[2283] Both operational VVER-1000 (V-320) reactors (Units 5 and 6), that started up in 1987 and 1991, respectively, are undergoing a relicensing program to extend their operating lifetimes up to 60 years, compared to their original 30-year license.[2284] Regulation does not allow for individual operational licenses to

2277 - Kozloduy NPP, "Завърши Плановият Годишен Ремонт На Пети Блок На Аец 'Козлодуй'", Press Release (in Bulgarian), 10 June 2024, see https://www.kznpp.org/bg/novini/610-ZAVARShI-PLANOVIYaT-GODIShEN-REMONT-NA-PETI-BLOK-NA-AETs-%E2%80%9EKOZLODUY%E2%80%9D, accessed 31 July 2024.

2278 - Kozloduy NPP, "Министър Христов: С Подписаното Споразумение С Фраматом Завършва Процесът По Диверсификация На Доставките За Българската Ядрена Централа", Press Release (in Bulgarian), 30 December 2022, see https://www.kznpp.org/bg/novini/560-MINISTAR-HRISTOV%3A-S-PODPISANOTO-SPORAZUMENIE-S-FRAMATOM-ZAVARShVA-PROTsESAT-PO-D, accessed 31 July 2024.

2279 - Ibidem.

2280 - Framatome, "Framatome and Bulgarian Technical University to Collaborate on Education and Training", Press Release, 2 May 2024, see https://www.framatome.com/medias/framatome-and-bulgarian-technical-university-to-collaborate-on-education-and-training/, accessed 31 July 2024.

2281 - Council of Ministers, "Bulgaria and France explore opportunities for cooperation in power and defense sectors", Government of Bulgaria, 12 October 2023, see https://www.gov.bg/special/en/Press-center/News/Bulgaria-and-France-explore-opportunities-for-cooperation-in-power-and-defense-sectors; and Ministry of Energy, "Deputy Minister Samandov presented our nuclear energy priorities at a U.S.-Bulgarian workshop", Government of Bulgaria, 7 May 2024, see https://www.me.government.bg/en/news/deputy-minister-samandov-presented-our-nuclear-energy-priorities-at-a-u-s-bulgarian-workshop-3429.html?p=eyJoeXBlIjoiaG90bmV3cyJ9; Ministry of Energy, "Kozloduy Nuclear Power Plant has already loaded the first 43 cartridges of an alternative type of fuel produced by the U.S. Westinghouse", Government of Bulgaria, 29 May 2024, see https://me.government.bg/en/news/kozloduy-nuclear-power-plant-has-already-loaded-the-first-43-cartridges-of-an-alternative-type-of-fuel-produced-by-the-u-s-westinghouse-3446.html; all accessed 31 July 2024.

2282 - *NEI Magazine*, "Bulgaria to continue imports from Russia for Kozloduy NPP", 24 March 2023, see https://www.neimagazine.com/news/newsbulgaria-to-continue-imports-from-russia-for-kozloduy-npp-10701347, accessed 26 July 2023.

2283 - European Commission, "Proposal for a Council Regulation on Community Financial Assistance with Respect to the Decommissioning of Units 1 to 4 of the Kozloduy Nuclear Power Plant in Bulgaria", Commission Staff Working Document COM(2009) 581 final, 27 October 2009, see https://data.consilium.europa.eu/doc/document/ST-15112-2009-ADD-1/en/pdf; and Michael Winfrey, "Bulgaria fumes as EU demands nuke reactor shutdowns", *Reuters*, 21 January 2007, see https://www.reuters.com/article/uk-eu-candidates-nuclear-idUSL0585015220061227; both accessed 26 July 2023.

2284 - Vladimir Popov, "Kozloduy NPP Units 5&6 Modernization and Plant Life Extension (PLEX) Programs", Lifetime Management Section, Kozloduy NPP, as published by *BgNS Transactions*, Bulgarian Nuclear Society, 2018, see https://bgns-transactions.org/Journals/23-1/14_V.%20POPOV.pdf, accessed 7 August 2024.

exceed ten years.[2285] Consequently, Unit 5 was awarded an additional 10-year operating license in 2017 to enable it to continue operating until 2027, and in October 2019, Unit 6 was granted a license to operate until 2029. Reportedly, the total cost of the two-unit lifetime extension program was just BGN292 million (US$$_{2019}$167 million),[2286] a number by an order of magnitude lower than similar programs in other countries (e.g. France). An IAEA review conducted in June 2023 concluded that the plant's operator had "completed all major actions to safely operate the reactors in the LTO [long-term operation] period", yet some further work remained to be carried out concerning the proper implementation of new ageing management programs for mechanical components and cables.[2287]

Parliament passed a draft decision to order the then acting government to speed up the license approval and construction process of the planned seventh reactor at Kozloduy

Meanwhile, plans to build two additional reactors at the Kozloduy site have been advancing. In January 2023, Parliament passed a draft decision to order the then acting government to speed up the license approval and construction process of the planned seventh reactor at Kozloduy, including by assigning "the Council of Ministers to hold negotiations with the U.S. Government on the conclusion of an Intergovernmental Agreement on the construction of a new nuclear power plant at NPP Kozloduy with AP1000 technology." The vote also motioned the government to begin licensing and environmental impact assessment procedures for an eighth reactor.[2288]

In March 2023, state-owned company Kozloduy NPP-Newbuild signed an MoU with U.S. manufacturer Westinghouse to begin the planning of one or two AP-1000 PWRs at the site[2289] which was formalized through a Front-End Engineering and Design (FEED) contract in June 2023.[2290] The government instructed the Ministry of Energy to "organize the necessary procedures on the selection of a contractor" and "negotiations with financial institutions

2285 - Pavlin Groudev, Neli Zaharieva and Antoaneta Stefanova, "Status and future prospects of nuclear industry development in Bulgaria", *Nuclear Engineering and Design*, July 2024, see https://linkinghub.elsevier.com/retrieve/pii/S0029549324002887, accessed 7 August 2024.

2286 - *WNN*, "Kozloduy unit 6 clear to operate for another 10 years", 2 October 2019, *World Nuclear News*, see https://www.world-nuclear-news.org/Articles/Kozloduy-unit-6-clear-to-operate-for-another-10-ye, accessed 4 April 2021.

2287 - IAEA, "IAEA Concludes Long Term Operation Safety Review at Bulgaria's Kozloduy Nuclear Power Plant", Press Release 57/2023, International Atomic Energy Agency, 16 June 2023, see https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operation-safety-review-at-bulgarias-kozloduy-nuclear-power-plant, accessed 23 June 2023.

2288 - National Assembly of the Republic of Bulgaria, "The Parliament has obliged the Council of Ministers to change the National Recovery and Resilience Plan in the coal-fired power plants part", 12 January 2023, see https://www.parliament.bg/en/news/ID/5628, accessed 31 July 2024.

2289 - Westinghouse, "Westinghouse Signs MOU with Bulgaria's Kozloduy NPP-Newbuild for AP1000® Technology Deployment", 2 March 2023, see https://info.westinghousenuclear.com/news/westinghouse-signs-mou-with-bulgarias-kozloduy-npp-newbuild-for-ap1000-technology-deployment, accessed 31 July 2024; and Kamen Kraev, "Westinghouse Signs Agreement To Begin Planning For New Nuclear At Kozloduy", *NucNet*, 3 March 2023, see https://www.nucnet.org/news/westinghouse-signs-deal-to-begin-planning-for-new-nuclear-at-kozloduy-3-5-2023, accessed 30 May 2023.

2290 - Westinghouse, "Westinghouse Signs Key Contract for AP1000® Reactor with Bulgaria's Kozloduy NPP-Newbuild to Support Bulgaria's Energy Future", Press Release, 14 June 2023, see https://info.westinghousenuclear.com/news/westinghouse-signs-kozloduy-contract-in-bulgaria, accessed 31 July 2024.

on the provision of a loan resource" in October 2023.[2291] On 18 December 2023, Parliament also approved a set of instructions, which included a detailed preliminary schedule up to the commissioning of the first unit by 31 December 2034.[2292] An "invitation for expressions of interest" for the engineering, construction, delivery and commissioning before 2035 was issued in January 2024,[2293] and by February 2024, five companies—French EDF, U.S. companies Bechtel and Fluor, South Korean Hyundai, and the China National Nuclear Corporation (CNNC)—had expressed their interest.[2294] Russian bidders had been explicitly excluded.[2295] Hyundai was subsequently preselected as the only potential contractor using Westinghouse's AP-1000 technology,[2296] prompting the beginning of talks with a final investment decision expected by 30 July 2025[2297] ahead of which former Bulgarian Energy Minister Ruman Radev said that the costs "should not exceed 14 billion"; without specifying the currency.[2298] Reportedly, he further said that the cost of electricity generated by the new units would be capped at €65/MWh (US$70/MWh), and that the official project cost was to be announced in a report by Westinghouse, due in March 2024.[2299] As of the time of writing in July 2024, this report had not been made publicly available. Reported target completion dates for Unit 7 vary from 2033[2300] over "end-2034"[2301] to 2035.[2302] Unit 8 shall follow "two or three years after the first one"

2291 - Daria Sito-Sucic, "Bulgaria to begin work on two reactors at Kozloduy nuclear site", *Reuters*, 25 October 2023, see https://www.reuters.com/world/europe/bulgaria-begin-work-two-reactors-kozloduy-nuclear-site-2023-10-25/, accessed 28 May 2024; and Ministry of Energy, "The Council of Ministers approved action to build units 7 and 8 of Kozloduy Nuclear Power Plant with AP 1000 technology", Government of Bulgaria, 25 October 2023, see https://me.government.bg/en/news/the-council-of-ministers-approved-action-to-build-units-7-and-8-of-kozloduy-nuclear-power-plant-with-ap-1000-technology-3274.html?, accessed 31 July 2024.

2292 - National Assembly of the Republic of Bulgaria, "Решение за предприемане на действия по изграждането на 7-и и 8-и блок на площадка № 2 на АЕЦ „Козлодуй" ЕАД с технология AP1000", adopted 18 December 2023, published 19 December 2023, see https://dv.parliament.bg/DVWeb/showMaterialDV.jsp;jsessionid=4DD3FC0824C6F823190C23654F2F2266?idMat=202021, accessed 1 August 2024.

2293 - Kozloduy NPP New Builds' PLC, "Invitation For Expression Of Interest—Selection of a Constructor for engineering, construction, procurement and commissioning of new nuclear power plant on the approved site in Kozloduy with AP1000® technology (EP+C turnkey contract, called the Contract)", January 2024, see https://npp-nb.bg/wp-content/uploads/2024/01/Invitation-for-expression-of-interest-1.pdf, accessed 1 August 2024.

2294 - Kozloduy NPP, "Five Companies Submitted Applications Under an Announced Call for Expressions of Interest for the Construction of New Nuclear Plant by 'Kozloduy Npp-New Builds PLC'", 2 February 2024, see https://www.kznpp.org/en/news/592-FIVE-COMPANIES-SUBMITTED-APPLICATIONS-UNDER-AN-ANNOUNCED-CALL-FOR-EXPRESSIONS-OF, accessed 31 July 2024.

2295 - Krassen Nikolov, "Bulgaria's two US nuclear reactors to cost under $14 billion", *Euractiv*, 14 February 2024, see https://www.euractiv.com/section/politics/news/bulgarias-two-us-nuclear-reactors-to-cost-under-14-billion/, accessed 28 May 2024.

2296 - Kozloduy NPP, "Information Notice", 16 February 2024, see https://www.kznpp.org/en/news/595-INFORMATION-NOTICE, accessed 31 July 2024; and National Assembly of the Republic of Bulgaria, "РЕШЕНИЕ за провеждане на преговори с потенциален строител, включен в кратката листа на потенциални строители за инженеринг, строителство, доставка и въвеждане в експлоатация на ядрена централа на одобрената площадка в Козлодуй, с технология AP1000", adopted 23 February 2024, see https://www.parliament.bg/bg/desision/ID/165374, accessed 31 July 2024.

2297 - Ministry of Energy, "Minister Malinov discussed the financing of project for new nuclear capacity with the President of Exim Bank", Republic of Bulgaria, 21 May 2024, see https://www.me.government.bg/en/news/minister-malinov-discussed-the-financing-of-project-for-new-nuclear-capacity-with-the-president-of-exim-bank-3438.html?, accessed 31 July 2024.

2298 - Yoana Vodenicharova, "Bulgarian, US Governments Sign Strategic Agreement on Nuclear Energy Development in Bulgaria", *Bulgarian News Agency*, 12 February 2024, see https://www.bta.bg/en/news/economy/617000-bulgarian-us-governments-sign-strategic-agreement-on-nuclear-energy-development, accessed 31 July 2024.

2299 - *NEI Magazine*, "Bulgaria and USA formalise agreement on Kozloduy 7&8", *Nuclear Engineering International*, 14 February 2024, see https://www.neimagazine.com/news/bulgaria-and-usa-formalise-agreement-on-kozloduy-78-11512686/, accessed 28 May 2024.

2300 - Daria Sito-Sucic, "Bulgaria to begin work on two reactors at Kozloduy nuclear site", *Reuters*, 25 October 2023, op. cit.

2301 - Antonia Kakalova-Grey, "Bulgarian Parl Approves Funding for New Units at Kozloduy NPP", *SeeNews*, 18 December 2023, see https://seenews.com/news/bulgarian-parl-approves-funding-for-new-units-at-kozloduy-npp-843427, accessed 28 May 2024.

2302 - *WNN*, "First Westinghouse fuel at Bulgaria's Kozloduy nuclear power plant", 22 April 2024, see https://world-nuclear-news.org/Articles/First-Westinghouse-fuel%C2%A0at-Bulgaria-s-Kozloduy-nuc, accessed 15 May 2024.

according to *World Nuclear News*.[2303] Discussions with U.S. Export-Import (EXIM) Bank are underway, working towards meeting the 30 July 2025 deadline to gather the necessary funding, as set by Parliament's preliminary timeline.[2304] EXIM Bank is involved in financing several nuclear projects in Eastern Europe, including Romania (see Romania in Annex 1) and Poland (see Poland Focus).

In parallel, the former government entered into two independent cooperation agreements to "strengthen nuclear cooperation" with both France and the U.S.[2305]

The Belene Saga

There have been ongoing attempts to build another nuclear power plant at Belene in Northern Bulgaria. Construction started in 1987 but was halted in 1990 and suspended indefinitely in 1991. Work officially resumed in 2008 but was abandoned again in 2012.[2306] After multiple failed attempts to relaunch the project (see previous WNISR editions), the idea was definitely abandoned in 2023.

In July 2023, negotiations were to begin with Ukrainian authorities regarding the purchase of mothballed equipment to be used for the planned resumption of the construction of Units 3 and 4 of the Western Ukrainian Khmelnytskyi plant.[2307] In October 2023, the Belene project was officially terminated by government (for the fourth time) and the equipment transfer became more concrete, as the volume (including "two reactor [pressure vessels?], four steam generators and four circulation pumps") as well as the envisaged price tag, BGN1.2 billion ($644 million), were made public.[2308] Amidst political uncertainty regarding a joint E.U. stance regarding financial aid to Ukraine, the procedure of the transfer project was briefly delayed in January 2024,[2309] but nonetheless, a Ukrainian delegation, joined by nuclear experts sent by the U.S. Embassy in Sofia, visited the Belene site in May 2024 to inspect the to-be-bought material.[2310] Acting Bulgarian Energy Minister Vladimir Malinov expects the National Assembly

2303 - *WNN*, "Five express interest in Kozloduy new nuclear construction", 5 February 2024, see https://www.world-nuclear-news.org/Articles/Five-express-interest-in-Kozlody-new-nuclear-const, accessed 28 May 2024.

2304 - Ministry of Energy, "Minister Malinov discussed the financing of project for new nuclear capacity with the President of Exim Bank", Government of Bulgaria, 21 May 2024, see https://www.me.government.bg/en/news/minister-malinov-discussed-the-financing-of-project-for-new-nuclear-capacity-with-the-president-of-exim-bank-3438.html?p=eyJwYWdlIjoofQ==, accessed 31 July 2024.

2305 - U.S. Embassy in Bulgaria, "The United States and Bulgaria Sign Agreement on Civil Nuclear Cooperation", Press Release, U.S. Embassy in Bulgaria, 12 February 2024, see https://bg.usembassy.gov/the-united-states-and-bulgaria-sign-agreement-on-civil-nuclear-cooperation/, accessed 28 May 2024; and National Assembly of the Republic of Bulgaria, "The National Assembly ratified the Agreement between the Governments of Bulgaria and the United States on cooperation on the nuclear capacity construction project at the Kozloduy NPP site", 22 March 2024; also Ministry of Energy, "Bulgaria and France signed a Declaration on cooperation in civil nuclear energy", Government of the Republic of Bulgaria, 22 February 2024, see https://me.government.bg/en/news/bulgaria-and-france-signed-a-declaration-on-cooperation-in-civil-nuclear-energy-3377.html, accessed 1 August 2024.

2306 - *WNN*, "Bulgarian government drops Belene", 29 March 2012, see https://www.world-nuclear-news.org/Articles/Bulgarian-government-drops-Belene, accessed 26 July 2023.

2307 - Kamen Kraev, "Bulgaria / Minister To Begin Talks With Ukraine On Sale Of Russia-Made Belene Nuclear Equipment", *NucNet*, 6 July 2023, see https://www.nucnet.org/news/minister-to-begin-talks-with-ukraine-on-sale-of-russia-made-belene-nuclear-equipment-7-4-2023, accessed 28 May 2024.

2308 - *NEI Magazine*, "Bulgaria cancels Belene NPP project", 17 October 2023, see https://www.neimagazine.com/news/newsbulgaria-cancels-belene-npp-project-11224401, accessed 17 October 2023.

2309 - *NEI Magazine*, "Bulgaria holds back on sale of Belene nuclear equipment to Ukraine", 16 January 2024, see https://www.neimagazine.com/news/bulgaria-holds-back-on-sale-of-belene-nuclear-equipment-to-ukraine-11439134/, accessed 28 May 2024.

2310 - Valentin Evstatiev, "US, Bulgarian, Ukrainian Experts Conclude Joint Technical Assessment of Belene Nuclear Power Plant", *Bulgarian News Agency*, 17 May 2024, see https://www.bta.bg/en/news/economy/672420-us-bulgarian-ukrainian-experts-conclude-joint-technical-assessment-of-belene-n, accessed 28 May 2024.

to approve of the deal "in the coming months", while an earlier *Reuters* report suggested the contract could be signed as early as June 2024.[2311] The Bulgarian Ministry of Energy indicated that as of early June 2024, "Bulgaria sent to Ukraine the general terms of the contract for the sale of equipment from the Belene Nuclear Power Plant site", which "became clear" during a discussion between the Ministers of both countries, while the "verification of the suitability and storage of the equipment has been successfully completed."[2312] Parliament has issued a decision in late 2023 which provides for the funds acquired through the sale of equipment to be directed towards the Kozloduy construction project.[2313] In the meantime, a tender for the transport of the transformer of the Belene plant, as back-up for the currently operational units at the Kozloduy plant, was launched in July 2024.[2314]

Energy Policy

In January 2023, then acting Energy Minister Rossen Hristov announced Bulgaria's energy strategy for 2023 to 2053 with plans to eliminate coal by 2038, albeit beginning to reduce coal usage only in 2030, while emphasizing Bulgaria's role as electricity exporter in the region.[2315] The plan includes the installation of 7 GW of solar and 2 GW of wind power by 2030, to be increased by 12 GW and 4 GW by 2050, respectively. Battery storage, electric vehicle charging stations and additional hydropower are also envisioned. Most notably however are the plans to increase nuclear power capacities. At the Belene site, despite project cancellations, the strategy reportedly envisions 2 GW of nuclear capacity by 2035–2040, and additional 2 GW are to be constructed at Kozloduy.[2316] In 2023, coal accounted for 28.9 percent of electricity generation, topped only by nuclear at 40.4 percent. The remainder was divided amongst solar PV (8.8 percent), hydro (7.8 percent), bioenergy (5.5 percent), wind (3.9 percent) and natural gas (3.9 percent).[2317]

2311 - Pavel Polityuk, "Exclusive: Ukraine hopes to start installing nuclear reactors from Bulgaria in June", *Reuters*, 22 March 2024, see https://www.reuters.com/business/energy/ukraine-hopes-start-installing-nuclear-reactors-bulgaria-june-2024-03-22/, accessed 28 May 2024.

2312 - Ministry of Energy, "Minister Malinov: Bulgaria will support Ukraine's energy sector", Government of Bulgaria, 12 June 2024, see https://www.me.government.bg/en/news/minister-malinov-bulgaria-will-support-ukraine-s-energy-sector-3457.html, accessed 1 August 2024.

2313 - National Assembly of the Republic of Bulgaria, "The National Assembly adopted at second reading the budgets of the National Health Insurance Fund and the State Social Insurance for 2024", 18 December 2023, see https://www.parliament.bg/en/news/ID/5897, accessed 1 August 2024.

2314 - *BBN*, "Kozloduy Nuclear Power Plant in Search of a Carrier for the Transformer from Belene Nuclear Power Plant", *Balkan Business News*, 12 July 2024, see https://www.balkanbusinessnews.com/kozloduy-nuclear-power-plant-in-search-of-a-carrier-for-the-transformer-from-belene-nuclear-power-plant/, accessed 7 August 2024.

2315 - *WNN*, "Bulgaria energy strategy includes four new nuclear reactors", 19 January 2023, see https://www.world-nuclear-news.org/Articles/Bulgaria-sets-out-plans-for-four-new-nuclear-react, accessed 22 January 2023; and Ministry of Energy, "Росен Христов: Енергетиката съдейства за конкурентоспособността на икономиката в криза", Government of Bulgaria, 17 January 2023 (in Bulgarian), see https://www.me.government.bg/bg/news/rosen-hristov-energetikata-sadeistva-za-konkurentosposobnostta-na-ikonomikata-v-kriza-3137.html?p=eyJoeXBlIjoiaG90bmV3cyJ9, accessed 25 August 2024.

2316 - *Balkan Green Energy News*, "Bulgaria's 2053 energy strategy: coal until 2030, new nuclear capacities", 18 January 2023, see https://balkangreenenergynews.com/bulgarias-2053-energy-strategy-coal-until-2030-new-nuclear-capacities/, accessed 30 May 2023.

2317 - Ember, "Electricity Data Explorer—Bulgaria electricity generation by source", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 29 May 2024.

Given the current political turmoil, the Bulgarian energy strategy, also related to the nuclear projects, remains uncertain, especially with pro-Russian nationalist parties, who oppose the sale of equipment to Ukraine[2318], potentially gaining political power.[2319]

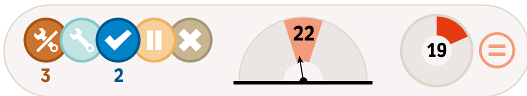
Czech Republic

See Focus Countries – Czech Republic Focus.

Hungary

See Focus Countries – Hungary Focus.

Romania



Romania has one nuclear power plant at Cernavodă, where two Canadian-designed CANDU heavy-water reactors are in operation, with a total capacity of 1.3 GW. In 2023, they provided 10.3 TWh or 18.9 percent of the country's electricity, slightly up from 10.2 TWh in the previous year. The historic maximum of 20.6 percent electricity production share was reached in 2009 and production has since remained roughly in this range.

The Romanian electricity mix today is dominated by hydro that supplies around 1/3 of the country's power, followed by nuclear (19.9 percent), gas (14.8 percent) and coal (14.4 percent). Renewable generation is dominated by wind that supplies 13.4 percent of the electricity share. Solar PV supplies only 3.7 percent.[2320] Romania's updated National Energy and Climate Plan as of November 2023 envisions the expansion of PV capacities from 1.4 GW in 2021 to 8.3 GW in 2030 and 30.5 GW in 2050, and of wind power capacities from 3 GW to 7.6 GW and finally 16 GW in the same timeframe. This is to be complemented by a total nuclear capacity of 3.3 GW from 2035 onwards. Coal is to be phased out by 2030, and gas capacities are to be increased by more than 2.4 GW to 5.3 GW by 2030.[2321]

The Romanian reactors are the only CANDU reactors operating in Europe. Construction started between 1982 and 1987 on five reactors. Following years-long construction interruptions, Unit 1 was completed in 1996, and Unit 2 started up in 2007, respectively 14 and 24 years after construction originally started. Both were partly funded by the Canadian Export Development Corporation, Unit 2 also partly by the Euratom Loan Facility.

As with other ageing CANDU reactors, major refurbishment will be needed to ensure continued operation. In 2017, the plan to upgrade Unit 1 to allow for a 30-year lifetime

2318 - *Novinite*, "Bulgaria: 'Revival' Party Halts Ukrainian Delegation Visit to Belene NPP", 14 May 2024, see https://www.novinite.com/articles/226069/Bulgaria%3A+%22Revival%22+Party+Halts+Ukrainian+Delegation+Visit+to+Belene+NPP, accessed 28 May 2024.

2319 - Henry Foy, "What Bulgaria's government collapse means for the rest of the EU", *The Financial Times*, 27 March 2024, see https://www.ft.com/content/670818b4-1c2c-4188-b362-6b7a1816cfde, accessed 28 May 2024.

2320 - Ember, "Electricity Data Explorer—Romania electricity generation by source", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 30 May 2024.

2321 - Romanian Government, "Integrated National Energy and Climate Plan of Romania: 2021 - 2030 Update—First Draft Version", November 2023, see https://commission.europa.eu/document/download/c42fd541-c493-4479-8bdf-b2ba6aad85b8_en?filename=ROMANIA%20-%20DRAFT%20UPDATED%20NECP%202021-2030.pdf, accessed 19 June 2024.

extension was initiated.[2322] In February 2020, the IAEA lead a Pre-SALTO (Safety Aspects of Long-Term Operation) mission onsite, identifying fifteen issues considered needing further improvement.[2323] Another pre-SALTO mission concluded in March 2024, noting improvement compared to 2020, but also highlighting a handful of further improvement recommendations.[2324] In February 2022, the investment decision for the refurbishment project was approved based on an "enhanced safety" scenario with overnight costs estimated at €1.85 billion (US$$_{2022}$2 billion) as laid out in the feasibility study.[2325]

Since July 2022, Candu Energy, subsidiary of AtkinsRéalis, formerly SNC-Lavalin,[2326] has landed two pre-project engineering contracts, totaling US$64 million and US$65 million, respectively.[2327] In November 2023, the company was awarded, together with the Canadian Commercial Corporation, a CAD750 million (US$$_{2023}$556 million) contract to "provide engineering, technology and procurement of tooling and reactor components" for the lifetime extension project.[2328] In June 2024, a so-called framework agreement for the provision of project management operations for the refurbishment work was signed with Canadian Nuclear Partners SA, valued at €240 million (US$260 million).[2329] The large-scale refurbishment was initially expected to start in 2026,[2330] and is now to be carried out in 2027–2029.[2331] Candu

2322 - SNN, "Resolution number 9 /28.09.2017 of the Extraordinary General Meeting of Shareholders of Societatea Nationala Nuclearelectrica S.A.", Societatea Nationala Nuclearelectrica S.A., 28 September 2017, see https://www.nuclearelectrica.ro/wp-content/uploads/2017/08/Hotarare-AGEA-28.09.2017-ORA-12-ENG.pdf, accessed 2 August 2023; and *NEI Magazine*, "Romania to upgrade Cernavoda 1", 5 October 2017, see https://www.neimagazine.com/news/romania-to-upgrade-cernavoda-1-5940262/, accessed 19 June 2024.

2323 - IAEA, "Executive Summary", International Nuclear Energy Agency, Undated, see https://www.iaea.org/sites/default/files/documents/review-missions/45_cernavoda_pre-salto_executive_summary.pdf, accessed 31 August 2023.

2324 - IAEA, "IAEA Concludes Long Term Operational Safety Review at Romania's Cernavoda Nuclear Power Plant", Press Release 20/2024, 7 March 2024, see https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-at-romanias-cernavoda-nuclear-power-plant, accessed 3 June 2024.

2325 - Nuclearelectrica, "The General Meeting of Shareholders has approved today the investment decision for Cernavoda NPP Unit 1 Refurbishment Project", Press Release, 23 February 2022, see https://www.nuclearelectrica.ro/2022/02/23/the-general-meeting-of-shareholders-has-approved-today-the-investment-decision-for-cernavoda-npp-unit-1-refurbishment-project/?lang=en; and Nuclearelectrica, "Refurbishment of Cernavoda NPP Unit 1", Undated, see https://www.nuclearelectrica.ro/project-development-activities/refurbishment-of-cernavoda-npp-unit-2/?lang=en; also Ernst & Young SRL, "Cernavodă NPP Unit 1 Refurbishment—Project Feasibility Study", v1 version, commissioned by SN Nuclearelectrica S.A., 17 January 2022, see https://www.nuclearelectrica.ro/ir/wp-content/uploads/sites/9/2022/01/EN-2.-Executive-Summary-SNN-U1-FS-Stage-2-EY-Feasibility-Study-v1-fn-.pdf; all accessed 3 August 2023.

2326 - AtkinsRéalis, "SNC-Lavalin changing name to AtkinsRéalis—New name. New era.", Press Release, 12 September 2023, see https://www.atkinsrealis.com/en/media/press-releases/2023/12-09-2023, accessed 30 May 2024.

2327 - AtkinsRéalis/SNC-Lavalin, "SNC-Lavalin Advances Romanian Nuclear Refurbishment Project with $64 Million Contract Win", Press Release, 21 July 2022, see https://www.atkinsrealis.com/en/media/press-releases/2022/21-07-2022; and AtkinsRéalis/SNC-Lavalin, "SNC-Lavalin Continues to Advance Romanian Nuclear Refurbishment with $65 Million Contract", Press Release, 7 March 2023, see https://www.atkinsrealis.com/fr-fr/media/press-releases/2023/07-03-2023; both accessed 21 June 2024.

2328 - Petre Barac, "Nuclearelectrica announces new 509 million Euro project for the refurbishment of Cernavoda NPP Unit 1", *The Diplomat*, 8 November 2023, see https://www.thediplomat.ro/2023/11/08/nuclearelectrica-announces-new-509-million-euro-project-for-the-refurbishment-of-cernavoda-npp-unit-1/; and AtkinsRéalis, "AtkinsRéalis-led consortium signs $750M contract supporting Romanian CANDU reactor life extension", Press Release, 28 November 2023, see https://www.atkinsrealis.com/en/media/press-releases/2023/28-11-2023-a, both accessed 30 May 2024.

2329 - Nuclearelectrica, "Press release SN Nuclearelectrica S.A. and Canadian Nuclear Partners S.A. sign Framework Agreement for Romania Cernavoda NPP Unit 1 Refurbishment Project", 11 June 2024, see https://www.nuclearelectrica.ro/2024/06/11/press-release-sn-nuclearelectrica-s-a-and-canadian-nuclear-partners-s-a-sign-framework-agreement-for-romania-cernavoda-npp-unit-1-refurbishment-project/?lang=en, accessed 2 July 2024.

2330 - AtkinsRéalis/SNC-Lavalin, "SNC-Lavalin awarded nuclear contract in Romania to assess Cernavoda Unit 1 for continued operation", Press Release, 21 January 2020, see https://www.atkinsrealis.com/en/media/press-releases/2020/21-01-2020, accessed 26 August 2024.

2331 - Nuclearelectrica, "Project Development Activities—Refurbishment of Cernavoda NPP Unit 1", Undated, as of June 2024, see https://www.nuclearelectrica.ro/project-development-activities/refurbishment-of-cernavoda-npp-unit-2/?lang=en, accessed 21 June 2024.

Energy will be supported by Italian Ansaldo Nucleare and South Korean KHNP, the latter having also been tasked by Cernavodă's operator Nuclearelectrica to construct an onsite tritium removal facility for a reported US$225 million,[2332] majority funded by the European Investment Bank.[2333] On 10 June 2024, the groundbreaking ceremony for the facility was held.[2334] The Italian supplier, supported by the Italian export credit agency SACE, signed an additional MoU for refurbishment work at Unit 1 and for the support of the construction of Units 3 and 4,[2335] see below. Concerning lifetime extensions at Unit 2, Nuclearelectrica's website indicates "Unit 2 was started up in 2007, so we can talk about the refurbishment of Unit 2 in 2037."[2336]

Various foreign companies have been involved in attempts to revive the construction of Units 3, 4, and 5 of the Cernavoda plant. In November 2013, Nuclearelectrica and China General Nuclear (CGN) signed a letter of intent for the construction of Units 3 and 4.[2337] This was followed in November 2015 with the signature of an MoU between Nuclearelectrica and CGN for the construction, operation and decommissioning of the two units. The MoU also included agreements on investments, and remarkably, given geopolitical tensions with China, CGN was to be the majority share owner of the future Joint Venture with at least 51 percent of the shares; a strategy which had received Romanian Government approval.[2338]

In January 2016, the Romanian Government formally expressed support for the CGN-led project. The cost of the completion of two reactors with a 720 MW capacity each was expected to be €7.2 billion (US$$_{2016}$8 billion).[2339] However, in January 2020, the government announced that it would cancel the deal and then-Prime Minister Ludovic Orban stated that "the partnership with the Chinese company is not going to work."[2340]

2332 - David Dalton, "Romania / KHNP And Candu Energy Sign Agreement On Cernavodă-1 Refurbishment Project", *NucNet*, 7 May 2024, see https://www.nucnet.org/news/khnp-and-candu-energy-sign-agreement-on-cernavoda-1-refurbishment-project-5-2-2024, accessed 30 May 2024.

2333 - EIB, "Romania: EIB announces financing for nuclear safety project", Press Release, European Investment Bank, 22 December 2023, see https://www.eib.org/en/press/all/2023-555-eib-announces-financing-for-nuclear-safety-project-in-romania, accessed 30 May 2024.

2334 - Nuclearelectrica, "Ceremony for the Inauguration of the Works at the Tritium Removal Facility in Cernavoda Nuclear Power Plant", 10 June 2024, see https://www.nuclearelectrica.ro/2024/06/10/ceremony-for-the-inauguration-of-the-works-at-the-tritium-removal-facility-in-cernavoda-nuclear-power-plant/?lang=en, accessed 2 July 2024.

2335 - Nuclearelectrica, "Nuclearelectrica signs Memorandum of Understanding with SACE and Ansaldo Nucleare to advance the development and financing of Cernavoda NPP Unit 1 Refurbishment and Cernavoda NPP Units 3 and 4 strategic Projects", 15 February 2024, see https://www.nuclearelectrica.ro/ir/wp-content/uploads/sites/9/2024/02/CR-SNN-SACE-ANSALDO.pdf, accessed 30 May 2024.

2336 - Nuclearelectrica, "Project Development Activities—Refurbishment of Cernavoda NPP Unit 1", Undated, as of June 2024, op. cit.

2337 - *NEI Magazine*, "CGN signals intent to participate in Romania's Cernavoda 3&4", 28 November 2013, see https://www.neimagazine.com/news/newscgn-signals-intent-to-participate-in-romanias-cernavoda-34, accessed 3 August 2023.

2338 - *Romania Insider*, "Romania and China seal deal for Cernavoda nuclear plant expansion", 9 May 2019, see https://www.romania-insider.com/index.php/romania-china-seal-deal-nuclear-plant; and Nuclearelectrica, "The signing of the Memorandum of Understanding regarding the development, construction, operation and decommissioning of Units 3 and 4 of Cernavoda NPP", Press Release, 10 November 2015, see https://www.nuclearelectrica.ro/2015/11/10/the-signing-of-the-memorandum-of-understanding-regarding-the-development-construction-operation-and-decommissioning-of-units-3-and-4-of-cernavoda--npp/?lang=en; both accessed 3 August 2023.

2339 - *WNN*, "Romania expresses support for China's role at Cernavoda", 25 January 2016, see https://www.world-nuclear-news.org/NN-Romania-expresses-support-for-China-role-at-Cernavoda-25011601.html, accessed 10 April 2021.

2340 - *NEI Magazine*, "Romania Cancels China Deal on Cernavoda but Proceeds with Life Extension", 24 January 2020, op. cit.; and *HotNews.ro*, "Ludovic Orban, despre reactoarele 3 și 4 de la Cernavodă: Mie îmi este clar că nu o să meargă cu chinezii/ Vom vedea cu ce partener", 19 January 2020 (in Romanian), see https://hotnews.ro/ludovic-orban-despre-reactoarele-3-si-4-de-la-cernavoda-mie-mi-este-clar-ca-nu-o-sa-mearga-cu-chinezii-vom-vedea-cu-ce-partener-279958, accessed 23 June 2024.

In August 2019, the U.S. had blacklisted CGN for allegedly stealing nuclear technology for "military uses" by adding the state-owned Chinese firm and its three subsidiaries to its "entity list". The move makes it virtually impossible for American companies to supply or cooperate with the Chinese firm without specific permissions.[2341]

On 9 October 2020, the U.S. and Romania "initialed a draft Intergovernmental Agreement to cooperate on the expansion and modernization of Romania's civil nuclear power program."[2342] Adrian Zuckerman, the U.S. ambassador to Romania, said in a speech at the signing ceremony: "Now we have a great clean American company, Aecom, leading this [US]$8 billion project, with assistance from clean Romanian, Canadian and French companies."[2343] U.S. Export-Import (EXIM) Bank signed an MoU the same day with the Romanian Ministry of Economy to provide US$50 million in funds for pre-project operations, and up to US$3 billion for engineering and project management services if the project advances.[2344] Three weeks later, Romania and France signed a declaration of intent for a partnership on the construction of Units 3 and 4 and the upgrade of Unit 1.[2345]

In December 2020, U.S. EXIM President and Chairman Kimberly A. Reed stated:

> The Cernavoda success comes in the aftermath of the rejection of a plan for a nuclear power entity in the People's Republic of China to undertake this project. I am happy that Romania rejected Beijing's predatory financing and is working with the United States through EXIM and the U.S. Department of Energy on a better, more reliable, alternative at Cernavoda.[2346]

Since late 2021, progress was made on the preparatory phase of the project. Stage 1 effectively started with Energonuclear, the project company, signing the first contract with Candu Energy in November 2021. Under said contract, Candu Energy was to provide "engineering services for drafting and updating the necessary documentation for initiating the Project of Units CANDU 3 and 4." This phase was expected to last 24 months. Stage 2 would then begin with site preparations and is expected to last for 18–24 months,[2347] though more recently, in

2341 - Felix Todd, "China nuclear firm blacklisted by US for 'unauthorised' use of tech", *NS Energy*, 15 August 2019, see https://www.nsenergybusiness.com/news/china-nuclear-us-tech/, accessed 31 August 2023; and Bureau of Industry and Security, "Addition of Certain Entities to the Entity List, Revision of Entries on the Entity List, and Removal of Entities From the Entity List", Department of Commerce, U.S. Government, Federal Register, Vol. 84, No. 157, 14 August 2019, see https://www.govinfo.gov/content/pkg/FR-2019-08-14/pdf/2019-17409.pdf, accessed 6 November 2023.

2342 - Stephanie Cooke, "Aecom to Lead $8 Billion Completion of Romania's Cernavoda-3 and -4", *Energy Intelligence*, 7 October 2020, see https://www.energyintel.com/0000017b-a7db-de4c-a17b-e7dbb8d20000, accessed 31 August 2023; and Department of Energy, "U.S. and Romania Announce Initial Agreement on Cooperation for the Cernavoda Nuclear Power Projects and Civil Nuclear Power Sector in Romania", United States Government, 9 October 2020, see https://www.energy.gov/articles/us-and-romania-announce-initial-agreement-cooperation-cernavoda-nuclear-power-projects-and, accessed 23 June 2024.

2343 - U.S. Embassy in Romania, "Ambassador Adrian Zuckerman at the DOE Intergovernmental Agreement Signing Event", 9 October 2020, see https://ro.usembassy.gov/ambassador-adrian-zuckerman-at-the-doe-intergovernmental-agreement-signing-event/, accessed 3 August 2023.

2344 - Nuclearelectrica, "Investment Projects", August 2024, see https://www.nuclearelectrica.ro/ir/investment-projects/?lang=en, accessed 26 August 2024.

2345 - *NEI Magazine*, "Romania and France to partner on Cernavoda expansion", 29 October 2020, see https://www.neimagazine.com/news/romania-and-france-to-partner-on-cernavoda-expansion-8206702/, accessed 23 June 2024.

2346 - EXIM, "EXIM Chairman Kimberly Reed Meets with Romania's New Interim Prime Minister Nicolae-Ionel Ciuca to Strengthen U.S.-Romania Economic Partnership and U.S. Energy and Infrastructure Export", Export-Import Bank of the United States, 10 December 2020, see https://www.exim.gov/news/exim-chairman-kimberly-reed-meets-romanias-new-interim-prime-minister-nicolae-ionel-ciuca, accessed 31 August 2023.

2347 - Nuclearelectrica, "Project Development Activities—Units 3 and 4", Undated, see https://www.nuclearelectrica.ro/project-development-activities/units-3-and-4/?lang=en, accessed 6 November 2023.

March 2023, Nuclearelectrica estimated it could take "up to 30 months",[2348] followed by Stage 3, the construction phase, expected to last 69–78 months with commissioning of Unit 3 expected in 2030 and Unit 4 within the subsequent year.[2349]

Romanian legislators in late 2022 introduced a draft law to allow the implementation of a "Contract for Difference" support scheme for the Cernavodă project.[2350] The law was approved by Parliament in March 2023,[2351] allowing for the "Support Agreement" between the Romanian Government and Nuclearelectrica to be signed in June 2023, paving the way for Stage 2 and envisioning construction start in 2026. Through the agreement, the government commits to secure the financing of the two units. Nuclearelectrica emphasized the intention to "carry out this project in a Euro-Atlantic consortium" based on the cooperation agreement between Romanian and U.S. Governments.[2352] In September, an additional CAD3 billion (US$$_{2023}$2.2 billion) were approved by the Canadian Government for export financing to Nuclearelectrica.[2353] As of the time of writing in July 2024, no definite estimate of the total cost of the project has been officialized, but over the years various statements drew an estimated range of "at least €6.5 billion [US$$_{2023}$7 billion]",[2354] to US$8 billion.[2355]

In an amendment of this "Support Agreement", announced in February 2024, the budget for the preliminary work for the new reactors was upped to €350 million (US$379 million) from

2348 - Nuclearelectrica, "Nuclearelectrica welcomes the adoption of the Law approving the signing of the Support Agreement between the Romanian State and Nuclearelectrica for the development of the National Strategic Project Units 3 and 4 of the Cernavoda NPP", Press Release, 14 March 2023, see https://www.nuclearelectrica.ro/2023/03/14/nuclearelectrica-welcomes-the-adoption-of-the-law-approving-the-signing-of-the-support-agreement-between-the-romanian-state-and-nuclearelectrica-for-the-development-of-the-national-strategic-project-u/?lang=en, accessed 31 August 2023.

2349 - Nuclearelectrica, "Project Development Activities—Units 3 and 4", Undated, op. cit.; and Nuclearelectrica, "Nuclearelectrica announces the advancement of CANDU Units Project: Within the Preparatory Stage, Energonuclear S.A. the project company, signed the first contract, with Candu Energy", Press Release, 25 November 2021, see https://www.nuclearelectrica.ro/2021/11/25/nuclearelectrica-announces-the-advancement-of-candu-units-project-within-the-preparatory-stage-energonuclear-s-a-the-project-company-signed-the-first-contract-with-candu-energy/?lang=en, accessed 29 August 2022.

2350 - *WNN*, "Romanian government adopts draft law on Cernavoda 3 and 4", 21 December 2022, see https://world-nuclear-news.org/Articles/Romania-adopts-draft-law-on-Cernavoda-3-and-4, accessed 31 August 2023.

2351 - Nuclearelectrica, "Nuclearelectrica welcomes the adoption of the Law approving the signing of the Support Agreement between the Romanian State and Nuclearelectrica for the development of the National Strategic Project Units 3 and 4 of the Cernavoda NPP", Press Release, 14 March 2023, see https://www.nuclearelectrica.ro/2023/03/14/nuclearelectrica-welcomes-the-adoption-of-the-law-approving-the-signing-of-the-support-agreement-between-the-romanian-state-and-nuclearelectrica-for-the-development-of-the-national-strategic-project-u/?lang=en, accessed 23 June 2024.

2352 - *WNN*, "Support agreement for Cernavoda 3 and 4 signed", 12 June 2023, see https://world-nuclear-news.org/Articles/Support-agreement-for-Cernavoda-3-and-4-agreed; and NuclearElectrica. "Signing of the Support Agreement between the Romanian State and Nuclearelectrica for the development of the National Strategic Project Units 3 and 4 Cernavoda NPP", Press Release, 9 June 2023, see https://www.nuclearelectrica.ro/2023/06/09/signing-of-the-support-agreement-between-the-romanian-state-and-nuclearelectrica-for-the-development-of-the-national-strategic-project-units-3-and-4-cernavoda-npp/?lang=en; both accessed 3 August 2023.

2353 - Government of Canada, "Government of Canada announces $3 Billion CAD in Export Finance for Cernavoda New Build Project", 20 September 2023, see https://www.international.gc.ca/country_news-pays_nouvelles/2023-09-20-romania-roumanie.aspx?lang=eng, accessed 2 July 2024.

2354 - Luiza Ilie, "Romanian planned two nuclear reactors estimated to cost around $7 bln", *Reuters*, 19 July 2023, see https://www.reuters.com/article/business/energy/romanian-planned-two-nuclear-reactors-estimated-to-cost-around-7-bln-idUSL8N3953FN/, accessed 26 August 2024.

2355 - U.S. Embassy in Romania, "Ambassador Adrian Zuckerman at the DOE Intergovernmental Agreement Signing Event", 2020, op. cit.

€185 million (US$200 million).[2356] Until 30 June 2024, or until a later date if agreed amongst the project partners, Nuclearelectrica has the option to reverse the so-called "Investment Decision I" that moves the project into Stage 2. "Investment decision II" that will determine whether construction of the reactors will actually be followed through is scheduled for 30 September 2026 at the latest, with an option to revoke the decision until the end of November of the same year or at a later date if the project partners agree.[2357]

In addition, Romania also intends to deploy Small Modular Reactors (SMRs), with U.S. support.

In addition, Romania also intends to deploy Small Modular Reactors (SMRs), with U.S. support. In March 2019, NuScale and Nuclearelectrica signed a first MoU, to explore the potential of SMR deployment.[2358] Then, in January 2021, Nucleareletrica received a US$1.28 million grant from the U.S. Trade and Development Agency to help identify potential sites. At the time, the Agency described that their technical assistance (Sargent & Lundy) would "identify a short list of SMR-suitable sites, assess SMR technology options and develop site-specific licensing roadmaps."[2359] In November 2021, Nucleareletrica signed a "teaming agreement" with U.S. vendor NuScale to build a 462 MW six module facility at former coal plant Doiceşti "as early as 2027/2028."[2360]

Talks continued through 2022 and 2023, allowing some developments, including the signing of an MoU in May 2022 between NuScale, Nucleareletrica, and E-Infra, the owner of the former coal plant site, to conduct engineering studies, technical reviews, and licensing and permitting activities at the Doiceşti site.[2361] Most notably, in September 2022, Nucleareletrica and Nova Power & Gas launched their joint venture RoPower Nuclear SA, the project company tasked with "deploying the first NuScale VOYGR-6 (462 MWe) power plant in Romania this

2356 - Nuclearelectrica, "Note on the approval by the Extraordinary General Meeting of Shareholders and respectively by the Ordinary General Meeting of Shareholders of certain measures necessary to continue of Units 3 and 4 Cernavodă NPP Project", October 2022, see https://www.nuclearelectrica.ro/ir/wp-content/uploads/sites/9/2022/06/OGMS-ITEM-23-EGMS-ITEM-2-Note-EGSM-and-OGSM-approval-continuation-Units-3-and-4-Project-1.pdf; and Nuclearelectrica, "Addendum no. 1 to the Support Agreement between the Romanian State and Societatea Nationala 'Nuclearelectrica' - S.A. (SNN) regarding the Cernavodă NPP Units 3 and 4 Project", April 2024, see https://www.nuclearelectrica.ro/ir/wp-content/uploads/sites/9/2024/03/EGMS-ITEM-2-AND-3-Annex-1_Act-aditional-la-Acord-de-sprijin-U3-si-4-actualizat_EN_clean.pdf; both accessed 30 May 2024.

2357 - Ibidem.

2358 - Nuclearelectrica, "NuScale and Romanian Energy Company Sign Agreement to Explore SMRs for Romania", Press Release, 19 March 2019, see https://www.nuclearelectrica.ro/2019/03/19/nuscale-and-romanian-energy-company-sign-agreement-to-explore-smrs-for-romania/?lang=en, accessed 4 August 2023.

2359 - USTDA, "USTDA Supports Civil Nuclear Energy in Romania", Press Release, U.S. Trade and Development Agency, 14 January 2021, see https://ustda.gov/ustda-supports-civil-nuclear-energy-in-romania/, and *WNN*, "US grant made for Romanian SMR siting assessment", 14 January 2021, see https://www.world-nuclear-news.org/Articles/US-grant-for-Romanian-SMR-siting-assessment; both accessed 4 August 2023.

2360 - Phil Chaffee, "Newbuild: Romania Talks of Building 'Europe's First SMR'", *Nuclear Intelligence Weekly*, 5 November 2021; and Nuclearelectrica, "NuScale and Nuclearelectrica Reach Agreement at COP26 to Initiate the Deployment of the First Small Modular Reactor in Europe", 4 November 2021, see https://www.nuclearelectrica.ro/2021/11/04/nuscale-and-nuclearelectrica-reach-agreement-at-cop26-to-initiate-the-deployment-of-the-first-small-modular-reactor-in-europe/?lang=en, accessed 4 August 2023.

2361 - Nuclearelectrica, "Nuclearelectrica, NuScale & E-Infra sign Memorandum of Understanding to deploy NuScale's SMR technology on the first SMR site location in Romania", Press Release, 24 May 2022, see https://www.nuclearelectrica.ro/2022/05/24/nuclearelectrica-nuscale-e-infra-sign-memorandum-of-understanding-to-deploy-nuscales-smr-technology-on-the-first-smr-site-location-in-romania/?lang=en; and NuScale, "NuScale Power Signs Agreement with Nuclearelectrica and Owner of Preferred Site for First SMR Site in Romania", Press Release, 23 May 2023, see https://www.nuscalepower.com/en/news/press-releases/2022/nuscale-signs-agreement-with-nuclearelectrica-and-owner-of-preferred-site-for-first-smr-in-romania; both accessed 4 August 2023.

decade" at Doiceşti,[2362] and in late December 2022, NuScale and RoPower inked the contract for Front-End Engineering and Design (FEED) work[2363], the first phase of which concluded in December 2023.[2364] The study had been supported by a US$14 million grant from the U.S. Government[2365] and additional €75 million (US$$_{2023}$81 million) from South Korean DS Private Equity (DSPE).[2366] In April 2024, the IAEA concluded that this site selection "complied with the agency's safety standards."[2367]

A 2023-presentation by Nucleareletrica envisions the six-module SMR plant to be up and running, together with both new CANDU units, by 2031.[2368] Reports suggest that NuScale expects the Romanian project to be "up to a third cheaper" than the Utah project that was canceled in November 2023 (see United States in chapter on SMRs).[2369]

During the 2023 G7 summit in Hiroshima (Japan), the Japanese, South Korean, UAE and U.S. Governments announced public-private commitments to invest a total of up to US$275 million into the Romanian NuScale project. Further, it was revealed that the U.S. International Development Finance Corporation (DFC) and the U.S. EXIM Bank would consider financial support of up to US$1 and US$3 billion, respectively.[2370] U.S. Ambassador Kathleen Kavalec announced on 18 March 2024 that both the "U.S. EXIM Bank and the U.S. [DFC] have committed to financing to ensure the success of [the] SMR project in Doiceşti".[2371]

In August 2023, the Romanian nuclear regulator CNCAN confirmed that the "Licensing Basis Documents" conformed with national regulatory requirements, establishing "the foundation

2362 - Nuclearelectrica, "Nuclearelectrica SA and Nova Power & Gas SRL launch RoPower Nuclear SA, the project company for the development of small modular reactors in Romania", Press Release, 27 September 2022, see https://www.nuclearelectrica.ro/2022/09/27/nuclearelectrica-sa-and-nova-power-gas-srl-launch-ropower-nuclear-sa-the-project-company-for-the-development-of-small-modular-reactors-in-romania/?lang=en, accessed 4 August 2023.

2363 - Nuclearelectrica, "NuScale Power and RoPower Announce Signing of the Contract for Phase 1 of Front-End Engineering and Design Work for First SMR Power Plant in Romania", Press Release, 4 January 2023, see https://www.nuclearelectrica.ro/2023/01/04/nuscale-power-and-ropower-announce-signing-of-the-contract-for-phase-1-of-front-end-engineering-and-design-work-for-first-smr-power-plant-in-romania/?lang=en, accessed 4 August 2023.

2364 - Nuclearelectrica, "Quarterly Report of The Board of Directors of S.N. Nuclearelectrica S.A. ('SNN') Q1 2024", May 2024, see https://www.nuclearelectrica.ro/ir/wp-content/uploads/sites/9/2024/05/SNN_EN_Raport_CA_Trim-I-2024_final.pdf, accessed 30 May 2024.

2365 - *Balkan Green Energy News*, "Romania on track to become first country with SMR nuclear power plant", 25 February 2023, see https://balkangreenenergynews.com/romania-on-track-to-become-first-country-with-smr-nuclear-power-plant/; and The White House, "Fact Sheet: President Biden and G7 Leaders Formally Launch the Partnership for Global Infrastructure and Investment", Press Release, U.S. Government, 26 June 2023, see https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/26/fact-sheet-president-biden-and-g7-leaders-formally-launch-the-partnership-for-global-infrastructure-and-investment/; both accessed 4 August 2023.

2366 - Nuclearelectrica, "Presentation for investors", 2023, see https://www.nuclearelectrica.ro/ir/wp-content/uploads/sites/9/2023/11/prezentare-investitori-T3-2023_EN_20230817.pdf, accessed 30 May 2024.

2367 - IAEA, "IAEA SEED Follow Up Mission Highlights Good Progress in SMR Site Selection in Romania", International Atomic Energy Agency, 24 April 2024, see https://www.iaea.org/newscenter/news/iaea-seed-follow-up-mission-highlights-good-progress-in-smr-site-selection-in-romania, accessed 21 June 2024.

2368 - Nuclearelectrica, "Presentation for Investors", 2023, op. cit.

2369 - Luiza Ilie, "Romania's Nuclearelectrica sees preliminary decision on SMR plant in 2025", *Reuters*, 18 March 2024, see https://www.reuters.com/business/energy/romanias-nuclearelectrica-sees-preliminary-decision-smr-plant-2025-2024-03-18/, accessed 30 May 2024.

2370 - U.S. Department of State, "The United States and Multinational Public-Private Partners Look to Provide Up To $275 Million to Advance the Romania Small Modular Reactor Project; United States Issues Letters of Interest for Up To $4 Billion in Project Financing", Press Release, United States Government, 20 May 2023, see https://www.state.gov/the-united-states-and-multinational-public-private-partners-look-to-provide-up-to-275-million-to-advance-the-romania-small-modular-reactor-project-united-states-issues-letters-of-interest-for-up-to/, accessed 23 June 2024.

2371 - Ambassador Kathleen Kavalec, "Ambassador Kathleen Kavalec at the Doicesti SMR Site", United States Embassy in Romania, 18 March 2024, see https://ro.usembassy.gov/doicesti-03182024/, accessed 30 May 2024.

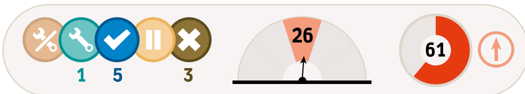
to ini[ti]ate the second phase of the [FEED] study" according to Nuclearelectrica.[2372] In early December 2023, the so-called "FEED Phase 1" was completed and the transition to Phase 2 was approved.[2373]

In its Annual Report 2023 published in March 2024, Nuclearelectrica indicated:

> We estimate that the first modular reactor of the Doicești SMR project will be commissioned and connected to SEN [the National Energy System] at the end of this decade; however, the timeline will be fine-tuned after completion of the studies (FEED) by the Special Purpose Vehicle, - RoPower Nuclear.[2374]

There appears to be some delay, since the General Shareholders meeting of April 2024 failed to gather the votes to advance the project, with two items missing approval, namely "Continuing the project based on the prefeasibility study", and "Conclusion on the FEED phase 2 contracts Offshore/Onshore as well as the Technology License Agreement".[2375] Later General Meetings are to address the project and contracts again.

Slovakia



In Slovakia, Slovenské Elektrárne (SE), majority owned by Czech and Italian utilities, operates two nuclear plants, Jaslovské Bohunice, which houses two operating VVER-440/v213 units, and Mochovce, which, as of mid-2024, has three similar reactors connected to the grid. A fourth unit remains under construction. Nuclear production in 2023 increased by 15 percent from 15.92 TWh in 2022 to 18.34 TWh. This increased the nuclear share in electricity generation to a new maximum of 61.3 percent.

The country has three permanently closed reactors at the Bohunice site. These are the A-1, a small 93-MW unit which started operation in 1972 and was closed in 1977 following several accidents, and two VVER-440/v230 reactors that were closed in 2006 and 2008, respectively, as part of the agreement to join the European Union in 2004[2376] (for more information see Decommissioning Status Report).

2372 - Nuclearelectrica, "Nuclearelectrica and NuScale Power salute the approval by CNCAN of the Licensing Basis Document (LBD) for the NuScale small modular reactor powerplant with a gross installed power of 462 MWe", Press Release, 29 September 2023, see https://www.nuclearelectrica.ro/2023/09/29/nuclearelectrica-and-nuscale-power-salute-the-approval-by-cncan-of-the-licensing-basis-document-lbd-for-the-nuscale-small-modular-reactor-powerplant-with-a-gross-installed-power-of-462-mwe/?lang=en, accessed 23 June 2024.

2373 - Nuclearelectrica, "S.N. Nuclearelectrica S.A. Annual Report 2023", 20 March 2024, see https://www.nuclearelectrica.ro/ir/wp-content/uploads/sites/9/2024/04/SNN_EN_Raport_CA_Anual-2023_FINAL_20.03.2024.pdf, accessed 23 June 2024.

2374 - Nuclearelectrica, "S.N. Nuclearelectrica S.A. Annual Report 2023", 20 March 2024, op. cit.

2375 - Nuclearelectrica, "Quarterly Report of the Board of Directors of S.N. Nuclearelectrica S.A. ("SNN")—Q1 2024", May 2024, see https://www.nuclearelectrica.ro/ir/wp-content/uploads/sites/9/2024/05/SNN_EN_Raport_CA_Trim-I-2024_final.pdf, accessed 23 June 2024.

2376 - *Official Journal of the European Union*, "Protocol No 9 on unit 1 and unit 2 of the Bohunice V1 nuclear power plant in Slovakia" of the "Act concerning the conditions of accession of the Czech Republic, the Republic of Estonia, the Republic of Cyprus, the Republic of Latvia, the Republic of Lithuania, the Republic of Hungary, the Republic of Malta, the Republic of Poland, the Republic of Slovenia and the Slovak Republic and the adjustments to the Treaties on which the European Union is founded", L 236/33, 23 September 2003, see https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2003_236_R_0033_01&qid=1719411537059, accessed 26 June 2024.

The operational Units 3 and 4 of the Bohunice plant (collectively referred to as Bohunice V2 and both in commercial operation since 1985) underwent an extensive modernization program from 2000 to 2010 that included capacity uprates from 440 MWe to 505 MWe (gross). Capacities of Units 1 and 2 of the Mochovce plant, that began operation in 1998, and 2000, respectively, were also uprated, from 440 to 470 MWe (gross).[2377] SE plans to operate Bohunice-3 and -4 to 2044 and 2045, respectively, and Mochovce-1 and -2 until 2058 and 2060, respectively.[2378]

The Mochovce Saga

In April 2006, Italian national utility Enel (Ente Nazionale per l'Energia Elettrica) finalized the acquisition of a 66-percent stake in SE and, as part of its bid, committed to invest around €2 billion (US$$_{2006}$2.5 billion) between 2006 and 2013,[2379] including into the completion of Mochovce-3 and -4, two units of the Russian design VVER-440/213 from the Soviet era, whose construction originally began in January 1985 and that had been halted in 1990.[2380] The State of Slovakia holds the remaining 34 percent stake of SE. See section on Slovakia in WNISR2023 for a detailed account of the construction and financing history.

Mochovce-3 reached first criticality on 22 October 2022[2381] and was finally connected to the grid on 31 January 2023,[2382] and full capacity was reached on 22 September 2023. After the completion of a 114-hour test run from 8 to 14 October 2023, SE on 17 October 2023 announced that the reactor had now completed commissioning.[2383]

Since then, as of 31 May 2024, according to Entso-E, the association of European transmission grid operators, Mochovce-3 has been running continuously,[2384] apart from a scheduled refueling and maintenance outage that began on 18 May and is planned to conclude in September.[2385] However, as of July 2024, the IAEA's PRIS database had not updated any commercial operation

2377 - Ludovit Kupca, "Long term operation of Bohunice NPP", presented at the 4th International Conference on Nuclear Power Plant Life Management, 23 October 2017, see https://www.iaea.org/publications/13640/nuclear-power-plant-life-management?supplementary=91871, accessed 12 September 2023.

2378 - GRS, "Nuclear energy in Slovakia", Gesellschaft für Anlagen- und Reaktorsicherheit, 2 March 2023, see https://www.grs.de/en/nuclear-energy-slovakia-02032023, accessed 12 September 2023.

2379 - Enel, "Enel: Acquisition of 66% of Slovenske Elektrarne completed", Press Release, 28 April 2006, see https://www.enel.com/media/explore/search-press-releases/press/2006/04/enel-acquisition-of-66-of-slovenske-elektrarne-completed, accessed 5 August 2023.

2380 - IAEA-PRIS, "Reactor Details–Mochovce-3", as of 15 April 2019. This date was later changed, and as of June 2024 construction suspension is indicated as 27 January 1990. IAEA-PRIS, "Country Statistics—Mochovce-3", 22 July 2023, see https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=544, accessed 23 July 2023.

2381 - Kamen Kraev, "Mochovce-3 Generates First Power After Successful Grid Connection", *NucNet*, 1 February 2023, see https://www.nucnet.org/news/mochovce-3-generates-first-power-after-successful-grid-connection-2-3-2023, accessed 18 August 2023.

2382 - *NEI Magazine*, "Delays for Mochovce 3", *Nuclear Engineering International*, 9 December 2022, see https://www.neimagazine.com/news/newsdelays-for-mochovce-3-10422185; and Slovenské Elektrárne, "Mochovce 3 first connection to the grid", Press Release, 1 February 2023, see https://www.seas.sk/en/press-releases/mochovce-3-grid-connection/; both accessed 18 August 2023.

2383 - SE, "Energetické spúšťanie 3. bloku Mochoviec je dokončené", Slovenské Elektrárne, Press Release (in Slovak), 17 October 2023, see https://www.seas.sk/tlacove-spravy/mochovce-3-spustanie-preukazny-chod/, accessed 31 May 2024.

2384 - ENTSO-E, "Actual Generation per Generation Unit", European Network of Transmission System Operators for Electricity, 31 May 2024, see https://tinyurl.com/24kkpz3c, accessed 31 May 2024.

2385 - SE, "Historická chvíľa! Tretí blok v Mochovciach ide do prvej odstávky", Slovenské Elektrárne, Press Release (in Slovak), 16 May 2024, see https://www.seas.sk/tlacove-spravy/odstavka-mochovce-3-2024/, accessed 31 May 2024; and SE, "Plánovaná rozšírená odstávka 3. bloku bohunickej jadrovej elektrárne", Press Release (in Slovak), 19 June 2024, see https://www.seas.sk/tlacove-spravy/bohunice-odstavka-3-blok-2024/, accessed 2 July 2024.

date,[2386] and other information or communication regarding the official begin thereof was also lacking. Meanwhile, Mochovce-4, that as of fall last year had been scheduled to come online in 2024,[2387] is now expected to be connected to the grid sometime in 2025.[2388]

The grid connection of Unit 3, planned for 2012 at construction restart, happened with an eleven-year delay. Unit 4 is delayed by at least another twelve years; the connection date having been set to 2013 at construction restart. Uncertainty remains regarding the currently planned connection in 2025. At the time of project relaunch in 2007 (construction restarted in 2009), costs for the total project had been estimated at €$_{2007}$2.8 billion (€$_{2020}$3.5 billion); the most recent estimate from December 2020 puts total project costs at €$_{2020}$6.2 billion, close to a two-fold increase.[2389]

Other Slovak Expansion Ambitions

The Jaslovské Bohunice site has also been considered for years to host further newbuild projects. JESS (Jadrová energetická spoločnosť Slovenska/Nuclear Energy Company of Slovakia), was founded in 2009 by Slovak decommissioning-company JAVYS (51 percent) and Czech utility ČEZ for the extension of the Bohunice site, the so-called Project NJZ. The Environmental Impact Assessment and the preferred project to establish a single Gen III+ PWR with a 1700 MW capacity, received governmental approval in 2016.[2390] In February 2023, JESS submitted a request for a siting permit to the Slovak Nuclear Regulatory Authority for a new reactor at the Bohunice site,[2391] while SE executives pointed to the need for other, more flexible, electricity generation technologies.[2392] In July 2023, JAVYS signed an MoU with Westinghouse for cooperation on the deployment of its AP-1000 and AP-300 SMR Slovakia.[2393] The submission of an application for a construction license was, as of February 2023, planned for the end of 2025, with construction work to begin by 2031.[2394]

2386 - IAEA-PRIS, "Reactor Details: Mochovce-3", 30 May 2024, see https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=544, accessed 22 July 2024.

2387 - *NEI Magazine*, "Mochovce 3 approved for energy start-up", 20 January 2023, see https://www.neimagazine.com/news/newsmochovce-3-approved-for-energy-start-up-10531895, accessed 22 January 2023.

2388 - *The Slovak Spectator*, "Slovakia breaks its record in electricity generated from nuclear power", 6 February 2024, see https://spectator.sme.sk/c/23278787/slovakia-breaks-its-record-in-electricity-generated-from-nuclear-power.html, accessed 31 May 2024.

2389 - Enel, "Enel updates agreement with EPH for sale of stake in Slovenské elektrárne", Press Release, 22 December 2020, see https://www.enel.com/media/explore/search-press-releases/press/2020/12/enel-updates-agreement-with-eph-for-sale-of-stake-in-slovensk-elektrrne, accessed 5 August 2023; and *WNN*, "Mochovce new-build project receives loan boost", 24 December 2020, see https://www.world-nuclear-news.org/Articles/Mochovce-new-build-project-receives-loan-boost, accessed 10 April 2021.

2390 - Ministry of the Environment, "Novy jadrovy zdroj v lokalite jaslocské Bohunice—Záverečné Stanovisko", 1404/2016 – 3.4/hp, Government of the Slovak Republic, 15 April 2016 (in Slovak), see https://www.jess.sk/media/1471-2023_zs-njz-jaslovske-bohunice-zverejnene-15-04-2016-pdf.pdf; and JESS, "The Ministry of Environment of the Slovak Republic issued a positive final opinion on the project of a new nuclear source", Press Release, Jadrová energetická spoločnost' Slovenska, 15 April 2016, see https://www.jess.sk/en/the-ministry-of-environment-of-the-slovak-republic-issued-a-positive-final-opinion-on-the-project-of-a-new-nuclear-source; both accessed 22 August 2023.

2391 - JESS, "Project New nuclear source", 2024, see https://www.jess.sk/en/project-new-nuclear-source, accessed 26 June 2024.

2392 - Michal Hudec, "Slovakia may build new nuclear power plant as electricity consumption rises", *Euractiv*, 28 February 2023, see https://www.euractiv.com/section/politics/news/slovakia-may-build-new-nuclear-power-plant-as-electricity-consumption-rises/, accessed 7 June 2023.

2393 - Westinghouse, "Interest in Westinghouse AP300™ Small Modular Reactor, AP1000® Technology Surging in Europe as Slovakia Begins Deployment Discussions", Press Release, 17 July 2023, see https://info.westinghousenuclear.com/news/westinghouse-ap300-smr-ap1000-interest-in-europe-slovakia-deployment-discussions, accessed 22 August 2023.

2394 - *WNN*, "Siting permit requested for new Slovak plant", 20 February 2023, see https://world-nuclear-news.org/Articles/Siting-permit-requested-for-new-Slovak-plant, accessed 2 July 2024.

In May 2024, Prime Minister Fico, elected in September 2023 on a pro-Russian and anti-U.S. agenda, announced that a 1200 MW nuclear power plant was to be built at the Bohunice site.[2395] A plan is to be set up by the end of October 2024. While details on financing and schedule remain opaque, Fico said the project would be fully state-owned. Economy Minister Denisa Sakova pointed out that the supplier would be chosen via a competitive tender and that Russian actors were banned from participating; leaving only French, South Korean or U.S. suppliers.[2396] In August 2023, JAVYS and France's EDF signed a Framework Agreement for cooperation on the development of nuclear energy in Slovakia, and the potential of EDF's EPR1200 and Nuward EPR designs.[2397] Talks with South Korean officials on newbuild cooperation have also begun.[2398] This tender shall be concluded during the ongoing legislative period that is due to end in 2027.[2399]

In an unrelated attack, Fico was shot and dangerously injured on 15 May 2024, the day of the newbuild announcements. He was released from the hospital two weeks later but will not return to office for several months due to his severe injuries.[2400] Government operations are currently being overseen by Deputy Prime Minister Robert Kaliňák, who is also the country's Defense Minister.[2401]

In September 2023, SE was awarded a US$2 million grant—as were Slovakia's neighboring countries Poland and the Czech Republic—from the U.S. Government's "Project Phoenix" that aims to "accelerate the global clean energy transition by providing technical assistance to support decision making on pursuing the conversion of one or more coal-fired power plants to secure and safe zero-carbon small modular reactor (SMR) nuclear energy generation".[2402] The feasibility study commenced promptly and is planned to conclude in 2025. The process is also to assess the suitability of five potential sites, among which two coal plants, Nováky and Vojany, but also Bohunice and Mochovce. The Slovak plan envisions the SMR design and licensing process to last from 2026 to 2029, and a first reactor to be commissioned in

2395 - *AP News*, "Slovakia plans to build a new nuclear reactor", *The Associated Press*, 15 May 2024, see https://apnews.com/article/slovakia-new-nuclear-reactor-jaslovske-bohunice-48b8cc3bd20bbf851133325357071524, accessed 31 May 2024.

2396 - Ibidem; and Jan Lopatka, "Slovak government seeks plan for new nuclear power plant by October", *Reuters*, 15 May 2024, see https://www.reuters.com/business/energy/slovak-government-seeks-plan-new-nuclear-power-plant-by-october-2024-05-15/, accessed 31 May 2024.

2397 - JAVYS, "JAVYS and EDF signed a Framework Cooperation Agreement", Press Release, 25 August 2023, see https://www.javys.sk/mobile/en/information-service/news-press-release/press-releases/2073-javys-and-edf-signed-a-framework-cooperation-agreement, accessed 26 June 2024.

2398 - *WNN*, "Slovakia and South Korea discuss cooperation on new nuclear", *World Nuclear News*, 20 May 2024, see https://www.world-nuclear-news.org/Articles/Slovakia-and-South-Korea-discuss-cooperation-on-ne, accessed 1 June 2024.

2399 - Jan Lopatka, "Slovakia considers building another 1.2 GW nuclear power unit, PM Fico says", *Reuters*, 13 May 2024, see https://www.reuters.com/business/energy/slovakia-considers-building-another-12-gw-nuclear-power-unit-pm-fico-says-2024-05-13/, accessed 31 May 2024.

2400 - Peter Dlhopolec, "News digest: PM Fico released from hospital", *The Slovak Spectator*, 30 May 2024, see https://spectator.sme.sk/c/23337774/slovak-prime-minister-fico-released-from-hospital.html, accessed 26 June 2024.

2401 - Ministry of Defence of the Slovak Republic, "Deputy Prime Minister and Minister of Defence of the Slovak Republic—Robert Kaliňák", 2024, see https://www.mosr.sk/53452-en/robert-kalinak/, accessed 26 June 2024.

2402 - First Program, "Project Phoenix – Out of the Ashes – Conversion of Coal to Clean SMR Energy Supply - Foundational Infrastructure for Responsible use of SMR Technology (FIRST) Program", Foundational Infrastructure for Responsible Use of SMR Technology, Undated, see https://www.smr-first-program.net/project-phoenix/, accessed 30 June 2024; and MHSR, "Slovensko so svojimi susedmi dostane z projektu Phoenix 2 milióny USD na štúdiu uskutočniteľnosti malých modulárnych reaktorov", Ministerstvo hospodárstva slovenskey republiky/Ministry of Economy of the Slovak Republic, 10 November 2023 (in Slovak), see https://www.economy.gov.sk/top/slovensko-so-svojimi-susedmi-dostane-z-projektu-phoenix-2-miliony-usd-na-studiu-uskutocnitelnosti-malych-modularnych-reaktoroch; accessed 31 May 2024.

2035.[2403] The previously mentioned agreements signed over the Summer 2023 by JAVYS with Westinghouse and EDF also provisioned cooperation on SMRs based on their respective AP300 and Nuward designs.[2404]

Market Regulations and Russia Dependencies

Prompted by Russia's attack on Ukraine, the former Slovak Government agreed with SE on a supply-and-pricing agreement to curb high electricity prices for households, in exchange for the withdrawal of a bill addressing "excessive profit in trading with electricity generated by nuclear facilities" and the commitment from the government "not to take any initiative between 2022 and 2025 [included] to introduce, increase or tighten any new tax, levy, fee, specific payment or regulation that could financially jeopardise Slovenské elektrárne."[2405] Accordingly, as for 2023, SE will supply up to 6.15 TWh at €61.20 per MWh (US$66.19 per MWh) in 2024.[2406] The agreement was supposedly extended in 2023 until 2027 with annually changing price caps,[2407] but official statements suggest that a price cap will only be applied for 2024,[2408] an observation confirmed by the European Commission.[2409]

Like in many other countries in the region, the Slovak energy sector relies heavily on Russian supply. As of April 2023, reportedly, 60 percent of natural gas, 95 percent of oil and all nuclear fuel for the VVER-440 reactors came from Russia.[2410] Despite this dependency, the former Slovak Government had supported Ukraine with military equipment, including fighter jets, and financial aid; the new Fico Administration however halted arms deliveries and has taken a more pro-Russian stance together with Hungary,[2411] most recently blocking a €6.5 billion

2403 - Ibidem; and SE, "It's already getting underway: Project Phoenix for SMRs in Slovakia", Press Release, Slovenské Elektrárne, 14 February 2024, see https://www.seas.sk/en/news/project-phoenix-start-smr-slovakia/, accessed 24 June 2024.

2404 - Westinghouse, "Interest in Westinghouse AP300™ Small Modular Reactor, AP1000® Technology Surging in Europe as Slovakia Begins Deployment Discussions", Press Release, 17 July 2023, op. cit.; and JAVYS, "JAVYS and EDF signed a Framework Cooperation Agreement", Press Release, 25 August 2023, op. cit.

2405 - SE, "Shareholders of Slovenské elektrárne agree with the government to mitigate the impact of rising electricity prices", Press Release, 16 February 2022, see https://www.seas.sk/en/press-releases/shareholders-agreement-on-electricity-prices/, accessed 27 June 2024

2406 - SE, "Slovenské elektrárne and Slovak government ink deal for favourable-priced household electricity in 2024", Press Release, 19 September 2023, see https://www.seas.sk/en/press-releases/slovakia-household-electricity-price-2024/, accessed 27 June 2024.

2407 - *WNN*, "Mochovce 3 output increased to 55%", 31 March 2023, see https://www.world-nuclear-news.org/Articles/Mochovce-3-output-increased-to-55, accessed 22 August 2023.

2408 - SE, "Slovenské elektrárne and Slovak government ink deal for favourable-priced household electricity in 2024", Press Release, 19 September 2023, see https://www.seas.sk/en/press-releases/slovakia-household-electricity-price-2024/, accessed 1 June 2024.

2409 - European Commission, "Economic surveillance of EU Economies—Economic forecast for Slovakia", 15 May 2024, see https://economy-finance.ec.europa.eu/economic-surveillance-eu-economies/slovakia/economic-forecast-slovakia_en, accessed 1 June 2024.

2410 - Victor Jack, "You don't scare us: Slovakia shrugs off Kremlin energy retaliation for arming Ukraine", *Politico*, 3 April 2023, see https://www.politico.eu/article/slovakia-russia-energy-fossil-fuel-retaliation-war-ukraine-jets/, accessed 5 June 2023.

2411 - Andrew Higgins, "Slovakia Says It's Halting Arms Deliveries to Ukraine", *The New York Times*, 26 October 2023, see https://www.nytimes.com/2023/10/26/world/europe/slovakia-weapons-ukraine-war.html, accessed 1 June 2024.

(US$7 billion) EU aid package in May 2024.[2412] In April 2024, Slovak presidential elections saw the win of Peter Pellegrini, party head of one of Fico's coalition partners, showing a shift towards a more pro-Russian view on the ongoing war.[2413]

According to Eurostat data, August 2023 marked the highest monthly import of Russian crude oil, topping previous record imports from December 2002 and 2008.[2414] In 2023, Slovakia imported Russian crude oil and pipeline gas for €184 million (US$$_{2023}$199 million) and €133 million (US$$_{2023}$144 million), respectively, with gas volumes slowly decreasing. Most of the gas is transferred to neighboring Austria.[2415] However, Slovakia is planning to further reduce Russian gas imports, including by striking a deal with Azerbaijan to transport gas via Ukrainian pipelines.[2416]

Two nuclear fuel deliveries in March 2022 to cover supply for 2022 and some of 2023, showcase the level of current dependence, when Russian cargo planes were granted exemption from the ban of Russian aircraft in European airspace.[2417] A current delivery contract with Rosatom-owned fuel company TVEL, signed in 2019, sees the delivery of fuel until 2026, possibly until 2030. 2023 marked a record amount of 230 tons of fuel valued at €200 million (US$$_{2023}$216 million) imported to Slovakia. This marks an impressive increase from 50 to 60 tons from 2019 to 2021, and 80 tons in 2022, which consumption and fuel loading activities at Mochovce-3 and -4 cannot fully account for, indicating that Slovakia might be building-up several years' worth of fuel reserves.[2418]

While in May 2023 SE signed an MoU with Framatome which included cooperation on the provision of "100% European" fuel for VVER reactors,[2419] by August 2023, a separate agreement on fuel supply had been reached with Westinghouse Electric Sweden AB. Expectation is that deliveries from Westinghouse will begin one year after a license is secured and the fuel is cleared for implementation in Slovakia.[2420] In February 2024, SE Chairman and General

2412 - Theodoros Benakis, "Hungary and Slovakia block EU military aid to Ukraine", *European Interest*, 27 May 2024, see https://www.europeaninterest.eu/hungary-and-slovakia-block-eu-military-aid-to-ukraine/, accessed 1 June 2024.

2413 - Radovan Stoklasa and Jan Lopatka, "Pellegrini wins Slovak presidential election in boost for pro-Russian PM Fico", *Reuters*, 7 April 2024, see https://www.reuters.com/world/europe/government-backed-pellegrini-takes-lead-slovak-presidential-election-2024-04-06/, accessed 1 June 2024.

2414 - *Trading Economics*, "Slovakia Crude Oil Imports From Russia—Slovakia", 2024, see https://tradingeconomics.com/slovakia/crude-oil-imports-from-russia, accessed 1 June 2024.

2415 - Isaac Levi, "January 2024 — Monthly analysis of Russian fossil fuel exports and sanctions", Centre for Research on Energy and Clean Air, 14 February 2024, see https://energyandcleanair.org/january-2024-monthly-analysis-of-russian-fossil-fuel-exports-and-sanctions/, accessed 1 June 2024.

2416 - Jason Hovet and Jan Lopatka, "Slovakia lays plans to receive gas from Azerbaijan", *Reuters*, as published on *Gas Processing & LNG*, 13 May 2024, see http://gasprocessingnews.com/news/2024/05/slovakia-lays-plans-to-receive-gas-from-azerbaijan/, accessed 1 June 2024.

2417 - *The Slovak Spectator*, "More Russian nuclear fuel lands in Slovakia", 16 March 2022, see https://spectator.sme.sk/c/22862758/more-russian-nuclear-fuel-lands-in-slovakia.html, accessed 22 August 2023.

2418 - Bellona, "Europe doubled its import of Russian nuclear fuel for 2023, data say", 15 March 2024, see https://bellona.org/news/nuclear-issues/2024-03-europe-russian-nuclear-fuel, accessed 1 June 2024.

2419 - Framatome, "Framatome signs Memorandum of Understanding with Slovenské elektrárne to extend long-term partnership" Press Release, 31 May 2023, see https://www.framatome.com/medias/framatome-signs-memorandum-of-understanding-with-slovenske-elektrarne-to-extend-long-term-partnership/, accessed 23 July 2023.

2420 - SE, "Strengthening Slovakia's energy security: Slovenské elektrárne concluded a fuel supply agreement with Westinghouse", Press Release, 25 August 2023, see https://www.seas.sk/en/press-releases/slovenske-elektrarne-nuclear-fuel-westinghouse/, accessed 27 June 2024.

Director Branislav Strýček announced at Westinghouse's "5th Annual VVER Forum", hosted by SE in Bratislava, that he "[expected] to finish the licensing process by 2026-2027."[2421]

Energy Policy—Low-Level Focus on Options Besides Nuclear

Slovak power production is highly and increasingly dependent on nuclear energy. In 2023, close to 62 percent of electricity was produced by nuclear, followed by hydro at around 15.6 percent, and natural gas, bioenergy, and coal with single digit percentages. Solar PV made up just 2 percent of generation. As of today, wind energy plays no role.[2422]

Over the past decade, Slovak solar PV capacity has slowly but steadily increased to 537 MW by 2022. Additional 220 MW were added in 2023, and another 600 MW are forecast to be installed by the end of 2025.[2423] Current plans envision the share of renewables in electricity generation to be at 29.5 percent in 2030. Most of the energy is to be supplied by hydroelectric capacity that will not be expanded from today's capacity of 2.5 GW. The 2030 target for solar PV target lies at a mere 1.4 GW, and bioenergy capacities are to be at only 400 MW. Onshore wind energy is targeted at 750 MW, up from 3 MW in 2023, a significant increase but still a very modest target.

By the end of 2024, the current National Energy and Climate Plan (NECP), submitted in September 2023, expects 100 MW of onshore wind to be on the grid.[2424] Several studies have concluded Slovakia's high potential for onshore wind, but development thereof has reportedly been halted by a series of "legislative, regulatory, administrative, technical and other barriers".[2425] In 2023, state-owned utility Slovenský Plynárenský Priemysel (SPP) announced plans to construct two wind farms, one of which being planned with 50 MW capacity and a price tag of €63 million (US$$_{2023}$68 million).[2426] The NECP envisions the closure of so-called "solid fuel" heat and power plants by 2025, and plans for the "[d]ecarbonisation of electricity generation after 2020 thanks to [renewables] and the development of nuclear energy". It is assumed that the latter will "dominate" the electricity sector by 2050, but no target shares or capacity have been communicated.[2427]

2421 - Westinghouse, "Westinghouse Organizes VVER Fuel Forum with Customers", Press Release, 22 February 2024, see https://info.westinghousenuclear.com/news/westinghouse-organizes-vver-fuel-forum-with-customers, accessed 1 June 2024.

2422 - Ember, "Electricity Data Explorer—Slovakia electricity generation by source", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 1 June 2024.

2423 - Patrick Jowett, "Slovakia's solar additions hit 220 MW in 2023", *PV Magazine*, 4 January 2024, see https://www.pv-magazine.com/2024/01/04/slovakias-solar-additions-hit-220-mw-in-2023/, accessed 1 June 2024.

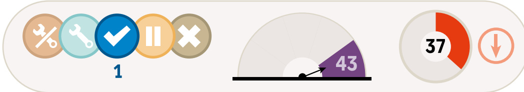
2424 - Marian Maraffko, Boris Valach and Ján Karaba, "Slovak Renewable Electricity Market Report 2022", Slovak Association of Photovoltaic Industry and RES (SAPI), February 2023, see https://www.sapi.sk/files/246_slovak-renewable-electricity-market-report-2022-finalpdf.pdf, accessed 14 September 2023; and Ministerstvo Hospodárstva Slovenskej Republiky, "Draft update of the Integrated National energy and climate plan for 2021-2030", Ministry of Economy of the Slovak Republic, August 2023, see https://commission.europa.eu/document/download/4f373d12-ce73-403a-a2d5-0107bf3e0c24_en?filename=SLOVAKIA%20-%20DRAFT%20UPDATED%20NECP%202021-2030_EN.pdf, accessed 15 February 2024.

2425 - Marian Maraffko, Boris Valach and Ján Karaba, "Slovak Renewable Electricity Market Report 2022", Slovak Association of Photovoltaic Industry and RES, February 2023, see https://www.sapi.sk/files/246_slovak-renewable-electricity-market-report-2022-finalpdf.pdf, accessed 14 September 2023.

2426 - Michal Hudec, "Slovakia now turning towards wind", *Euractiv*, 6 March 2023, see https://www.euractiv.com/section/politics/news/slovakia-now-turning-towards-wind/, accessed 1 June 2024.

2427 - Marian Maraffko, Boris Valach and Ján Karaba, "Slovak Renewable Electricity Market Report 2022", Slovak Association of Photovoltaic Industry and RES (SAPI), February 2023, see https://www.sapi.sk/files/246_slovak-renewable-electricity-market-report-2022-finalpdf.pdf, accessed 14 September 2023; and Ministerstvo Hospodárstva Slovenskej Republiky, "Draft update of the Integrated National energy and climate plan for 2021-2030", Ministry of Economy of the Slovak Republic, August 2023, see https://commission.europa.eu/document/download/4f373d12-ce73-403a-a2d5-0107bf3e0c24_en?filename=SLOVAKIA%20-%20DRAFT%20UPDATED%20NECP%202021-2030_EN.pdf, accessed 15 February 2024.

Slovenia



Slovenia jointly owns the Krško nuclear power plant with Croatia. As a multi-national site, the 688-MW Westinghouse PWR is sometimes also referred to as JEK (Jedrska elektrarna Krško) in Slovenia or NEK (Nuklearna elektrarna Krško) in Croatia. In 2023, it provided 5.33 TWh or 36.8 percent of Slovenia's electricity, down from the historic maximum of 42.8 percent in 2022, albeit absolute power generation increased minimally.[2428]

The reactor began its commercial operation in 1983 and was initially licensed to operate for 40 years. In 2012, a refurbishment program was approved,[2429] and in July 2015, an Inter-State Commission principally agreed to extend the plant's operating license to 60 years. Despite opposition from neighboring Austria[2430] (see previous WNISR editions), the Slovenian Ministry of the Environment granted "environmental consent" in January 2023, thereby approving the continued operation of Krško for an additional 20 years, allowing the plant to operate until 2043.[2431] In October 2021, the IAEA lead a Pre-SALTO (Safety Aspects of Long Term Operation) at the site, and a SALTO mission is scheduled to take place in May 2025.[2432]

The onsite spent fuel dry storage facility received its operating permit from the nuclear safety administration in October 2022, and was commissioned in early April 2023, when Holtec started loading spent fuel casks into the facility,[2433] thus completing all "physical improvements" of JEK's long-term Safety Upgrade Program which were required under Slovenia's Post-Fukushima stress test Action Plan as reviewed by European Regulators.[2434] All further measures of the national action plan had been implemented by the end of 2021, and the first transfer of fuel from the reactor's pool to the storage facility was completed in September 2023.[2435]

2428 - Ember, "Electricity Data Explorer—Slovenia electricity generation by source", 2024, see https://ember-climate.org/data/data-tools/data-explorer/, accessed 3 June 2024.

2429 - SNSA, "Slovenian Technical Review Report on the Krško NPP Ageing Management Program—Final Report", Slovenian Nuclear Safety Administration, Ministry of the Environment and Spatial Planning, Government of the Republic of Slovenia, December 2017, see https://www.ensreg.eu/sites/default/files/attachments/slovenia.pdf, accessed 2 September 2023.

2430 - Umweltbundesamt, BIEGE Nuklearexpertise, Ebner ZT and pulswerk, "Umweltverträglichkeitsprüfung—KKW Krško/Slowenien—Laufzeitverlängerung', Federal Environment Agency, commissioned/published by the Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation, and Technology, Government of Austria, 2022, see https://www.umweltbundesamt.at/uvp-kkw-krsko-lte, accessed 30 July 2022.

2431 - Ministry of the Environment and Spatial Planning, "Life span of the Krško Nuclear Power Plant (NEK) extended until 2043", Press Release, Government of Slovenia, 16 January 2023, see https://www.gov.si/en/news/2023-01-16-life-span-of-the-krsko-nuclear-power-plant-nek-extended-until-2043/, accessed 3 March 2023.

2432 - IAEA, "IAEA Concludes Long Term Operational Safety Review of Slovenia's Krško Nuclear Power Plant", Press Release 63/2021, 15 October 2021, see https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-of-slovenias-krsko-nuclear-power-plant; and IAEA, "Peer Review and Advisory Services Calendar—Safety Aspects of Long Term Operation (SALTO), Undated, see https://www.iaea.org/services/review-missions/calendar?type=3169&year%5Bvalue%5D%5Byear%5D=&location=All&status=All; both accessed 2 September 2023.

2433 - Holtec, "Holtec Moves Krško's Used Fuel Into Slovenia's First Dry Storage Facility to Support Continued Plant Operations", Press Release, 5 April 2023, see https://holtecinternational.com/2023/04/05/holtec-moves-krskos-used-fuel-into-slovenias-first-dry-storage-facility-to-support-continued-plant-operations/, accessed 2 September 2023.

2434 - ENSREG, "Slovenia", European Nuclear Safety Regulators Group, Updated December 2021, see https://www.ensreg.eu/country-profile/Slovenia; and SNSA, "Updated of the Slovenian Post-Fukushima Action Plan", Slovenian Nuclear Safety Administration, Ministry of the Environment and Spatial Planning, Government of the Republic of Slovenia, December 2021, see https://www.ensreg.eu/sites/default/files/attachments/stress_test_nacp_slovenia_2021.pdf; both accessed 30 June 2024.

2435 - NEK, "Annual Report 2023", 2024, see https://www.nek.si/upload/publications/nek-ang-2023-net.pdf; and Holtec, "Holtec Completes Design, Manufacturing, Construction and Commissioning of Industry's Most Robust On-Site Fuel Storage Facility at Slovenia's Krško Nuclear Power Plant", 31 October 2023, see https://holtecinternational.com/2023/10/31/holtec-completes-design-manufacturing-construction-and-commissioning-of-industrys-most-robust-on-site-fuel-storage-facility-at-slovenias-krsko-nuclear-power-plant/; and

In 2006, the Slovenian Government proposed the construction of a second reactor at the Krško site by 2017 as one potential measure to increase the sustainable development of the country.[2436] So, in the same year, state-owned GEN energija began with preparations for a feasibility study for the construction of two 1100 MW reactors.[2437] Initial cost estimates were set at €2 billion (US$$_{2006}$2.5 billion).[2438] In 2010, it was said that the "JEK 2 project [was] going according to schedule". Plans were now being made for a single reactor with a capacity ranging from 1100 to 1600 MW, a construction time of seven years, and grid connection by 2025.[2439] Five years later, after not much progress, the grid connection date had been pushed to 2030.[2440]

Slovenia's "Long-Term Climate Strategy Until 2050", adopted by Parliament on 13 July 2021 and filed with the United Nations, assumed a 43 percent share of renewables in electricity production by 2030, and "a comprehensive examination of options for the long-term use of nuclear energy and the adoption of a decision relating to the construction of a new nuclear power plant by 2027" with small modular reactors (SMR) among the considered options.[2441] This paved the way for the Ministry of Infrastructure to issue an "energy permit" for JEK-2 a week later, allowing further administrative proceedings to proceed.[2442]

The assumption was that JEK-2 would reach full power around 2034.[2443] However, other than the decision for a pressurized water reactor (PWR) design, no supplier or specific reactor design had been chosen. "Possible suppliers" were listed as China General Nuclear Power (CGN), Korea Hydro Nuclear Power (KHNP), U.S.-American Westinghouse and French EDF.[2444] Meanwhile, reports suggested that the Chinese option had been rejected, and emphasis was now put towards American, Korean, and French technologies.[2445]

In May 2022, responding to a question what the alternative approach would be if the schedule could not be met, GEN representatives replied "there is no Plan B" pointing to power imports

2436 - Government Office for Growth, "Resolution on National Development Projects for the Period 2007-2023", Government of the Republic of Slovenia, December 2006, see http://www.slovenijajutri.gov.si/fileadmin/urednik/publikacije/resolution_en.pdf, accessed 1 July 2024.

2437 - GEN Group, "Letno poročilo 2006", March 2007 (in Slovenian), see https://www.gen-energija.si/files/materials/10/pdf/Letno_porocilo2006_1b.pdf, accessed 3 June 2024.

2438 - Jan Bratanic, "Slovenia Pushes on With Pricey Nuclear Project to Phase Out Coal", *Bloomberg.com*, 18 October 2023, see https://www.bloomberg.com/news/articles/2023-10-18/slovenia-pushes-on-with-pricey-nuclear-project-to-phase-out-coal, accessed 3 June 2024; and Government Office for Growth, "Resolution on National Development Projects for the Period 2007-2023", Government of the Republic of Slovenia, December 2006, op. cit.

2439 - GEN Group, "Annual Report 2010", June 2011, see https://www.gen-energija.si/files/materials/6/pdf/GEN_LP_2010_ENG_web_2c.pdfhttps://www.gen-energija.si/files/materials/6/pdf/GEN_LP_2010_ENG_web_2c.pdf, accessed 3 June 2024.

2440 - GEN Group, "Annual Report 2015 of the Company GEN and the GEN Group", May 2016, see https://www.gen-energija.si/files/materials/34/pdf/GEN_2015_ENG_LP_interactive_2.pdf, accessed 3 June 2024.

2441 - Government of the Republic of Slovenia, "Resolution on Slovenia's Long-Term Climate Strategy Until 2050 (ReDPS50)", 24 August 2021, p. 30–34, see https://unfccc.int/sites/default/files/resource/LTS1_SLOVENIA_EN.pdf, accessed 2 September 2023.

2442 - Ministry of Infrastructure, "Ministry of infrastructure issues an energy permit for the second nuclear reactor unit in Krško", Press Release, Government of the Republic of Slovenia, 20 July 2021, see https://www.gov.si/en/news/2021-07-20-ministry-of-infrastructure-issues-an-energy-permit-for-the-second-nuclear-reactor-unit-in-krsko/, accessed 2 September 2023.

2443 - Bruno Glaser and Tomaž Žagar, "GEN's vision for decarbonisation and energy independence - by 2035", GEN Energija, May 2022, see https://gmfeurope.org/wp-content/uploads/2022/07/Levicar.pdf, accessed 1 July 2024.

2444 - Ibidem.

2445 - Borut Tavčar, "Če želimo napredek, Krško ne more biti edina lokacija za jedrsko tehnologijo", interview with Danijel Levičar, Gen energije (in Slovenian), *DELO*, 18 October 2022, see https://www.delo.si/dpc-energetika/porocimo-se-z-drzavo-dobaviteljico, accessed 6 June 2023.

as the only option.[2446] The Association of Ecological Movements of Slovenia is pointing to the relatively high final energy consumption in Slovenia—7 percent above E.U. average per capita—leaving plenty of room for efficiency gains. The solar potential on buildings alone has been estimated at 27 TWh, more than twice the current Slovenian electricity consumption. Additional solar potential is seen in floating plants on hydro dams and in agrivoltaics. One of the Association's energy experts concluded: "In Slovenia, we can produce all the necessary energy, not just electricity, entirely from renewable energy sources if we reduce energy waste and use the available renewable energy sources. Free of fossil and nuclear energy."[2447]

The surprising April 2022 election win of the center-left Freedom Movement might have some impact on the future of the energy and nuclear policy in the country.

The surprising April 2022 election win of the center-left Freedom Movement might have some impact on the future of the energy and nuclear policy in the country. Prime Minister Robert Golob and his Minister of the Environment, Climate and Energy, Bojan Kumer, both former energy executives, see promise in nuclear technology, including SMRs, but Kumer stated that is was "imperative to hear the people's opinion" and promised to introduce legislation to boost the development of renewable energies.[2448] Several changes have been implemented to remove regulatory hurdles, such as restrictive spatial laws, but analysts of the European Commission still conclude that substantial entry barriers for renewables remain, such as "lengthy permitting procedures" and lack of administrative staff.[2449] The Croatian Government was apparently open to expanding nuclear capacities,[2450] confirmed in March 2024 in a statement from Prime Minister Plenković at the Nuclear Energy Summit held in Brussels.[2451] Like the Czech Republic, Poland and its neighbor Slovakia, Slovenia had submitted a bid for the U.S.-funded "Pheonix Project" for SMR development. The country was selected as a recipient of "coal-to-nuclear technical advisory and consultancy services" in February 2024.[2452] This was followed by the announcement of GEN that it had joined the European Industrial Alliance on SMRs in May 2024,[2453] and the adoption of a parliamentary resolution on the "long-term peaceful use of nuclear energy in Slovenia" later in the month. The resolution emphasizes the

2446 - Exchange between Mycle Schneider and GEN representatives Bruno Glaser and Tomaž Žagar during a visit to the GEN-Offices at Krško, 18 May 2022, organized by the Friedrich Ebert Foundation, Zagreb.

2447 - Matjaž Valenčič, "The future of Slovenia: Renewable energy, without fossil and nuclear", Unpublished, May 2022.

2448 - Igor Todorović, "Priority of new Government of Slovenia is to tackle energy crisis", *Balkan Green Energy News*, 6 June 2022, see https://balkangreenenergynews.com/priority-of-new-government-of-slovenia-is-to-tackle-energy-crisis/, accessed 8 July 2022.

2449 - EC, "2023 Country Report Slovenia", European Commission, June 2023, see https://data.europa.eu/doi/10.2765/339082 accessed 1 August 2024.

2450 - Government of the Republic of Slovenia, "Prime Minister Janez Janša meets Croatian Prime Minister Andrej Plenković", 28 March 2022, see https://www.gov.si/en/news/2022-03-28-prime-minister-janez-jansa-meets-croatian-prime-minister-andrej-plenkovic/, 1 July 2024.

2451 - Milica Stojanovic, "Serbia Mulls Scrapping Ban on Nuclear Power Production", *Balkan Insight*, 21 March 2024, see https://balkaninsight.com/2024/03/21/serbia-mulls-scrapping-ban-on-nuclear-power-production/, accessed 22 March 2024.

2452 - U.S. Embassy Ljubljana, "Press Release", United States Embassy in Slovenia, 6 February 2024, see https://si.usembassy.gov/press-release/, accessed 1 July 2024.

2453 - GEN Energija, "GEN energija postala članica Evropskega industrijskega zavezništva za male modularne jedrske reaktorje", 8 May 2024 (in Slovenian), see https://www.gen-energija.si/medijsko-sredisce/novice/323/gen-energija-postala-lanica-evropskega-industrijskega-zaveznitva-za-male-modularne-jedrske-reaktorje, accessed 1 July 2024.

supposed necessity of the JEK2 project and the deployment of SMRs for the decarbonization of the Slovenian power system.[2454]

Early on, Prime Minister Golob had also stated that once a technology has been selected for the newbuild project, a referendum would be held[2455] and has since maintained his intention to "seek the broadest possible national consensus for constructing this unit".[2456] According to GEN's timeline as of July 2023, a final decision would then be made by the end of 2027.[2457] In June 2023, the company also indicated that their application for JEK2 had been supplemented to accommodate a plant with greater capacity—up to 2400 MW—in the expressed hope to "expand the range of potential suppliers".[2458] As a result, Golob put the price tag of JEK-2 at €11 billion (US$12 billion) "should Slovenia decide to go ahead with the largest of several possible units under consideration". He further pointed out that unless proceedings were sped up, Slovenia could not finance the project alone and that "investors from [neighboring] countries [had] shown interest in […] funding the project."[2459]

A coordination body gathering officials from various government entities with the active participation of senior management from GEN, Eles and NEK, has been holding regular meetings since its creation in September 2023 to optimize and accelerate the implementation of the project,[2460] including the preparation of key information to be provided to citizens in view of the referendum.[2461]

In January 2024, Golob announced that at a cross-party summit, involving the Presidents of the Republic, of the National Assembly, of the National Council, and of the Parliamentary parties, an agreement had been reached to jointly pursue efforts for the construction of JEK2. Additionally, it had been agreed upon the phrasing of the planned referendum to determine whether "we want nuclear energy to remain part of Slovenia's future and whether people support the construction of the second unit." No date was set, but participants of the meeting were "thinking" of organizing it "in the second half of the year."[2462]

2454 - Uradni List, "Vsebina Uradnega lista", Government of Slovenia, Official Gazette of the Slovenian Republic, 24 May 2024, see https://www.uradni-list.si/glasilo-uradni-list-rs/vsebina, accessed 1 August 2024.

2455 - Prime Minister of the Republic of Slovenia, "Predsednik vlade dr. Robert Golob obiskal Nuklearno elektrarno Krško (NEK)", Government of the Republic of Slovenia, 28 October 2022 (in Slovenian), see https://www.gov.si/novice/2022-10-28-predsednik-vlade-dr-robert-golob-obiskal-nuklearno-elektrarno-krsko-nek/, accessed 1 July 2024.

2456 - John Adkins, "Cost Estimate For New Krško Plant Is €11 Billion, Prime Minister Says", *NucNet*, 4 July 2023, see https://www.nucnet.org/news/cost-estimate-for-new-krsko-plant-is-eur11-billion-prime-minister-says-7-2-2023; accessed 2 September 2023.

2457 - Ibidem.

2458 - JEK2, "Prime Minister Dr. Golob announced a preliminary decision on the JEK2 project during his visit to Krško", 16 June 2023, see https://jek2.si/en/news/prime-minister-dr-golob-announced-a-preliminary-decision-on-the-jek2-project-during-his-visit-to-krsko/; and JEK2, "Questions and answers—In which stage is the JEK2 project?", 2024, see https://jek2.si/en/questions-and-answers/; both accessed 1 July 2024.

2459 - John Adkins, "Cost Estimate For New Krško Plant Is €11 Billion, Prime Minister Says", *NucNet*, 4 July 2023, op. cit.

2460 - Government of the Republic of Slovenia, "Delovna skupina za koordinacijo pripravljalnih aktivnosti na projektu JEK2", Press Release (in Slovenian), 7 September 2023, see https://www.gov.si/zbirke/delovna-telesa/delovna-skupina-za-koordinacijo-pripravljalnih-aktivnosti-na-projektu-jek2/, accessed 1 July 2024

2461 - Government of the Republic of Slovenia, "Seznanitev z napredkom projekta JEK2", 18 June 2024, see https://www.gov.si/novice/2024-06-18-seznanitev-z-napredkom-projekta-jek2/, accessed 1 July 2024.

2462 - Prime Minister of the Republic of Sovenia, "Important consensus reached on the role of nuclear energy in energy policy and the activities for Nuclear Power Plant 2", 30 January 2024, see https://www.gov.si/en/news/2024-01-30-important-consensus-reached-on-the-role-of-nuclear-energy-in-energy-policy-and-the-activities-for-nuclear-power-plant-2/, accessed 1 July 2024.

A final investment decision was expected to be made in 2027 or 2028 if the referendum is accepted.[2463] In May 2024, in parallel to the adoption of the above-mentioned resolution on the "peaceful use of nuclear energy,"[2464] the Slovenian Parliament voted in favor of holding the proposed referendum with rare bipartisan support (71 votes for, 6 against). Critics of the Levica ("Left") junior coalition party reportedly said that "the referendum was about getting a blank cheque for a potentially unviable project".[2465] Notably, Slovenian President Nataša Pirc Musar, a proponent of nuclear energy, expressed that at this stage the "project raised more questions than it answered", for what would be "the biggest investment [in] the country's history".[2466] The referendum is expected to take place before the end of November 2024.[2467]

In May 2024, GEN energija presented findings of a recent study, which concluded that a 1300 MW reactor would be the optimal size. Estimated overnight construction costs (i.e. excl. financing cost) of the new plant range from €9.3 billion (US$10 billion) for a 1000-MW reactor to €15.4 billion (US$16.7 billion) for a 1650-MW reactor. GEN hopes for a final investment decision in 2028, construction start in 2032 and grid connection by 2039.[2468] While in November 2023, EDF had announced that it had made an offer to "support the construction of two EPR1200 units and alternatively one EPR unit in Slovenia",[2469] Westinghouse and KHNP are still to be considered as potential vendors, as no design had been officially selected as of mid-2024.[2470]

Just as of last year, the government had been criticized by the opposition for "dragging its feet" in terms of advancing the JEK-2 project and to instead be promoting renewable energy technology development.[2471] In June 2023, Prime Minister Golob told parliament that the project needed special legislation without which completion would be only around 2047. This would be too late, he added, stating that if the process was accelerated, under the most

2463 - *WNN*, "Slovenia aiming for referendum on new nuclear this year", *World Nuclear News*, 31 January 2024, see https://www.world-nuclear-news.org/Articles/Slovenia-aiming-for%C2%A0referendum-on-new-nuclear-this, accessed 1 June 2024.

2464 - Uradni List, "Vsebina Uradnega lista", Government of Slovenia, Official Gazette of the Slovenian Republic, May 2024, op. cit.

2465 - *Agenzia ANSA*, "Slovenian MPs support referendum on new Krsko nuclear plant", 23 May 2024, see https://www.ansa.it/nuova_europa/en/news/sections/news/2024/05/23/slovenian-mps-support-referendum-on-new-krsko-nuclear-plant_2410c099-3a62-4661-8d70-e795b3c4fed8.html, accessed 3 June 2024.

2466 - *The Slovenia Times*, "Slovenia's nuclear energy expansion gains further momentum", 23 May 2024, see https://sloveniatimes.com/40529/slovenias-nuclear-energy-expansion-gains-further-momentum, accessed 3 June 2024; and *STA*, "Pirc Musar warns public not being informed properly about N-plant project", *The Slovenian Press Agency*, 13 May 2024, see https://english.sta.si/3299416/pirc-musar-warns-public-not-being-informed-properly-about-n-plant-project, accessed 1 July 2024.

2467 - *Slovenia Press Agency*, "DZ potrdil razpis posvetovalnega referenduma o JEK2", as published on N1 (in Slovenian), 23 May 2024, see https://n1info.si/novice/slovenija/poslanci-danes-o-referendumu-o-jek2-pomisleke-imajo-le-v-levici/, accessed 2 August 2024.

2468 - GEN energija "GEN energija predstavila oceno ekonomike projekta JEK2", 21 May 2024 (in Slovenian), see https://www.gen-energija.si/medijsko-sredisce/novice/326/gen-energija-predstavila-oceno-ekonomike-projekta-jek2, accessed 1 July 2024.

2469 - EDF, "EDF submits a set of technical and commercial proposal for a new nuclear programme with EPR technology in Slovenia during the World Nuclear Exhibition 2023 and further signs key agreements with international partners.", Press Release, 30 November 2023, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/edf-submits-a-set-of-technical-and-commercial-proposal-for-a-new-nuclear-programme-with-epr-technology-in-slovenia-during-the-world-nuclear-exhibition-2023-and-further-signs-key-agreements, accessed 1 July 2024.

2470 - *NEI Magazine*, "Slovenia unveils JEK2 nuclear project details ahead of referendum", 27 June 2024, see https://www.neimagazine.com/news/slovenia-unveils-jek2-nuclear-project-details-ahead-of-referendum/, accessed 2 August 2024.

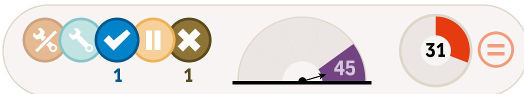
2471 - Sebastijan R. Maček, "Slovenian energy minister causes furor[e] over new nuclear unit timeline", *Euractiv*, 16 March 2023, see https://www.euractiv.com/section/politics/news/slovenian-energy-minister-causes-furore-over-new-nuclear-unit-timeline/, accessed 2 September 2023.

optimistic scenario, the completion date could be brought forward to 2037.[2472] The currently operational reactor is scheduled to close in 2043 (pending further lifetime extensions).

Slovenia is targeting the end coal generation by 2033,[2473] necessitating a rapid build-up of replacement capacity from other sources, because in 2023, coal accounted for 3.2 TWh, or 21 percent of the total electricity generated. This was surpassed by nuclear with 37.1 percent and hydro at 32.6 percent. Gas, bioenergy, and other fossil fuels' shares are in the low single digits.[2474] Slovenia targets a 52 percent share of renewable energies in the electricity mix by 2030.[2475] With a share of only 4.5 percent solar in 2023 power generation, and wind being, as of today, fully neglected, this target seems rather ambitious.[2476] The installation of a 250-kW wind turbine in September 2023 increased the current number of operational wind turbines in Slovenia to a total of three.[2477] While Turbine No. 3 had apparently not even begun operating as of May 2024, a fourth turbine (1 MW) has been approved, and several additional projects were in various planning stages. With a €200,000 (US$ 216,000) grant per installed MW, the government is hoping to incentivize local municipalities to allow the construction of additional wind turbines.[2478]

FORMER SOVIET UNION

Armenia



Armenia has one operating reactor at the Metsamor (or Medzamor) nuclear power plant, also called the Armenian Nuclear Power Plant (ANPP), within 30 km of the capital, Yerevan. In 2023, it produced 2.5 TWh of electricity (31.1 percent of total power consumption), roughly the same as in 2022, but up from 1.8 TWh in 2021.

Amenia has practically no fossil fuel resources, and two-thirds of its primary energy consumption comes from energy imports, with the remaining one-third coming from nuclear, hydro, biofuels and a small share of solar and wind. Consequently, energy production and use are significant economic and security considerations.

2472 - Igor Todorović, "Second unit of Slovenia's Krško nuclear power plant to cost up to EUR 11 billion", *Balkan Green Energy News*, 27 June 2023, see https://balkangreenenergynews.com/second-unit-of-slovenias-krsko-nuclear-power-plant-jek2-to-cost-up-to-eur-11-billion/, accessed 24 July 2023.

2473 - Government of the Republic of Slovenia, "Draft update proposal (2024): Integrated National Energy and Climate Plan of the Republic of Slovenia", 22 June 2023, see https://commission.europa.eu/document/download/88f140fc-424f-4740-8b6f-6d4d89b2a701_en?filename=EN_SLOVENIA%20DRAFT%20UPDATED%20NECP.pdf; and Vladimir Spasić, "Slovenia confirms coal phaseout date in updated NECP", *Balkan Green Energy News*, 11 June 2024, see https://balkangreenenergynews.com/slovenia-confirms-coal-phaseout-date-in-updated-necp/; both accessed 1 July 2024.

2474 - Ember, "Electricity Data Explorer—Slovenia electricity generation by source", 2024, op. cit.

2475 - Government of the Republic of Slovenia, "Draft update proposal (2024): Integrated National Energy and Climate Plan of the Republic of Slovenia", 22 June 2023, op. cit.

2476 - Ember, "Electricity Data Explorer—Slovenia electricity generation by source", 2024, op. cit.

2477 - *Balkan Green Energy News*, "LEITWIND LTW42 250 kW, the third wind turbine installed in the entire state of Slovenia", 26 September 2023, see https://balkangreenenergynews.com/leitwind-ltw42-250-kw-the-third-wind-turbine-installed-in-the-entire-state-of-slovenia/, accessed 15 November 2023.

2478 - Igor Todorović, "State-owned DEM to operate Slovenia's fourth wind turbine", *Balkan Green Energy News*, 10 May 2024, see https://balkangreenenergynews.com/state-owned-dem-to-operate-slovenias-fourth-wind-turbine/, accessed 3 June 2024.

The reactor started generating in January 1980. Its design, VVER-440 v270, a first-generation Soviet-designed reactor, is deemed to have the least adequate safety systems of the VVER reactors, and those of similar vintage in former Eastern Germany, Bulgaria, and Slovakia have been closed. In December 1988, Armenia suffered a significant earthquake that led to the rapid closure of its two reactors in March 1989. However, during the early 1990s and following the collapse of the former Soviet Union, a territorial dispute between Armenia and Azerbaijan led to an energy blockade that resulted in power shortages, leading to the government's decision in 1993 to re-open Unit 2, which resumed operation in 1995.[2479]

Metsamor's closure has been gradually delayed as plans for developing a replacement reactor have stalled. In 2011, the Armenian Nuclear Regulatory Authority (ANRA) granted the reactor an extension of its operating license until 2021, subject to annual safety demonstrations starting in 2016, the initial expiration date.[2480] In October 2012, the Armenian Government announced that it planned to operate Metsamor until 2026. This was funded by a US$170 million loan and a US$19 million grant from Russia, and a AMD63.4 billion (US$161 million) investment from the state.[2481] The engineering work enabling the reactor to operate until 2026 at an increased output was completed in November 2021, when the reactor was also uprated from 407.5 MW to 448 MW (gross).[2482]

In March 2023, the Armenian Government approved a strategy to operate the reactor until 2036, with works expected to cost US$150 million and be completed by 2026.[2483] Once again the intention is to give sufficient time for constructing a new nuclear power and for the power from the existing reactor to be replaced.

In 2024, Rosatom began work to extend the unit's lifetime by testing the reactor pressure vessel material to assess how ageing has affected its strength and brittleness. Annealing of the pressure vessel was undertaken during the process to extend the reactor's life until 2026, but further tests will be carried out.[2484]

The power plant has been a source of tension with neighboring countries for decades. The situation escalated in July 2020 when a senior Azerbaijani official threatened a missile strike against Metsamor during renewed fighting on the Armenia-Azerbaijan border. Around the same time, Galib Israfilov, Azerbaijan's ambassador to the IAEA—who condemned the threats against the plant—sent a letter to the Director General in which he said the "continued

2479 - WNA, "Nuclear Power in Armenia", World Nuclear Association, Updated 10 May 2024, see https://world-nuclear.org/information-library/country-profiles/countries-a-f/armenia, accessed 13 August 2024.

2480 - IAEA, "IAEA Concludes Long-Term Operational Safety Review at Armenia's Nuclear Power Plant", Press Release 61/2018, 10 December 2018, see https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-at-armenias-nuclear-power-plant, accessed 13 August 2024.

2481 - Armenian Government, "Republic of Armenia Energy Sector Development Strategic Program to 2040", 2021, see https://policy.asiapacificenergy.org/sites/default/files/Energy%20Sector%20Development%20Strategic%20Program%20to%202040%20.pdf, accessed 13 August 2024.

2482 - *NEI Magazine*, "Life extension work completed at Armenian NPP", *Nuclear Engineering International*, 18 November 2021, see https://www.neimagazine.com/news/life-extension-work-completed-at-armenian-npp-9260626/, accessed 13 August 2024.

2483 - *Interfax*, "Utilization period of Armenian NPP extended until 2036", 23 March 2023, see https://interfax.com/newsroom/top-stories/88975/, accessed 13 August 2024.

2484 - *NEI Magazine*, "Rosatom supports Armenian NPP life extension", 2 August 2024, see https://www.neimagazine.com/news/rosatom-begins-work-to-support-life-extension-of-armenian-npp/, accessed 13 August 2024.

operations of Metsamor NPP would be a high risk for the entire region due to potential earthquakes in the immediate area."[2485]

Türkiye has also raised concerns about the facility's safety, given that it is only 16 km from the Turkish city of Iğdır. In October 2023, it was reported that the Grand National Assembly of Türkiye (TBMM) Petitions Committee had received a public petition against the latest lifetime extension project and that the government had once again called for the closure of the facility.[2486] This was not well received in Armenia, and the Chair of the Parliamentary Foreign Affairs Committee reportedly said that the Turkish demands to close the plant were "inappropriate and outdated."[2487]

However, in February 2020, Armenian government officials said that they were considering, as part of the country's 2040 energy strategy, further extending the lifetime of the reactor.

The European Nuclear Safety Regulators Group (ENSREG) issued an E.U. Peer Review report of the Armenian Stress Test in June 2016[2488] and one on implementing the Armenian Stress Test National Action Plan in November 2019,[2489] confirming numerous safety-related problems. The E.U. has insisted on the decommissioning of Metsamor for decades, even making it official policy, or as summarized by the International Energy Agency in 2022: "An agreement in principle to close the ANPP, along with offers of assistance to do so, have been part of almost every major agreement between the E.U. and Armenia since at least 1998," yet the reactor was kept in operation.[2490] The Comprehensive and Enhanced Partnership Agreement (CEPA) contracted with the E.U. in 2017 included cooperation on "the closure and safe decommissioning of Medzamor nuclear power plant and the early adoption of a road map or action plan to that effect taking into consideration the need for its replacement with new capacity to ensure the energy security of the Republic of Armenia and conditions for sustainable development."[2491]

However, in February 2020, Armenian Government officials said that they were considering, as part of the country's 2040 energy strategy, further extending the lifetime of the reactor.[2492] In December 2020, the European Commission reiterated, "The nuclear power plant located in

2485 - Phil Chaffee, "Interview: Azerbaijan Eager for Mechanism to Address Metsamor Concerns", *Nuclear Intelligence Weekly*, 7 August 2020.

2486 - *BIA News Desk*, "Turkey demands closure of Armenia's Metsamor nuclear plant", 2 October 2023, see https://bianet.org/haber/turkey-demands-closure-of-armenias-metsamor-nuclear-plant-285683, accessed 13 August 2024.

2487 - *Armenpress*, "Turkey's demands on shutting down Armenian nuclear power plant are inappropriate and outdated – lawmaker", *Armenian News Agency*, 3 October 2023, see https://armenpress.am/en/article/1121095, accessed 13 August 2024.

2488 - ENSREG, "Armenia Stress Tests Peer Review (20th to 24th June 2016)—Executive Summary", European Nuclear Safety Regulators Group, June 2016, see http://www.ensreg.eu/document/armenia-stress-tests-peer-review-20-24-june-2016, accessed 13 August 2024.

2489 - ENSREG, "EU Peer Review Report Implementation of Armenian Stress Test National Action Plan", November 2019, see https://www.ensreg.eu/sites/default/files/attachments/armenia_nacp_peer_review_report-november_2019.pdf, accessed 13 August 2024.

2490 - IEA, "Armenia 2022 Energy Policy Review", International Energy Agency, March 2022, see https://iea.blob.core.windows.net/assets/8328cc7c-e65e-4df1-a96f-514fdd0ac31e/Armenia2022EnergyPolicyReview.pdf, accessed 13 August 2024.

2491 - European Union, European Atomic Energy Community, "Comprehensive and Enhanced Partnership Agreement", *Official Journal of the European Union*, 2018, see https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:22018A0126(01), accessed 13 August 2024.

2492 - *NEI Magazine*, "Armenia considers further life extension for Metsamor", 2 March 2020, see https://www.neimagazine.com/news/newsarmenia-considers-further-life-extension-for-metsamor-7802500, accessed 16 July 2023.

Medzamor cannot be upgraded to fully meet internationally accepted nuclear safety standards, and therefore requires an early closure and safe decommissioning."[2493]

In February 2024, nuclear tensions were downplayed, and the press announcement following the 5th meeting of the EU-Armenia Partnership Council noted that parties would "continue to work together to enhance Armenia's energy production from renewable sources, including through investments under the Economic and Investment Plan, as well as to ensure nuclear safety," with no specific reference to Metsamor.[2494]

The construction of a new reactor is also fraught with geopolitical tensions. Russia is keen to maintain its nuclear relationship, and in October 2021, talks were said to be launched and in January 2022, an MoU was signed to explore "possible cooperation to construct new nuclear power units of Russian design in the Republic of Armenia."[2495] A working group was established in June 2023 to explore various options, including Small Modular Reactors (SMRs).[2496] At the same time, the U.S. is pressing for a shift away from Russian influence. In May 2022, the U.S. and Armenian Governments signed an MoU on civil nuclear power, including cooperation on energy security and strengthening diplomatic and economic relationships.[2497]

In January 2024, Armenian Prime Minister, Nikol Pashinian, reportedly said they planned to build a new reactor in eight to ten years, but the technology was still undecided with Russia, South Korea and the U.S. being all possible vendors.[2498]

However, nuclear energy is not the only option on the table, and there is an increased focus on renewable energy. Solar and wind currently provide less than 1 percent of the country's power, but the Armenian Nationally Determined Contribution (NDC) submitted to the UNFCCC Secretariat, indicates a 2030-target of at least 15 percent, with 1 GW of solar due to be deployed.[2499] In June 2024, the World Bank approved a US$40 million loan to support the energy transition in the country by upgrading the grid.[2500] The government's energy sector development plan highlights the importance of renewables:

2493 - European Commission, "Joint Staff Working Document—Partnership Implementation Report on Armenia", 16 December 2020, see https://data.consilium.europa.eu/doc/document/ST-14188-2020-INIT/en/pdf, accessed 13 August 2024.

2494 - European Council, "Joint press statement following the 5th meeting of the EU-Armenia Partnership Council", Press Release, 13 February 2024, see https://www.consilium.europa.eu/en/press/press-releases/2024/02/13/joint-press-statement-following-the-5th-meeting-of-the-eu-armenia-partnership-council/, accessed 13 August 2024.

2495 - Rosatom, "ROSATOM and Armenia Sign Cooperation Agreement to Build New Nuclear Units", 20 January 2022, see https://www.rosatom.ru/en/press-centre/news/rosatom-and-armenia-sign-cooperation-agreement-to-build-new-nuclear-units/?sphrase_id=5849291, accessed 28 August 2024.

2496 - *ArmenPress*, "PM Pashinyan activates task force in charge of construction of new nuclear power reactor", 6 June 2023, see https://armenpress.am/en/article/1112610, accessed 28 August 2024.

2497 - U.S. Department of State, "The United States of America and the Republic of Armenia Sign a Memorandum of Understanding Concerning Civil Nuclear Cooperation", Press Release, United States Government, 22 May 2022, see https://www.state.gov/the-united-states-of-america-and-the-republic-of-armenia-sign-a-memorandum-of-understanding-concerning-strategic-civil-nuclear-cooperation/, accessed 14 August 2024.

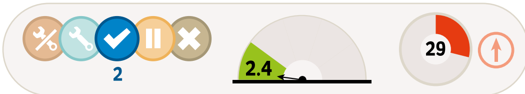
2498 - *NEI Magazine*, "Armenian PM confirms country's interest in new NPP and SMRs", 19 January 2024, see https://www.neimagazine.com/news/armenian-prime-minister-confirms-countrys-interest-in-new-npp-and-smrs-11447511/, accessed 13 August 2024.

2499 - Government of Armenia, "Approval of the Nationally Determined Contribution 2021-2030 of the Republic of Armenia to Paris Agreement", April 2021, see https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20of%20Republic%20of%20Armenia%20%20 2021-2030.pdf, accessed 13 August 2024.

2500 - World Bank, "Armenia's Transition to Clean Energy and Power Transmission Grid Upgrades to Benefit from World Bank Support", 3 June 2024, see https://www.worldbank.org/en/news/press-release/2024/06/03/armenia-s-transition-to-clean-energy-and-power-transmission-grid-upgrades-to-benefit-from-world-bank-support, accessed 13 August 2024.

> The fact that the solar and wind technologies are considered as part of the least cost solution for new generation under all scenarios stresses the importance to Armenia of ensuring a policy and institutional environment that supports development of these technologies to the maximum extent possible, not only to ensure the lowest cost generation but also to minimize reliance on other imported energy sources and to strengthen Armenia's energy security and competitiveness.[2501]

Belarus



Construction started in November 2013 at Belarus's first nuclear reactor at the Ostrovets power plant, also called Belarusian-1. Construction of a second 1200-MWe AES-2006 reactor started in June 2014. The first unit was completed and connected to the grid on 3 November 2020 and reached full power in January 2021.[2502] In May 2023, the Belarussian Energy Ministry announced the grid connection of the second unit.[2503]

In 2022, Belarusian-1 provided 4.4 TWh, down from 5.4 TWh the previous year, representing a share of 11.9 percent, down from 14 percent in 2021, of the electricity production. However, in 2023, the nuclear plant provided 11 TWh or 28.6 percent of the country's power as both units were operating.

The E.U. has imposed a series of sanctions against Belarus in response to the country's fraudulent elections of 2020, its human rights abuses, and its complicity with Russia's military aggression against Ukraine. These sanctions are directed against individuals and specific sectors, primarily related to financial transactions and the import-export of certain products, including coal and crude oil.[2504]

The original agreement on the construction of the reactors was signed in October 2011 between the Belarus Nuclear Power Plant Construction Directorate and Russia's Atomstroyexport (ASE), a Rosatom subsidiary.[2505] The Russian and Belarusian Governments agreed in November 2011 that Russia would lend up to US$10 billion for 25 years to finance 90 percent of the project. An amendment in 2021 extended the time from which the loan repayments would begin by two years, to start in April 2023, due to the later-than-planned completion date.[2506] The project assumes Russian liability for all fuel supply and repatriation of spent fuel for the plant's life. The fuel will be reprocessed in Russia, and the separated wastes will be returned to Belarus.

2501 - Armenian Government, "Republic of Armenia Energy Sector Development Strategic Program to 2040", 2021, see https://policy.asiapacificenergy.org/sites/default/files/Energy%20Sector%20Development%20Strategic%20Program%20to%20 2040%20.pdf, accessed 13 August 2024.

2502 - Belarusian Nuclear Power Plant, "Power Unit 1 of the Belarusian NPP brought to 100% capacity", 13 January 2021, see https://www.belaes.by/en/news/item/3128-power-unit-1-of-the-belarusian-npp-brought-to-100-capacity.html, accessed 1 September 2024.

2503 - *NEI Magazine*, "Grid connection for Belarus 2", 16 May 2023, see https://www.neimagazine.com/news/grid-connection-for-belarus-2-10852798/, accessed 14 August 2024.

2504 - European Council, "EU sanctions against Belarus", Consilium, 13 August 2024, see https://www.consilium.europa.eu/en/policies/sanctions-against-belarus/, accessed 13 August 2024.

2505 - *WNN*, "Contract signed for Belarusian reactors", 11 October 2011, see https://www.world-nuclear-news.org/Articles/Contract-signed-for-Belarusian-reactors, accessed 14 August 2024.

2506 - *NEI Magazine*, "Russia amends terms for Belarus NPP loan agreement", 29 March 2021, see https://www.neimagazine.com/news/russia-amends-terms-for-belarus-npp-loan-agreement-8633297/, accessed 14 August 2024.

Information on the fate of the plutonium extracted during reprocessing is unavailable, but it will likely remain in Russia.[2507]

While the complexity of nuclear plant construction is often at the root of delays and cost overruns, at Ostrovets, the project also suffered from significant accidents including involving the reactor pressure vessels (RPV). In 2016, during the installation of the RPV, it was dropped, which resulted in the need for replacement. Eventually, a vessel was shipped that had been destined for the never completed Baltic nuclear station in Russia.[2508]

It is not easy to assess the total investment. President Lukashenko said in 2019 that the cost would be below US$10 billion but refused to reveal the actual number, stating: "It is a commercial secret. The contract price shouldn't be made public."[2509] Fluctuating currency exchange rates between the U.S. dollar and the Russian ruble further complicate estimation. One analysis suggested that currency exchanges alone would put the construction bill at US$24 billion.[2510] However, given the scale of the delays and equipment changes, keeping to the original budget would not have been possible.

During the construction period, the Lithuanian Government was dissatisfied with the information provided by Belarus and appealed to the Espoo Convention. In 2019, the Parties of the Espoo convention's meeting concluded that the Belarus authorities had provided the necessary information on the technical and scientific questions but recognized it had failed to give adequate information on alternative sites and, therefore, why the Ostrovets site had been chosen. The parties recommended that Belarus and Lithuania continue a dialogue on this issue,[2511] a process that was still not concluded as of mid-2024.[2512]

The Lithuanian Government has continued to try and pressurize the Belarus Government to improve safety at the plant. As Unit 2 entered operation, the Lithuanian State Nuclear Power Safety Inspectorate (VATESI) stated that operation at both units should be suspended until all nuclear safety issues have been resolved.[2513]

In May 2023, the Lithuanian Government sent a letter to the Belarusian Ministry of Emergency Situations requesting the suspension of the operation at Ostrovets. The letter pointed to an alleged "lack of specific information of the nuclear power plant site selection and evaluation,

2507 - *Interfax*, "Russia, Belarus sign agreement on management of spent nuclear fuel", 21 November 2022, see https://interfax.com/newsroom/top-stories/85185/, accessed 14 August 2024.

2508 - *WNN*, "Russia to use Baltic NPP reactor vessel for Ostrovets 2", 25 April 2017, see https://www.world-nuclear-news.org/NN-Russia-to-use-Baltic-NPP-reactor-vessel-for-Ostrovets-25041701.html, accessed 14 August 2024.

2509 - *BelTA*, "Belarusian nuclear power plant to cost less than $10bn", 19 April 2019, see https://eng.belta.by/president/view/belarusian-nuclear-power-plant-to-cost-less-than-10bn-120494-2019/, accessed 14 August 2024.

2510 - Giedrius Česnakas and Justinas Juozaitis, "Nuclear Geopolitics in the Baltic Sea Region: Exposing Russian Strategic Interests Behind Ostrovets NPP", Atlantic Council, 2017, see https://www.jstor.org/stable/resrep03497, accessed 14 August 2024.

2511 - UNECE, "Decision IS/1d—Compliance by Belarus with its obligations under the Convention in respect of the Belarusian nuclear power plant in Ostrovets", 2019, see https://unece.org/DAM/env/eia/meetings/2019/IS_MOP_5-7_February_2019__Geneva/Decision_IS.1d_.pdf, accessed 14 August 2024.

2512 - Implementation Committee, "Meeting of the Parties to the Convention on Environmental Impact Assessment in a Transboundary Context serving as the Meeting of the Parties to the Protocol on Strategic Environmental Assessment—Report of the Implementation Committee on its fifty-eighth session", 31 May 2024, see https://unece.org/sites/default/files/2024-06/ece_mp.eia_ic_2024_2_e.pdf, accessed 14 August 2024.

2513 - VATESI, "Belarusian NPP Unit 2 goes into industrial operation without resolving all safety issues", Valstybinė atominės energetikos augos inspekcija/State Nuclear Power Safety Inspectorate of Lithuania, 25 October 2023, see http://www.vatesi.lt/index.php?id=551&L=1&tx_news_pi1%5Bnews%5D=1154&tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=1c7e12aaf3801051716334bfe7382d0b, accessed 29 October 2023.

NPP equipment resistance to seismic events and the effects of a large civil aircraft crash, implementation of stress tests recommendations, probabilistic safety assessment, fire hazard analysis and other safety issues."[2514]

However, moving towards isolating Belarus is not a strategy universally adopted in the E.U., and in April 2023, Hungary signed an agreement with Belarus on nuclear cooperation. Hungary's Foreign Minister Peter Szijjarto was reported to have said, "Nuclear security is of universal, global interest, regardless of the geopolitical situation."[2515] This was followed up in 2024 with an agreement on nuclear cooperation between the two countries; with Hungary striving for Belarus' support on the completion of Rosatom's Paks II newbuild project.[2516]

The loss of access to the Western European power market is significant as higher revenues from the sale of electricity to the West affect the economics of Ostrovets.

In response to the war in Ukraine, electricity import from Russia into E.U. member states has come under scrutiny, and in May 2022, the power exchange Nord Pool decided to stop trading Russian electricity.[2517] The further Baltic grid synchronization with the rest of Europe will physically exclude the import of electricity from Belarus. Estonia, Latvia, and Lithuania have accelerated their plans and intend to complete their full integration into the Continental Europe Network (CEN) by February 2025.[2518] The loss of access to the Western European power market is significant as higher revenues from the sale of electricity to the West affect the economics of Ostrovets. In the meantime, power continues to flow in both directions between Belarus and Lithuania, although the volume of electricity exchange is relatively low; in 2023, it was around 1 TWh or 9 percent of Ostrovets' output.[2519]

Russia and Belarus seek to develop a unified power market, and in August 2024, the two presidents signed a treaty laying out the legal framework for the operation and regulation of a common market. The start date for the market has not been formalized, but press reports suggest it could be in 2025, although several technical and legal issues are still to be resolved.[2520]

2514 - VATESI, "Belarusian NPP nuclear safety issues remain unresolved", 23 May 2023, see https://vatesi.lrv.lt/en/news/belarusian-npp-nuclear-safety-issues-remain-unresolved/, accessed 14 August 2024.

2515 - *About Hungary*, "Foreign Minister builds relations with Belarus", Prime Minister's Office, Government of Hungary, 13 April 2023, see https://abouthungary.hu/news-in-brief/foreign-minister-builds-relations-with-belarus, accessed 1 September 2024.

2516 - *Euractiv*, "Hungary breaks the diplomatic isolation of Belarus by seeking help for nuclear plant", 30 May 2024, see https://www.euractiv.com/section/global-europe/news/hungary-breaks-the-diplomatic-isolation-of-belarus-by-seeking-help-for-nuclear-plant/, accessed 13 August 2024; and Ministry of Energy, "A roadmap for cooperation between nuclear power plants of Belarus and Hungary was signed", Government of Belarus, as published by Belarusian Nuclear Power Plant, 29 May 2024, see https://www.belaes.by/en/news/item/4365-podpisana-dorozhnaya-karta-sotrudnichestva-aes-belarusi-i-vengrii.html, accessed 1 September 2024.

2517 - *CEE Energy News*, "Lithuania completely cuts imports of Russian energy supplies", 23 May 2022, see https://ceenergynews.com/ukraine-russia-crisis/lithuania-completely-cuts-imports-of-russian-energy-supplies/, accessed 14 August 2024.

2518 - Directorate-General for Energy, "Estonia, Latvia & Lithuania agree to synchronise their electricity grids with the European grid by early 2025", Press Release, European Commission, 3 August 2023, see https://energy.ec.europa.eu/news/estonia-latvia-lithuania-agree-synchronise-their-electricity-grids-european-grid-early-2025-2023-08-03_en, accessed 14 August 2024; and Augstsprieguma tīkls AS, "Baltic TSOs have sent a notice on decoupling from Russia-controlled electricity system in February 2025", Press Release, 16 July 2024.

2519 - Energy-Charts, "Monthly cross border physical flows of Lithuania in 2023", Fraunhofer ISE, Updated 14 August 2024, see https://energy-charts.info/charts/energy/chart.htm?l=en&c=BY&chartColumnSorting=default&source=cbpf_saldo&month=-1&legendItems=5y0&sum=0&partsum=1&year=2023, accessed 14 August 2024.

2520 - *BNE Intellinews*, "Russia, Belarus set up joint electricity market", 6 August 2024, see https://www.intellinews.com/russia-belarus-set-up-joint-electricity-market-337148/, accessed 14 August 2024.

Russia

See Focus Countries – Russia Focus.

Ukraine

See Focus Countries – Ukraine Focus.

ANNEX 2 – RUSSIA NUCLEAR DEPENDENCIES

Table 18 · Fuel Supply for Soviet-designed Reactors in the E.U. and Ukraine (as of mid-2024)

Country	Nuclear Share 2023	Unit	Type	TVEL (Russia)	Westinghouse (USA/Canada)	Framatome (France)
Bulgaria	40.5%	Kozloduy-5	VVER-1000	Contract until 2025,[1] terminated early, last fuel load for Unit 6 in autumn 2024[2]	- 10-year supply contract (December 2022) - First load: May 2024[3]	-
		Kozloduy-6	VVER-1000		-	10-year supply contract 2025–2034 (December 2022)[4]
Czech Republic	40%	Dukovany-1–4	VVER-440	- Fuel reload in October 2023 at Dukovany-4[5] - Fuel reserve until approx. 2026[6]	7-year supply contract starting 2024 (April 2023)[7]	Ongoing negotiations as of January 2024; No contract as of July 2024[8]
		Temelín-1 & -2	VVER-1000	- Supply since 2010[9] - Contract until 2023[10] - Fuel reload completed in June 2024[11]	- Supply 2000–2010[12] - 6 lead test assemblies loaded in 2019[13] - 10+-year contract, supply starting 2024 (June 2022)[14]	10+-year contract, supply starting 2024 (June 2022)[15]
Finland	42%	Loviisa-1	VVER-440	Contract until end 2027[16]	- Supply 2001–2007[17] - Supply contract (November 2022)[18] - Lead test assembly loaded: 2023[19]	
		Loviisa-2	VVER-440	Contract until end 2030[20]		
Hungary	48.8%	Paks-1–4	VVER-440	- "Lifetime" supply contract[21] - Fuel reserve until 2026[22]		MoU, incl. fuel supply (September 2023)[23]
Slovakia	61.3%	Bohunice-3-4	VVER-440	- Supply contract 2022–2026, with option until 2030 (June 2019)[24] - Fuel reserve until 2026–2027[25]	Supply contract (August 2023)[26]	MoU, incl. fuel supply (May 2023)[27]
		Mochovce-1-3	VVER-440			
Ukraine	55% (2021)	Rivne-1-2	VVER-440	Supply contract for 8 reactors 2021–2025 (December 2018)[28]	- Since 2010, fuel supplied to 6 VVER-1000[29] - Full load to South Ukraine-3 in July 2018[30] - Supply contract for all Ukrainian reactors (June 2022)[31] - First load Rivne: September 2023[32] - First load Khmelnistkyi: March 2024 [33]	
		Khmelnytskyi-1 & -2	VVER-1000			
		Rivne-3 & -4	VVER-1000			
		South Ukraine-1–3	VVER-1000			
		Zaporizhzhia-1–6	VVER-1000			

Notes:

1 - TVEL, "TVEL and Kozloduy NPP have contracted supplies of Russian nuclear fuel to Bulgaria through 2025", 19 December 2019, see https://www.tvel.ru/en/press-center/news/?ELEMENT_ID=8140, accessed 19 July 2023.

2 - *NEI Magazine*, "Kozloduy NPP to end contract for Russian fuel supplies", 30 May 2024, see https://www.neimagazine.com/fuel-fuel-cycle/kozloduy-npp-to-end-contract-for-russian-fuel-supplies/, accessed 15 July 2024.

3 - Westinghouse, "Westinghouse Delivers First VVER-1000 Fuel Reload to Bulgaria", Press Release, 29 May 2024, see https://info.westinghousenuclear.com/news/westinghouse-delivers-first-vver-1000-fuel-reload-to-bulgaria, accessed 26 June 2024; and Westinghouse, "Westinghouse's VVER-1000 Nuclear Fuel Fabrication Agreement Helps Cement Bulgaria's Energy Security", Press Release, 22 December 2022, see https://info.westinghousenuclear.com/news/westinghouse-vver-1000-nuclear-fuel-fabrication-agreement-helps-cement-bulgarias-energy, accessed 7 July 2024.

4 - *WNN*, “Kozloduy and Framatome sign nuclear fuel agreement”, 4 January 2023, see https://www.world-nuclear-news.org/Articles/Kozloduy-and-Framatome-sign-nuclear-fuel-agreement, accessed 4 January 2023.

5 - *NEI Magazine*, “Dukovany 4 to switch to new generation Russian fuel”, 24 October 2023, see https://www.neimagazine.com/news/dukovany-4-to-switch-to-new-generation-russian-fuel-11242878/, accessed 28 June 2024.

6 - CEZ Group, “The Americans are going to supply nuclear fuel also to Dukovany, not only to Temelín”, Press Release 29 March 2023.

7 - Westinghouse, “Westinghouse Reinforces its Commitment to Energy Security in Czech Republic”, Press Release, 29 March 2023, see https://info.westinghousenuclear.com/news/westinghouse-reinforces-its-commitment-to-energy-security-in-czech-republic, accessed 26 June 2024.

8 - As of January 2024, it was reported that “Negotiations with Framatome about fuel supplies for the Dukovany power plant are still ongoing”, see David Tramba, “Polovičatá náhrada ruského paliva v Temelíně. Framatome dodá palivové soubory v ruské licenci”, Ekonomický deník, 4 January 2024 (in Czech), see https://ekonomickydenik.cz/polovicata-nahrada-ruskeho-paliva-v-temeline-framatome-doda-palivove-soubory-v-ruske-licenci/, accessed 28 June 2024.

9 - ČEZ, “Temelin will buy fissionable fuel from the Russion TVEL”, Press Release, 17 May 2006, see https://www.cez.cz/en/media/press-releases/temelin-will-buy-fissionable-fuel-from-the-russion-tvel-70158, accessed 8 July 2024.

10 - ČEZ, “Refueling will start at Temelín. Six fuel assemblies made by Westinghouse Electric Sweden will be tested”, Press Release, 4 April 2019, see https://www.cez.cz/en/media/press-releases/refueling-will-start-at-temelin.-six-fuel-assemblies-made-by-westinghouse-electric-sweden-will-be-tested-69837, accessed 8 July 2024.

11 - CEZ Group, “The first Temelín Unit produces electricity again. It has been shut down for two months to inspect and replace fuel assemblies”, Press Release, CEZ Group, 12 June 2024, see http://www.cez.cz/en/media/press-releases/the-first-temelin-unit-produces-electricity-again.-it-has-been-shut-down-for-two-months-to-inspect-and-replace-fuel-assemblies-192183, accessed 8 July 2024.

12 - Daniel Ernst and Lukáš Milisdörfer, “10 years of experience with Westinghouse fuel at NPP Temelín”, ČEZ, as presented at the VVER 2010 Conference, 1–3 November 2010, see https://inis.iaea.org/collection/NCLCollectionStore/_Public/42/016/42016135.pdf, accessed 2 August 2023.

13 - Jan Höglund and Ulf Benjaminsson, “New fuel for Temelín 1”, Technical Lead for Fuel Engineering, and Fuel Marketing Manager, Westinghouse, published in Nuclear Engineering International, 3 October 2019, see https://www.neimagazine.com/analysis/new-fuel-temelin-1-7436970/, accessed 29 June 2024; and ČEZ, “Temelín’s Unit 1 restored the electricity production”, Press Release, 29 April 2019, see https://www.cez.cz/en/media/press-releases/temelins-unit-1-restored-the-electricity-production-69835, accessed 8 July 2024.

14 - ČEZ, “We are strengthening the energy security of the Czech Republic: we have signed contracts for the supply of fuel assemblies with Westinghouse and Framatome”, Press Release, 28 June 2022, see https://www.cez.cz/en/media/press-releases/we-are-strengthening-the-energy-security-of-the-czech-republic-we-have-signed-contracts-for-the-supply-of-fuel-assemblies-with-westinghouse-and-framatome-160156, accessed 26 July 2023; and Westinghouse, “Westinghouse Advances Energy Security in Czech Republic”, 28 June 2022, see https://info.westinghousenuclear.com/news/westinghouse-advances-energy-security-in-cz, accessed 26 June 2024.

15 - ČEZ, “We are strengthening the energy security of the Czech Republic: we have signed contracts for the supply of fuel assemblies with Westinghouse and Framatome”, 28 June 2022, op. cit.

16 - Fortum, “Sustainability 2023”, March 2024, see https://www.fortum.com/files/fortum-sustainability-2023/download, accessed 8 July 2024.

17 - Mark Dye, Jan Höglund and Ulf Benjaminsson, “Diversification of the VVER fuel market”, *Nuclear Engineering International*, September 2015, see https://westinghousenuclear.com/media/i5pjkvtk/westinghouse-reprint-vver-fuel-nei.pdf, 29 June 2024.

18 - Westinghouse, “Helping Finland to Secure Its Energy Future”, Press Release, 22 November 2022, see https://info.westinghousenuclear.com/news/helping-finland-secure-energy-future, accessed 26 June 2024.

19 - Fortum, “Fortum’s Loviisa nuclear power plant generated 8.09 terawatt-hours of carbon-free electricity in 2023”, Press Release, 4 January 2024, see https://www.fortum.com/media/2024/01/fortums-loviisa-nuclear-power-plant-generated-809-terawatt-hours-carbon-free-electricity-2023, accessed 4 June 2024.

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ANNEX 3 – SUMMARY OF REVENUE FLOWS IN THE U.K. NUCLEAR COMPLEX

In addition to Figure 55 in the chapter on Civil-Military Cross-Financing in the U.K. Nuclear Sector, the following table refers to a wide range of official documents to summarize the key primary funding sources underpinning civil and military nuclear-related services in the U.K. As a first approximation, these comprise two key inputs. First, there are expenditures on nuclear electricity across the full range of U.K. electricity consumers. Second, there is U.K. taxpayer funded public spending on nuclear-related 'civil' and 'defense' budgets. As a working baseline, the reference year is 2024. Where possible, this picture also accounts for various relevant fluctuations, including major multi-year allocations that are not explicitly annualized. To partly address such large uncertainties, the figures are given as ranges.

The primary source of funding to cover the vast array of activities associated with the operations of civil nuclear power, lies in revenues from wholesale market contracts for consumer electricity. They are listed in the table's 'Funding Sources' column. Here an overall figure can be estimated by means of government data for the aggregate value of wholesale electricity sales in the U.K.[2521] As contracted from generators prior to addition of transmission and distribution costs, these are projected for 2024 at around £60 billion (US$76 billion).[2522] With the proportional contribution of nuclear electricity to the supply mix projected for 2024 at 15 percent,[2523] this gives a rough annual consumer spend specifically on wholesale nuclear electricity of some £9 billion (US$11.4 billion). Below this, explicit public expenditures are quantified by aggregating individual agency and project budgets. The stated figures allow for various uncertainties about out-turns and ambiguities of interpretation.

The 'Principal Allocations' column illustrates the principal allocations from these sources that are well distinguished in the public domain – either as widely-recognized proportions of business revenues allocated to major aspects of nuclear-related commercial activity[2524], or as stated budgets to named organizations or programs.

More speculatively, the 'Detailed Activities' column lists more concrete nuclear-related detailed activities that are variously distinguished in the literature. This provisionally estimates the indicative magnitudes of associated flows of value from the better documented sources and allocations shown to the left. These figures are obviously subject to correction, but the

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scope for error is at least bounded in broad terms, by the overall magnitudes of the better-documented principal allocations in the central column.

Table 19 · Indicative Annual Value Flows to Diverse U.K. Civil and Military Nuclear-Related Activities in 2024

FUNDING SOURCES	£/y billion	Refs	PRINCIPAL ALLOCATIONS	£/y billion	Refs	DETAILED ACTIVITIES	£/y billion	Refs
			Capital Costs (Including During Construction)	6.3 – 6.8	b	Financial Services	0.8 – 1.0	b
Electricity Consumers	8.5 – 9.5	a	Fixed Operations, Maintenance, Backend	1.4 – 1.7	b	Nuclear Engineering	2.0 – 2.2	b
			Variable Operations, Maintenance, Backend	0.8 – 1.0	b	Design Provision	0.25 – 0.35	b
			Direct Capital Support For Construction (SZC)	0.3 – 0.5	c	Conventional Engineering	0.85 – 0.95	b
			Regulated Asset Base Policy (RAB)	0.05 – 0.15	d	Balance of System	1.2 – 1.4	b
			Nuclear Decommissioning Authority (NDA)	3.3 – 4.2	e	Facility Engineering	1.3 – 1.5	b
			Environment Agency (Nuclear)	0.015 - 0.025	f	Initial Commissioning	0.05 – 0.15	b
			Nuclear Liabilities Financing Assurance Board (FAB)	0.5 – 1.5	g	Specialized Transport	0.05 – 0.15	b
			Nuclear Sector Deal Policy (NSD)	0.15 – 0.25	h	Connection & Integration	0.9 – 1.1	b
Taxpayers' 'Civil' Budgets	5.4 – 6.4		Nuclear Skills Allocations (NSA)	0.05 – 0.15	i	Added Capital Equipment	0.09 - 0.11	b
			Nuclear Innovation Programme (NIP)	0.03 – 0,05	j	Fuel Mining, Processing, Enrichment	0.45 – 0.55	b
			National Nuclear Laboratory (NNL)	0.005 - 0.015	k	Fuel Fabrication	0.15 – 0.25	b
			UK Atomic Energy Authority (UKAEA)	0.35 – 0.45	l, m	Spent Fuel & Waste Management	0.45 – 0.55	b
			Great British Nuclear (GBN)	0.45 – 0.55	n, o	Facility Decommissioning	4.3 – 4.5	e
			Office of Nuclear Regulation (ONR)	0.085 - 0.095	p	Third Party Liability Cover	0.05 – 0.15	q
			Civil Nuclear Constabulary (CNC)	0.05 – 0.15	r	Skills, Industry Base, Supply Chains	0.3 – 0.4	k, s, p, t
			MoD Police (Nuclear) (Mdp)	0.07 – 0.09	v	Safety, Health, Environmental Regulation	0.16 – 0.18	f, p
			Defence Nuclear Safety Regulator (DNSR)	0.05- 0.09	p, t	Anti-Proliferation Safeguards	0.06 – 0.08	w
			Submarine Delivery Agency (SDA)	4.0 – 4.8	x	Strategy & Promotion	0.07 – 0.09	y
Taxpayers' 'Defense' Budgets	11 – 12	u	Atomic Weapons Establishment (AWE)	1.2 – 1.8	v, z	Specialist Nuclear Security	0.17 – 0.19	v
			Royal Navy Submarine Service (RNSS)	0.5 – 0.7	v, aa	General Research & Innovation	0.75 – 0.8	m, o
			Strategic Command Programmes (SCP)	0.03 – 0.05	v, aa	Military Programs Running Costs	0.25 – 0.35	v, aa
			Other Defence Nuclear Enterprise (DNE)	5.0 – 5.5	u	Submarine Waterfront Infrastructure	0.15 – 0.25	v, bb
						AUKUS Submarine Development	0.15 – 0.25	bb
						Other SSN Procurement & Support	0.55 – 0.65	v, aa

SSBN Dreadnought Procurement & Support	2.4 – 2.6	bb
Other SSBN Procurement & Support	1.0 – 1.2	cc
Nuclear Reactor Core Production	0.15 – 0.25	bb
Weapons Research & Manufacture	1.4 – 1.6	aa, z
SSN & SSBN Operations	0.55 – 0.65	v, aa
Submarine Dismantling	0.05 – 0.15	v

Notes: In the absence of any official, public attempts at systematic or fully comprehensive accounting, it is challenging to map the combined huge and complex webs of long-term value flow associated with nuclear facility and project financing on both civil and military sides. A key starting point lies in straightforward taxpayer budget allocations and consumer market expenditures, with onward additions and complexities addressed from there.

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ANNEX 4 - STATUS OF NUCLEAR POWER IN THE WORLD

Table 20 · Status of Nuclear Power in the World (as of 1 July 2024)

Country	Nuclear Fleet					Power	Energy
	Operating		LTO	Mean Age[a]	Under Construction	Share of Commercial Electricity[b] (2023)	Share of Commercial Primary Energy[c] (2023)
	Units	Capacity (MW)	Units	Years	Units		
Argentina	3	1 641		33.8	1	6.3% (=)	2.2% (=)
Armenia	1	416		44.5		31.1% (=)	N/A
Bangladesh	-	-		-	2		
Belarus	2	2 220		2.4		28.6% (+)	9.9% (+)
Belgium	5	3 908		45.2		41.2% (–)	12.8% (–)
Brazil	2	1 884		33.1		2.2% (=)	0.9% (=)
Bulgaria	2	2 006		34.8		40.4% (+)	20.2 (+)
Canada	18	12 821	1	41/41.5		13.7% (=)	5.7% (=)
China	57	54 152	1	10.5/10.4	27	4.9% (=)	2.3% (=)
Czech Republic	6	3 934		33		40% (+)	17.9% (=)
Egypt	-	-		-	4		
Finland	5	4 394		36.7		42% (+)	25.7% (+)
France	56	61 370		39.1	1	64.8% (+)	35% (+)
Germany	-	-		-		1.4% (–)	0.6% (–)
Hungary	4	1 916		39		48.8% (+)	15.7% (=)
India	19	6 718	4	25.1/21.1	7	3.1% (=)	1.1% (=)
Iran	1	915		12.8	1	1.7% (=)	0.5% (=)
Japan	12	11 046	21	33.5/38.5	1	5.6% (=)	4% (+)
Mexico	2	1 552		32.4		4.9% (=)	1.3% (=)
Netherlands	1	482		51		3.4% (=)	1% (=)
Pakistan	6	3 262		9.6		17.4% (+)	6% (=)
Romania	2	1 300		22.5		18.9% (=)	7.9% (=)
Russia	36	26 802		30.5	6	18.4% (–)	6.2% (=)
Slovakia	5	2 308		26.1	1	61.3% (+)	24.5% (+)
Slovenia	1	688		42.7		36.8% (–)	19.3% (=)
South Africa	2	1 854		39.6		4.4% (=)	1.6% (=)
South Korea	25	25 185	1	23.2/22.5	2	31.5% (+)	13% (=)
Spain	7	7 123		39.4		20.3% (=)	9% (=)
Sweden	6	6 944		42		28.6% (=)	20.2% (=)
Switzerland	4	2 973		48.3		32.4% (–)[d]	18.5% (–)
Taiwan	2	1 874		39.7		6.9% (–)	3.5% (=)
Türkiye	-	-		-	4		
UAE	4	5 321		2.2		19.7% (+)	5.6% (+)
U.K.	9	5 883		37.1	2	12.5% (–)	5.3% (=)
Ukraine	9	7 407	6	35.4/35		50.7% (–)[c]	21.2% (–)
U.S.	94	96 952		42.7		18.6% (=)	7.8% (=)
EU27	100	96 373		38.2	2	22.6 (=)[c]	9.9% (=)
World	**408**	**367 251**	**34**	**32.1/32**	**59**	**9.15% (=)[c]**	**4% (=)**

Sources: WNISR with IAEA-PRIS, Energy Institute, 2024

Notes: **LTO:** Long-Term Outage.

(a) – Including reactors in LTO/Excluding reactors in LTO.

(b) – Data for 2023, from IAEA-PRIS, "Nuclear Share of Electricity Generation in 2023", as of July 2024, unless otherwise indicated.

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ANNEX 5 – NUCLEAR REACTORS IN THE WORLD "UNDER CONSTRUCTION"

Table 21 · Nuclear Reactors in the World "Under Construction" (as of 1 July 2024)

Country	Units	Capacity MW net	Model	Initial Construction Start	Expected Grid Connection	Delayed
Argentina	**1**	**25**				
Carem25		25	CAREM (PWR)	08/02/2014	2028[1]	yes
Bangladesh	2	2 160				
Rooppur-1		1 080	VVER V-523	30/11/2017	2024[2]	yes
Rooppur-2		1 080	VVER V-523	14/07/2018	2025[3]	yes
China	**27**	**29 101**				
Changjiang SMR-1[4]		100	ACP100[5]	13/07/2021	2026[6]	
Changjiang-3		1 000	HPR1000[7]	31/03/2021	2026[8]	
Changjiang-4		1 000	HPR1000	28/12/2021	2026[9]	
Haiyang-3		1 161	CAP1000	07/072022	2027[10]	
Haiyang-4		1 161	CAP1000	22/04/2023	2027[11]	
Lianjiang-1		1 224	CAP1000	29/09/2023	2028[12]	
Lianjiang-2		1 224	CAP1000	26/04/2024	2028?[13]	
Lufeng-5		1 116	HPR1000	08/09/2022	2027[14]	
Lufeng-6		1 116	HPR1000	26/08/2023	2028[15]	
Sanaocun-1		1 117	HPR1000	31/12/2020	2026[16]	
Sanaocun-2		1 117	HPR1000	30/12/2021	2027[17]	
Sanmen-3		1 163	CAP1000	28/06/2022	2027?[18]	
Sanmen-4		1 163	CAP1000	23/03/2023	2028?[19]	
Shidao-Bay 2-1[20]		1 400	CAP1400	04/2019[21]	2024?[22]	
Shidao-Bay 2-2		1 400	CAP1400	11/2019[23]	2024?[24]	
Taipingling-1[25]		1 116	HPR1000	26/12/2019	2025[26]	
Taipingling-2		1 116	HPR1000	15/10/2020	2026[27]	
Tianwan-7		1 171	VVER V-491	19/05/2021	2026[28]	
Tianwan-8		1 171	VVER V-491	15/02/2022	2027[29]	
Xiapu-1		642	CFR-600	29/12/2017	2024[30]	yes
Xiapu-2		642	CFR-600	27/12/2020	2026?[31]	
Xudapu-1[32]		1 000	CAP1000	15/11/2023	2028[33]	
Xudapu-3		1 200	VVER V-491	19/05/2021	2027[34]	
Xudapu-4		1 200	VVER V-491	19/05/2022	2028[35]	
Zhangzhou-1		1 126	HPR1000	16/10/2019	2024[36]	
Zhangzhou-2		1 126	HPR1000	04/09/2020	2025[37]	
Zhangzhou-3		1 129	HPR1000	22/03/2024	2028/2029[38]	

Country	Units	Capacity MW net	Model	Initial Construction Start	Expected Grid Connection	Delayed
Egypt	**4**	**4 400**				
El Dabaa-1		1 100	VVER-1200	20/07/2022	2028[39]	
El Dabaa-2		1 100	VVER-1200	19/11/2022	2029[40]	
El Dabaa-3		1 100	VVER-1200	03/05/2023	2030[41]	
El Dabaa-4		1 100	VVER-1200	23/02/2024	2031[42]	
France	**1**	**1 630**				
Flamanville-3		1 630	EPR	03/12/2007	2024[43]	yes
India	**7**	**5 398**				
Kudankulam-3		917	VVER V-412	29/06/2017	2025/2026[44]	yes
Kudankulam-4		917	VVER V-412	23/10/2017	2026[45]	yes
Kudankulam-5		917	VVER V-412	29/06/2021	2026/2027[46]	likely[47]
Kudankulam-6		917	VVER V-412	20/12/2021	2027[48]	likely[49]
PFBR		470	FBR	23/10/2004	12/2024[50]	yes
Rajasthan-7		630	PHWR	18/07/2011	2025/2026[51]	yes
Rajasthan-8		630	PHWR	30/09/2011	2026[52]	yes
Iran	**1**	**974**				
Bushehr-2		974	VVER V-446	02/1976[53]	2028[54]	yes
Japan	**1**	**1 325**				
Shimane-3		1 325	ABWR	12/10/2007	2030?[55]	yes
Russia	**6**	**3 960**				
BREST-OD-300		300	FBR	08/06/2021	2027[56]	?
Kursk 2-1		1 200	VVER V-510	29/04/2018	2025[57]	yes
Kursk 2-2		1 200	VVER V-510	15/04/2019	2027[58]	yes
Leningrad 2-3		1 150	VVER V-491	14/03/2024	2030[59]	
Cape Nagloynyn 1-1[60]		55	RITM-200S	30/08/2022	?	
Cape Nagloynyn 1-2		55	RITM-200S	30/08/2022	?	
Slovakia	**1**	**440**				
Mochovce-4		440	VVER V-213	01/01/1985	2025[61]	yes
South Korea	**2**	**2 680**				
Saeul-3[62]		1 340	APR-1400	03/04/2017	2024?[63]	yes
Saeul-4		1 340	APR-1400	20/09/2018	10/2025[64] (commercial operation)	yes
Türkiye	**4**	**4 456**				
Akkuyu-1		1 114	VVER V-509	03/04/2018	2025[65]	yes
Akkuyu-2		1 114	VVER V-509	08/04/2020	2026[66]	yes
Akkuyu-3		1 114	VVER V-509	10/03/2021	2027[67]	yes
Akkuyu-4		1 114	VVER V-509	21/07/2022	2028[68]	yes

Country	Units	Capacity MW net	Model	Initial Construction Start	Expected Grid Connection	Delayed
U.K.	**2**	**3 260**				
Hinkley Point C-1	1	1 630	EPR-1750	11/12/2018[69]	2030?[70]	yes
Hinkley Point C-2	1	1 630	EPR-1750	12/12/2019[71]	2031?[72]	yes
World	**59**	**59 809**	-	**1976–2024**	**2024–2031**	**23**

Notes

1 - Further delayed. The construction of CAREM, was suspended in 2019 "due to breaches by contractor companies". Concreting restarted in January 2022, with a startup expected in 2027. However, construction seems to be halted again, with expected startup pushed back to 2028.
Candelaria Grimberg and Horacio Soria, "Argentina budget cuts hitting nuclear energy ambitions, atomic body says", *Reuters*, 2 May 2024, see https://www.reuters.com/business/energy/argentina-budget-cuts-hitting-nuclear-energy-ambitions-atomic-body-says-2024-05-02/, accessed 3 May 2024.

2 - Further delayed, at least by a few months. Startup at construction start was expected in 2023.
See Rosatom, "First concrete poured at the constructed Rooppur NPP site (Bangladesh)", Press Release, 30 November 2017, see http://www.rusatom-overseas.com/media/news/first-concrete-poured-at-the-site-constructed-npp-rooppur-bangladesh.html, accessed 17 August 2020.
In April 2024, press reports mentioned "December 2024" as a target date for startup. "One of the two units of the Rooppur Nuclear Power Plant will be commissioned this December if transmission lines are ready although the deadline for the project's completion has been extended to 2027." See Ahmed Humayun Kabir Topu, "Rooppur Nuclear Power Plant: First unit to start production in December", *The Daily Star*, 27 April 2024, see https://www.thedailystar.net/news/bangladesh/news/rooppur-nuclear-power-plant-first-unit-start-production-december-3596116, accessed 3 May 2024.
As already mentioned in WNISR2023, Rooppur-1 startup is more likely to take place in 2025, or beyond.

3 - First official delay. Startup at construction start was expected in 2024. See Rosatom, "Main construction of the 2nd Unit of Rooppur NPP begins with the 'First Concrete' ceremony", Press Release, 14 July 2018, see http://rosatom.ru/en/press-centre/news/main-construction-of-the-2nd-unit-of-rooppur-npp-begins-with-the-first-concrete-ceremony/, accessed 15 July 2018.
Commercial operation is now expected in 2026. See *The Business Standard*, "PM Hasina wants Russian Rosatom to build another nuclear power plant at Rooppur", 2 April 2024, see https://www.tbsnews.net/bangladesh/energy/pm-hasina-wants-russian-rosatom-build-another-nuclear-power-plant-rooppur-821276, accessed 3 May 2024.

4 - The Changjiang SMR is listed as Linglong-1 (Hainan Changjiang SMR) in IAEA-PRIS statistics.

5 - The ACP100 also goes by the name Linglong One.

6 - CNNC, "Workshop on the Application of Small Modular Reactor held in Hainan", 8 September 2023, see https://en.cnnc.com.cn/2023-09/08/c_919054.htm, accessed 8 November 2023.

7 - The HPR1000 also goes by the name Hualong One.

8 - Construction period is expected to be 60 months.
See *NEI Magazine*, "First concrete poured for China's Changjiang 3", 1 April 2021, see https://www.neimagazine.com/news/newsfirst-concrete-poured-for-chinas-changjiang-3-8644649, accessed 2 April 2021.

9 - *WNN*, "Construction begins at second Changjiang Hualong One", *World Nuclear News*, 29 December 2021, see https://world-nuclear-news.org/Articles/Construction-begins-at-second-Changjiang-Hualong-O, accessed 30 December 2021.

10 - No official startup date provided at construction start. WNISR used 2027, confirmed at construction start of Haiyang-4. See following note.

11 - According to Shanghai Nuclear Engineering Research and Design Institute (SNERDI), construction time of Haiyang-3 and -4 is expected to be 56 months, with both units to be in operation in 2027.
See SNERDI, "海阳核电4号机组顺利实现FCD [Haiyang Nuclear Power Unit 4 Successfully Achieves FCD]", Press Release (in Chinese), Shanghai Nuclear Engineering Research & Design Institute Co, LTD., 22 April 2023, see https://www.snerdi.com.cn/newsdetail?id=9277, accessed 28 April 2023.

12 - *WNN*, "Construction of first unit at Lianjiang under way", 9 October 2023, see https://www.world-nuclear-news.org/Articles/Construction-of-first-unit-at-Lianjiang-under-way, accessed 29 November 2023.

13 - No official startup date at construction start. Construction of Lianjiang-1 and -2 is expected to last 56 months.
See *NEI Magazine*, "Construction begins at unit 2 of China's Lianjiang NPP", Nuclear Engineering International, 21 April 2023, see https://www.neimagazine.com/news/newsconstruction-begins-at-unit-2-of-chinas-lianjiang-npp-10779693, accessed 24 April 2023.

14 - Commencement of operation of Lufeng-5 is expected in 2027.
See CGN, "Annual Report 2023: Professionalism Achieves a Bright Future", March 2024, see http://en.cgnp.com.cn/encgnp/c100882/2024-04/11/cb76379ce6e04b15829f4f8686032e0e/files/e0670ca0ee664b9a977afc238c6e47f4.pdf, accessed 13 May 2024.

15 - Commencement of operation of Lufeng-6 is expected in 2028. CGN, "Annual Report 2023", March 2024, op. cit.

16 - Commencement of operation of Sanaocun-1 (also known as San'ao or Cangnan-1) is expected in 2026.
See CGN Power, "Annual Report 2023", March 2024, op.cit.

17 - Commencement of operation of Sanaocun-2 (also known as San'ao or Cangnan-2) is expected in 2027.
See CGN Power, "Annual Report 2023", March 2024, op. cit.

18 - No official information on expected startup date at construction start. World Nuclear Association (WNA) uses 2027.
See WNA, "Plans for New Nuclear Reactors Worldwide", Updated June 2024, see https://world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx, accessed 28 June 2024.

19 - No official information on expected startup date at construction start. World Nuclear Association (WNA) uses 2028.
See WNA, "Plans for New Nuclear Reactors Worldwide", Updated June 2024, op. cit.

20 - Provisional names for the two CAP1400 at Rongcheng/Shidaowan. Construction of those reactors was introduced in WNISR statistics in 2020 following *Nuclear Intelligence Weekly* (*NIW*) articles (in particular 10 July 2019) and confirmation from sources in China. In July 2019, *NIW* classified the two units as "under construction" on the basis of the Chinese National Nuclear Safety Administration (NNSA) map as of June 2019.
See *NIW*, "Chinese Power Reactor Project Wrapped in Secrecy", Nuclear Intelligence Weekly, 12 July 2019.

21 - According to sources in China, first basemat concrete for the first CAP1400 reactor was poured on 8 April 2019.
See also C.F. Yu, "CGN's Taipingling Project Moves Ahead", *Nuclear Intelligence Weekly*, 20 December 2019. See previous note.

22 - No official startup dates at this point. According to sources in China, the expected construction duration of CAP1400 from Zheng Mingguang is about 56 months. WNISR2024 keeps 2024 as expected grid connection.

23 - According to sources in China, first basemat concrete for the second CAP1400 reactor was poured in November 2019. See previous notes.

24 - No official startup dates at this point. WNISR2024 keeps 2024 for grid connection date. See previous notes.

25 - Also known as Huizhou.

26 - CGN, "Annual Report 2023", 2024, op. cit.

27 - Ibidem.

28 - According to sources in China, the contract between China and Russia stipulated a construction duration of 65 months. Rosatom stated about the Tianwan-7 and -8 project "the units are scheduled to be commissioned in 2026-2027".
See Rosatom, "Start of new unit construction at China's Tianwan and Xudapu nuclear power plants", Press Release, 19 May 2021, see https://rosatom.ru/en/press-centre/news/start-of-new-unit-construction-at-china-s-tianwan-and-xudapu-nuclear-power-plants, accessed 14 June 2021.

29 - See Rosatom State Corporation Engineering Division, "The First Concrete has been Laid at Tianwan NPP Power Unit 8 in China", Press Release, ASE Rosatom, 28 February 2022, see https://ase-ec.ru/en/for-journalists/news/2022/feb/the-first-concrete-has-been-laid-at-tianwan-npp-power-unit-8-in-china/, accessed 28 February 2022.

30 - First delay. Commercial operation at construction start was expected in 2023.
WNN, "China begins building pilot fast reactor", 29 December 2017, see http://www.world-nuclear-news.org/NN-China-begins-building-pilot-fast-reactor-2912174.html, accessed 30 December 2017. According to Chinese sources, reported by IPFM, as of mid-2023, the CFR-600 was running at low power but no information on electricity production or grid connection had been provided. Hui Zhang, "China started operation of its first CFR-600 breeder reactor", IPFM Blog, 15 December 2023, see https://fissilematerials.org/blog/2023/12/china_started_operation_0.html, accessed 3 May 2024.

31 - No official information about expected grid connection. WNISR2024 uses 2026 (same originally expected duration as Xiapu-1).

32 - Also known as Xudabu or Xudabao.

33 - *WNN*, "Work on Xudabao unit 1 gets under way", 16 November 2023, see https://www.world-nuclear-news.org/Articles/Work-on-Xudabao-unit-1-gets-under-way, accessed 17 November 2023.

34 - According to sources in China, the expected construction duration of VVER-1200/V491 is 69 months. At construction start, Rosatom stated about the Xudabao Project, "the units are expected to be commissioned in 2027-2028".
See Rosatom, "Start of new unit construction at China's Tianwan and Xudapu nuclear power plants", Press Release, 19 May 2021, https://rosatom.ru/en/press-centre/news/start-of-new-unit-construction-at-china-s-tianwan-and-xudapu-nuclear-power-plants/, accessed 14 June 2021.

35 - According to Rosatom at construction start of Unit 4, commissioning of Xudabu-3 and -4 is scheduled for 2027–2028.
See ASE-Rosatom, "First Concrete laid at Xudapu NPP Power Unit 4 in China", Press Release, 19 May 2022, see https://ase-ec.ru/en/for-journalists/news/2009/may/first-concrete-laid-at-xudapu-npp-power-unit-4-in-china/, accessed 19 May 2022.

36 - No official startup date at construction start.
See CNNC, "CNNC's Zhangzhou nuclear plant goes into construction", China National Nuclear Corporation, 23 December 2019, see http://en.cnnc.com.cn/2019-12/23/c_435889.htm, accessed 17 January 2020.
Construction duration of Hualong One design is given as 60 months.

37 - No official startup date at construction start.
See *WNN*, "Zhangzhou unit 2 construction starts", 4 September 2020, see https://www.world-nuclear-news.org/Articles/Construction-starts-of-second-Zhangzhou-unit, accessed 4 September 2020.
Construction duration of Hualong One design is given as 60 months.

38 - No official startup date at construction start.
Xinhua, "China begins construction on 2nd phase of Zhangzhou nuclear power project", 22 February 2024, see http://english.scio.gov.cn/chinavoices/2024-02/23/content_117015492.htm, accessed 24 February 2024.

Construction duration of Hualong One design is given as 60 months. However, CGTN quotes 2028 for commencement of operation. See *CGTN*, "Construction on new unit of Zhangzhou nuclear power plant underway in Fujian", 23 February 2024, see https://news.cgtn.com/news/2024-02-23/Construction-on-new-unit-of-Zhangzhou-nuclear-power-plant-underway-1rqt4dAP1Li/p.html, accessed 10 May 2024.

39 - *EgyptToday*, "Egypt's Nuclear Plants Authority, Rosatom committed to Dabaa plant construction schedule: Official", 9 May 2022, see https://www.egypttoday.com/Article/3/115597/Egypt's-Nuclear-Plants-Authority-Rosatom-committed-to-Dabaa-plant-construction, accessed 17 July 2022.
However, officials are now expecting a "trial operation" of the reactor as soon as the second part of 2027. See *Asharq Al-Awsat*, "Egypt Reveals Start Date for Trial Operation at Dabaa Nuclear Plant", 29 March 2024, see https://english.aawsat.com/node/4938331, accessed 14 August 2024.

40 - No official specific startup date for El Dabaa-2 as of construction date. WNISR2024 uses 2029 (WNA uses 2030 for El Dabaa 2–4).

41 - No official specific startup date for El Dabaa-3 as of construction date; however, according the Ministry of Electricity as of June 2023, all four units are to be completed by 2030 or 2031. "Dabaa nuclear plant project progresses according to schedule: Minister of Electricity", *Daily News Egypt*, 14 June 2023, see https://www.dailynewsegypt.com/2023/06/14/dabaa-nuclear-plant-project-progresses-according-to-schedule-minister-of-electricity/, accessed 22 August 2023. WNISR2024 uses 2030 (WNA uses 2030 for El Dabaa 2–4)

42 - No official specific startup date for El Dabaa-4 as of construction date. As all four units are expected online by 2030 or 2031 (see previous note), WNISR2024 uses 2031 (WNA uses 2030 for El Dabaa 2–4).

43 - Further delayed. Delayed many times from its original planned startup date of 2012. Expected for the first quarter of 2024 in WNISR2023, fuel loading started in May 2024, with grid connection still expected during the summer of 2024.
See EDF, "Update on the Flamanville EPR", 8 May 2024, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/update-on-the-flamanville-epr-2 accessed 8 May 2024.

44 - Further delayed. Completion of Kudankulam-3 & -4 is now expected in 2026, compared to 2025 in WNISR2023. See MoSPI, "463rd Flash Report on Central Sector Projects (Rs. 150 crore and above)", Ministry of Statistics and Programme Implementation, Government of India, May 2024, see http://ns1.cspm.gov.in/english/fr_part/2024-25/May/Part-1.pdf, accessed 5 July 2024.

45 - Further delayed. Completion of Kudankulam-3 & -4 is now expected in 2026, compared to 2025 in WNISR2023. See previous note.

46 - Expected construction duration of Kudankulam-5 is 66 months.
See Department of Atomic Energy and Lok Sabha "Unstarred Question No.2756—Kudankulam Nuclear Power Plant", answered by Jitendra Singh, Minister of State for Personnel, Public Grievances & Pensions, Prime Minister's Office, Government of India, 10 March 2021, see https://dae.gov.in/writereaddata/lsusq%202756.pdf, accessed 30 June 2021.
Kudankulam-5 & -6 are still scheduled to be commissioned by 2027, see MoSPI, "463rd Flash Report on Central Sector Infrastructure Projects (Rs. 150 crore & above)—Part - II", Ministry of Statistics and Programme Implementation, Government of India, May 2024, see http://www.cspm.gov.in/english/fr_part/2024-25/May/Part-2.pdf, accessed 18 July 2024.

47 - In March 2022, the Indian government announced that the "project completion schedule" for the four reactors under construction at Kudankulam are "likely to be impacted" because "components and equipments to be imported from Ukraine and Russia may be delayed due to the logistical and ocean freight problems" arising from the war on Ukraine.
See Department of Atomic Energy and Rajya Sabha, "Unstarred Question No. 3286—Status of Work at Kudankulam Power Plant", answered by Jitendra Singh, Minister of State for Personnel, Public Grievances & Pensions, Prime Minister's Office, Government of India, 31 March 2022, see http://dae.gov.in/writereaddata/rsusq3286.pdf, accessed 7 April 2022.

48 - The expected construction duration of Kudankulam-6 is 75 months.
See Department of Atomic Energy, "Lok Sabha - Unstarred Question No.2756 to be answered on 10.03.2021- Kudankulam Nuclear Power Plant", Government of India, op. cit.

49 - See note on Kudankulam-5.

50 - Delayed several times. Fuel loading started in March 2024, with grid connection expected by the end of 2024.
Office of the Prime Minister of India, "PM witnesses the historic 'Commencement of Core Loading' at India's first indigenous Fast Breeder Reactor (500 MWe) at Kalpakkam, Tamil Nadu", Government of India, 4 March 2024, see https://www.pmindia.gov.in/en/news_updates/pm-witnesses-the-historic-commencement-of-core-loading-at-indias-first-indigenous-fast-breeder-reactor-500-mwe-at-kalpakkam-tamil-nadu/, accessed 19 March 2024; and IPFM, "India begins loading fuel in Prototype Fast Breeder Reactor", International Panel on Fissile Materials, 4 March 2024, see https://fissilematerials.org/blog/2024/03/india_begins_loading_fuel.html, accessed 10 May 2024.

51 - Delayed. Completion of Rajasthan-7 & -8 is expected in 2026.
See MoSPI, "463rd Flash Report on Central Sector Projects (Rs. 150 crore and above)", Ministry of Statistics and Programme Implementation, Government of India, May 2024, op. cit.
As of July 2024, the "Expected Date of Commercial Operation" is "under review" on NPCIL's dedicated webpage.

52 - Delayed. No new announcements since WNISR2023, completion of Rajasthan-7 & -8 is expected in 2026. See MoSPI, "463rd Flash Report on Central Sector Projects (Rs. 150 crore and above)", Ministry of Statistics and Programme Implementation, Government of India, May 2024, op.cit.
As of July 2024, the "Expected Date of Commercial Operation" is "under review" on NPCIL's dedicated webpage.

53 - Original construction of Bushehr-2 had started in February 1976 before it was halted in 1978. The reactor remained listed as "under construction" in PRIS-IAEA, "Nuclear Power Reactors in the World", until the 1994 edition. Currently, PRIS indicates September 2019 as construction start, when construction work resumed, and a new concrete slab was poured.
See WNISR, "Iran: Construction Restart of Busheer-2", 14 November 2019, see https://www.worldnuclearreport.org/Iran-Construction-Restart-of-Busheer-2.html, accessed 8 November 2023.

54 - Further delayed. 2024 was the date announced when construction resumed in 2019. The Head of the Atomic Energy Organization of Iran (AEOI) Mohammad Eslami was quoted as saying in October 2023, "We hope that the second unit will be completed and inaugurated in less than 5 years and the third unit 1.5 years after that"; see NEI Magazine, "Iran pours concrete for section of second Bushehr reactor", 13 October 2023, see https://www.neimagazine.com/news/iran-pours-concrete-for-section-of-second-bushehr-reactor-11216439/?cf-view accessed 8 August 2024.
In January 2024, WNA changed the expected grid connection year from 2024 to 2028; see WNA, "Plans for New Nuclear Reactors Worldwide", World Nuclear Association, January 2024, see https://world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx.

55 - Construction status unclear. Expected operation further delayed. At the end of April 2024, Chugoku Power Co. announced it now plans to start Shimane-3 by FY 2030. See *The Japan Times*, "Chugoku Electric delays restart of nuclear reactor at Shimane plant", 1 May 2024, see https://www.japantimes.co.jp/news/2024/05/01/japan/society/restart-of-shimane-nuclear-reactor-to-be-delayed/.

56 - Delayed? As of construction start, BREST-OD was to start operating in 2026, and shortly after, in 2027. Rosatom, "ROSATOM starts construction of unique power unit with BREST-OD-300 fast neutron reactor", Press Release, 8 June 2021, see https://rosatom-europe.com/press-centre/news/rosatom-starts-construction-of-unique-power-unit-with-brest-od-300-fast-neutron-reactor/, accessed 19 August 2022, and Rosatom, "Newsletter #247—Proryv: Breaking Through", November 2021, see https://rosatomnewsletter.com/2021/12/01/proryv-breaking-through/, accessed 8 August 2024
In March 2024, Rosatom Director General Alexei Likhachev stated that the launch will be in 2026, with grid connection planned for the first half of 2027. *NEI Magazine*, "Russia's Brest-OD-300 reactor scheduled for physical launch in 2026", 5 March 2024, see https://www.neimagazine.com/news/russias-brest-od-300-reactor-scheduled-for-physical-launch-in-2026-11572160/, accessed 12 July 2024.

57 - Delayed several times. Startup dates for Kursk 2-1 and 2-2 at construction start were never very explicit, with 2022 often quoted for Unit 1, while others used 2023. However, in the 2019 edition of IAEA's "Nuclear Power Reactors in the World", Kursk 2-1 is the only 'Construction Start During 2018' to have a grid connection date, set to June 2022. In the 2022 edition, Kursk 2-1 was listed in the "Scheduled connections to the grid during 2022". The 2023- and 2024 editions use March 2025 as grid connection date.

58 - Delayed. In the 2020 edition of IAEA's "Nuclear Power Reactors in the World", Kursk 2-2 is the only 'Construction Start During 2019' to have a grid connection date, set to December 2023. The 2023 and 2024 editions of IAEA's "Nuclear Power Reactors in the World" use March 2027 as grid connection date for Kursk 2-2.

59 - Original startup date is 2030 (Grid connection and commercial operation). PRIS-IAEA, "Reactor Basic Information - Leningrad 2-3", PRIS Database, 5 April 2024; and WNN, "First concrete poured at Leningrad 7", 14 March 2024, see https://www.world-nuclear-news.org/Articles/First-concrete-poured-at-Leningrad-7, accessed 14 March 2024.

60 - Status of the project unclear. In August 2022, Rosatom announced the keel-laying ceremony in China of the first Arctic-type Nuclear Floating Power Unit (NFPU) to be equipped with two RITM-200C reactors and to be deployed in Russia. As there is no official name yet for the reactors, those units are provisionally named Cape Nagloynyn 1-1 and 1 -2 according to the overall project name Cape Nagloynyn.
See Rosatom, "Keel-laying ceremony for the first Arctic-type Floating Power Unit with RITM-200 transport reactor vessels", Press Release, 30 August 2022, see https://rosatom-mena.com/press-centre/news/keel-laying-ceremony-for-the-first-arctic-type-floating-power-unit-with-ritm-200-transport-reactor-v/, accessed 5 October 2022; and *WNN*, "Construction starts on Russia's next floating nuclear power plant", 31 August 2022, see https://www.world-nuclear-news.org/Articles/Construction-starts-on-Russia-s-next-floating-nucl, accessed 20 September 2022.

61 - Further delayed. Fuel loading and grid connection are expected in the first quarter of 2025. TREND, "Palivo do 4. bloku Mochoviec zavezú v roku 2025", 6 November 2023, see https://www.trend.sk/spravy/zavezenie-paliva-stvrteho-bloku-jadrovej-elektrarne-mochovce-caka-roku-2025 accessed 5 July 2024.

62 - In late 2022, two reactors under construction, Shin-Kori Unit 3 and 4, were renamed Saeul-1 and -2.
See KHNP, "Saeul NPP Renames as Saeul Units 1, 2, 3 and 4", Press Release, Korea Hydro & Nuclear Power, 1 November 2022, see https://cms.khnp.co.kr/eng/selectBbsNttView.do;WCN_KHNPHOME=30yVBQtmOX8ttEVoH9XY011xjJSy2XlO2nToY1Bf0061D01j_Acf!-1320158464?key=565&bbsNo=84&nttNo=46397&searchCtgry=&searchCnd=all&searchKrwd=&integrDeptCode=&pageIndex=1, accessed 3 November 2022.

63 - Further delayed. Construction officially started in April 2017, suspended in July to resume in October of the same year. Commercial operation at construction start was October 2021; after numerous delays, it is expected in October 2024. However, according to KHNP, fuel loading was to take place in March 2024, which did not happen. See KHNP, "Nuclear Power Construction – Saeul #3,4", Korea Hydro & Nuclear Power, Various Dates, see https://cms.khnp.co.kr/eng/contents.do?key=525, last accessed July 2024.

64 - Delayed. As of July 2024, commercial operation is still announced as October 2025.
See KHNP, "Nuclear Power Construction—Saeul #3,4", Korea Hydro & Nuclear Power, Various Dates, see https://cms.khnp.co.kr/eng/contents.do?key=525, last accessed 6 July 2024.

65 - Further delayed. The Akkuyu reactors were officially expected to be completed one per year starting in 2023. Commissioning of Akkuyu-1 has been pushed back to 2024, and then 2025.

66 - The Akkuyu reactors were officially to be completed one per year starting in 2023. While startup of unit 1 has been pushed back to 2025, there is no specific information on the impact for the other units. WNISR keeps a one-per-year startup frequency.

67 - See previous note.

68 - See previous note.

69 - WNISR, "The Oddly Discreet Construction Start of Hinkley Point C", 29 December 2018, see https://www.worldnuclearreport.org/The-Oddly-Discreet-Construction-Start-of-Hinkley-Point-C.html, accessed 24 August 2019.

70 - Further delayed. On 23 January 2024, EDF presented three scenarios for the startup of Unit 1. The first would see startup in 2029, the second in 2030 ("base case"), and the third in 2031, compared to 2027 in WNISR2023. EDF, "Hinkley Point C Update", Press Release, 23 January 2024, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/hinkley-point-c-update-1.

71 - See WNISR, "Strangely Belated Announcement of Hinkley Point C-2 Construction Start", 18 March 2020, see https://www.worldnuclearreport.org/Strangely-Belated-Announcement-of-Hinkley-Point-C-2-Construction-Start.html.

72 - Further delayed. While scenarios presented by EDF in January 2024 puts grid connection of Unit 1 within the period between 2029 and 2031, no date has been indicated for Unit 2. WNISR assumes grid connection for Unit 2 will take place with the same time lag as for the construction start. EDF, "Hinkley Point C Update", Press Release, 23 January 2024.

ANNEX 6 – ABBREVIATIONS

ELECTRICAL AND OTHER UNITS

KW	kilowatt (unit of installed electric power capacity)
kWh	kilowatt hour (unit of electricity production or consumption)
MW	megawatt (10^6 watts)
MWe	megawatt electric (as distinguished from megawatt thermal, MWt)
GW	gigawatt (10^9 watts)
GWe	gigawatt electric
TWh	terawatt hour (10^{12} watt-hours)
Bq	Becquerel
mSv	millisievert
Sv	Sievert
Sv/h	Sievert per hour

ACRONYMS

3/11	"Great East Japan Earthquake"; beginning of the Fukushima nuclear disaster (11 March 2011)
ABWR	Advanced Boiling Water Reactor (Reactor design)
AEC	Atomic Energy Commission (Taiwan)
AGR	Advanced Gas-cooled Reactor (Reactor design)
AHWR	Advanced Heavy Water Reactor (Reactor design)
ALPS	Advanced Liquid Processing Systems
ANC	African National Congress (Political Party, South Africa)
ANF	Advanced Nuclear Fuels (Framatome subsidiary, Germany)
ASN	*Autorité de Sûreté Nucléaire* – Nuclear Safety Authority (France)
BNDES	*Banco Nacional de Desenvolvimento Econômico e Social* – Brazilian Development Bank
BPE	Basic Plan for Long-term Electricity Supply and Demand (South Korea)
BRL	Brazilian real (Currency)
BWR	Boiling Water Reactor (Reactor design)
CAD	Canadian dollar (Currency)
CAISO	California Independent System Operator (Grid operator, United States)
CANDU	CANadian Deuterium Uranium (Reactor design, Canada)
CAREM	*Central Argentina de Elementos Modulares* – Small Modular PWR Design (under construction in/by Argentina)
CDU	*Christlich Demokratische Union Deutschlands* (Political Party, Germany)
CEFR	China Experimental Fast Reactor
ČEZ	*České Energetické Závody* (Conglomerate, Czech Republic)
CfD	Contract for Difference
CFPP	Carbon Free Power Project (Small Modular Reactor project, United States)
CGN	China General Nuclear Power Corporation
CNEA	*Comisión Nacional de Energía Atómica* – National Atomic Energy Commission (Argentina)
CNEN	*Comissão Nacional de Energia Nuclear* – Federal Commission on Nuclear Energy (Brazil)
CNNC	China National Nuclear Corporation
CNSC	Canadian Nuclear Safety Commission
CNY	Chinese yuan renminbi (Currency)

COL	Construction and Operating License (United States)
COP	Conference of the Parties (of the United Nations Framework Convention on Climate Change)
CZK	Czech Koruna (Currency)
DESNZ	Department for Energy Security and Net Zero (United Kingdom)
DIW	*Deutsches Institut für Wirtschaftsforschung e.V.* – German Institute for Economic Research
[U.S.] DOE	Department of Energy (United States)
DPP	Democratic Progressive Party (Taiwan)
EDF	*Électricité de France* – Power Utility (France)
EIA	Environmental Impact Assessment or Energy Information Administration (United States Department of Energy)
EL-4	Reactor (France)
EnBW	Energie Baden-Württemberg AG.
Enresa	*Empresa Nacional de Residuos Radiactivos S.A.* – Radioactive Waste Management Agency (Spain)
EPC	Engineering, Procurement and Construction
EPR	European Pressurized Water Reactor or Evolutionary Power Reactor (Reactor Design)
ERCOT	Electric Reliability Council of Texas (Grid operator, United States)
E.U.	European Union
EXIM	Export-Import Bank (United States)
FBR	Fast Breeder Reactor (Reactor type)
FDP	*Freie Demokratische Partei* – Free Democratic Party (Germany)
FID	Final Investment Decision
FL3	Flamanville-3 (Reactor, France)
FOAK	First-of-a-Kind
FY	Financial Year
GBN	Great British Nuclear (United Kingdom)
GCR	Gas-Cooled Reactor
GDA	Generic Design Assessment
GE	General Electric
GEH	GE Hitachi
GEN III	Generation III – "Advanced" Nuclear Power Reactor designs
HAEA	Hungarian Atomic Energy Authority
HB	House Bill (United States)
HDR	Heißdampfreaktor (Reactor, Germany)
HPC	Hinkley Point C (Reactor, United Kingdom)
HTGR	High Temperature Gas Cooled Reactor
HTR	High Temperature (Gas-Cooled) Reactor or High Temperature Reactor
HTR-PM	High-Temperature gas-cooled Reactor Pebble-bed Module (Demonstration plant, China)
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
IIJA	Infrastructure Investment and Jobs Act (U.S. Federal legislation, 2021)
IRA	Inflation Reduction Act (U.S. Federal legislation, 2022)
IRENA	International Renewable Energy Agency
JAIF	Japan Atomic Industrial Forum
JPDR	Japan Power Demonstration Reactor
KAERI	Korea Atomic Energy Research Institute
KEPCO	Kansai Electric Power Company (Japan) or Korea Electric Power Corporation (South Korea)
KHNP	Korea Hydro & Nuclear Power (operator, subsidiary of Korea Electric Power Corporation, South Korea)

KMT	Kuomintang (Nationalist Party of China)
KPX	Korea Power Exchange
KRW	Korean won (Currency)
LCOE	Levelized Cost of Energy
LNG	Liquefied Natural Gas
LTE	Long-Term Enclosure
LTO	Long-Term Outage (WNISR reactor status category), or Long-Term Operation
LTS	Long-Term Shutdown (former reactor status category, International Nuclear Energy Agency)
LWR	Light Water Reactor
METI	Ministry of Economy, Trade and Industry (Japan)
MIT	Massachusetts Institute of Technology (United States)
MOE	Ministry of Energy and Natural Resources (Türkiye)
MOTIE	Ministry of Trade, Industry and Energy (South Korea)
MoU	Memorandum of Understanding
MOX	Uranium-plutonium Mixed-OXide
NA-SA	Nucleoeléctrica Argentina SA
NDA	Nuclear Decommissioning Authority (United Kingdom)
NDC	Nationally Determined Contribution
NEA	Nuclear Energy Agency (of the Organisation for Economic Co-operation and Development)
NECP	National Energy and Climate Plan
NPP	Nuclear Power Plant
NPT	Treaty on the Non-Proliferation of Nuclear Weapons (1968)
NRA	Nuclear Regulation Authority (Japan)
NSC	Nuclear Safety Commission (Taiwan)
NSSC	Nuclear Safety and Security Commission (South Korea)
NT$	New Taiwan Dollar (Currency)
OECD	Organisation for Economic Co-operation and Development
OL3	Olkiluoto-3 (Reactor, Finland)
ONR	Office for Nuclear Regulation (United Kingdom)
OPG	Ontario Power Generation (Company, Canada)
OSG	Orlen Synthos Green Energy (Company, Poland)
PEJ	*Polskie Elektrownie Jądrowe* – State-owned Polish company (former PGE EJ1)
PG&E	Pacific Gas and Electric Company (United States)
PGE	*Polska Grupa Energetyczn* – Polish Energy Group (Company, Poland)
PLEX	Plant Life Extension
PRIS	Power Reactor Information System (of the International Atomic Energy Agency)
PTC	Production Tax Credit
PV	Photovoltaics
PWR	Pressurized Water Reactor (Reactor type)
R&D	Research and Development
RAB	Regulated Asset Base
RBMK	*Reaktor Bolshoy Moshchnosti Kanalnyi* (Soviet reactor design)
REMIT	European Regulation on Wholesale Energy Market Integrity and Transparency
RITM	Russian reactor design (Generation III+)
RTE	*Réseau de Transport d'Électricité* – Transmission System Operator (France)
RUB	Russian Ruble (Currency)
RUSI	Royal United Services Institute (Think-thank, United Kingdom)

RWE	*Rheinisch-Westfälisches Elektrizitätswerk* – Rhine-Westphalia Power Utility (Germany)
SDA	Standard Design Approval
SEK	Swedish Krona (Currency)
SMART	System-integrated Modular Advanced Reactor (Reactor design, South Korea)
SMR	Small Modular Reactor
Sogin	*Societa Gestione Impianti Nucleari SpA* – state-owned Decommissioning Company (Italy)
SSM	*Strålsäkerhetsmyndigheten* – Swedish Radiation Safety Authority
SÚJB	*Státní úřad pro jadernou bezpečnost* – State Office for Nuclear Safety (Czech Republic)
TBPAR	Tritium-Producing Burnable Absorber Rods
TEPCO	Tokyo Electric Power Company (Japan)
THTR	Thorium High Temperature Reactor (Reactor, Germany)
TMI	Three Mile Island (Nuclear Power Plant, United States)
TVA	Tennessee Valley Authority
U.K.	United Kingdom
U.S.	United States of America
U.S. NRC	United States. Nuclear Regulatory Commission
UAE	United Arab Emirates
UAH	Ukraine Hryvnia (Currency)
UNFCCC	United Nations Framework Convention on Climate Change
US$	U.S. dollar (Currency)
VALCOE	Value-Adjusted Levelized Cost of Energy
VD	*Visite Décennale* – Decennial Safety Review (France)
VVER	*Vodo-Vodianoï Energuetitcheski Reaktor* (Russian Pressurized Water Reactor design)
WIP	*Fachgebiet Wirtschafts- und Infrastrukturpolitik* – Workgroup for Economic and Infrastructure Policy (of the Technische Universität Berlin, Germany)
WNA	World Nuclear Association
WNISR	World Nuclear Industry Status Report
WNN	*World Nuclear News* (publication of the World Nuclear Association)
ZAR	South African rand (Currency)
ZNPP	Zaporizhzhia Nuclear Power Plant (Ukraine)

ANNEX 7 – ABOUT THE AUTHORS

Andreas Molin Dipl.-Ing, has been director of the Division of Nuclear Co-ordination from October 1995 until his retirement in October 2021: first in the Federal Chancellery of Austria, finally in the Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology. In this capacity, he has been involved in numerous transboundary environmental impact assessment procedures regarding nuclear installations as well as related plans and programs. Andreas Molin has been representing Austria in the Steering Committee for Nuclear Energy of the OECD's Nuclear Energy Agency. From 2011 to 2015 he has served as vice-chairman of the European Nuclear Safety Regulators Group (ENSREG). From August 2020 until his retirement, he has been chairing the Board for Stress Tests in Third Countries, inter alia accompanying the Peer Review of the Belarus National Action Plan. In June 2015, he chaired the third ENSREG-Conference in Brussels. From 2007 to 2017, he has been serving on the Advisory Committee of the Euratom Supply Agency.

Currently he is a member of the High-Level Group on Stakeholder Engagement, Trust, Transparency and Social Science (HLG-SET) of the OECD Nuclear Energy Agency.

Maahin Ahmed is a copyeditor based in Vancouver, Canada. Her editing work focuses on academic and technical writing, and her academic background is in international relations with a focus on historical memory and oral histories. In the last three years she has been a copyeditor apprentice with the 1947 Partition Archive and contributed to two reports published by the International Union for Conservation of Nature's (IUCN) Commission on Ecosystem Management.

Antony Froggatt is an independent consultant. From 2007 to 2024 he was Senior Research Fellow and then the Deputy-Director of the Environment and Society Centre at Chatham House (from 2020). He studied energy and environmental policy at the University of Westminster and the Science Policy Research Unit at Sussex University. For over 20 years he has been involved in the publication of the World Nuclear Industry Status Report (WNISR). At Chatham House, he specialized on global electricity policy and the geopolitics of the energy transition. He has worked as an independent consultant for two decades with environmental groups, academics and public bodies in Europe and Asia. His most recent research project is understanding the energy and climate policy implications of the Russian invasion of Ukraine.

Özgür Gürbüz is a columnist and independent consultant working in Türkiye and abroad. Gürbüz has also been writing on environmental, economic, and energy issues since 1994 and is known for his work in various civil society organizations. He is the co-founder of the Ekosfer Association, which specializes in climate change and energy. He has published a book on climate change entitled "Energy and Cows" and has contributed to several other books and articles on journalism, energy, and the environment.

Julie Hazemann, based in Paris, France, is the Director of EnerWebWatch, an international documentation monitoring service, specializing in energy and climate issues, launched in 2004. As an information engineer and researcher, she has maintained, since 1992, a world nuclear reactor database and undertakes data-modelling and data-visualization work for the World Nuclear Industry Status Report (WNISR). Active in information and documentation project-management, she has a strong tropism for information structuration, dataviz and development of electronic information products. She also undertakes specialized translation and research activities for specific projects. She is a member of négaWatt (France) and develops EnerWebWatch in the framework of the Coopaname Coop.

Christian von Hirschhausen is Professor of Economics at the Workgroup for Economic and Infrastructure Policy (WIP) at Berlin University of Technology (TU Berlin), and Research Director at DIW Berlin (German Institute for Economic Research). He obtained a PhD in Industrial Economics from the Ecole Nationale Supérieure des Mines de Paris and was previously Chair of Energy Economics and Public Sector Management University of Technology (TU Dresden). Von Hirschhausen focuses on the regulation and financing of infrastructure sectors, mainly energy, and is a regular advisor to industry and policymakers, amongst them the World Bank, the European Commission, European Investment Bank, and several German Ministries. Von Hirschhausen also focusses on energy technologies and is one of the coordinators of a research project on nuclear energy in Germany, Europe, and abroad, including the first independent monitoring of the decommissioning process of German nuclear power plants.

Paul Jobin is Associate Research Fellow at the Institute of Sociology, Academia Sinica, Taiwan, and adjunct Associate Professor at the International College of Innovation, National Chengchi University. He has conducted extensive research on industrial risks and environmental justice issues in Taiwan and Japan, and more recently on geopolitical risks in the context of Taiwan and East Asia. Among his recent publications is the book Environmental Movements and Politics of the Asian Anthropocene, co-edited with Ming-sho Ho and Hsin-huang Michael Hsiao (2021).

Phil Johnstone is a Senior Research Fellow at the Science Policy Research Unit (SPRU), University of Sussex, U.K. He is a member of the Sussex Energy Group (SEG) and a patron of the Nuclear Information Service. He currently works in the Deep Transitions Lab, an interdisciplinary project which works with partners in the finance industry to understand and enact transformative investment for sustainability. Johnstone has researched and written widely on the political, democratic, and economic implications of energy transitions and for a number of years has worked on nuclear power issues particularly civil-military nuclear interdependencies.

Timothy Judson is an independent consultant who provides industrial and policy analysis, with over twenty years of experience in the United States. He has published several reports on the nuclear energy industry and energy and climate policy, including "Nuclear Power and Climate Change: An Assessment for the Future" and "Too Big to Bail Out: The Cost of a National Nuclear Energy Subsidy." Since 2014, he has served as the Executive Director of

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Yuki Kobayashi is a research fellow in the Security Studies Program of the Sasakawa Peace Foundation. His research focuses on nuclear energy and nuclear non-proliferation. He received a master's degree in international relations from Sciences Po Strasbourg in 2013, and a master's degree in public policy from Sciences Po Rennes, France, in 2014. He enrolled in the doctoral course at Mines ParisTech in 2015, earning his Ph.D. in 2019 with his thesis on "The Relationship between Politics and Science in the Crisis Response to the Accident at Fukushima Daiichi Nuclear Power Plant."

Doug Koplow is the founding director of Earth Track in Cambridge, MA. For more than three decades, he has worked with environmental groups and international agencies to identify and measure environmentally harmful subsidies to natural resource extraction, and to document their pervasive reach and enormous scale. His work has included detailed reviews of government support to the nuclear fuel chain, highlighting the many ways governments support the industry and shift business risks onto taxpayers. He holds an MBA from Harvard Business School and a BA in economics from Wesleyan University.

Edwin Lyman is the Director of Nuclear Power Safety at the Union of Concerned Scientists in Washington, DC. He earned a doctorate in physics from Cornell University in 1992. He is a co-author (with David Lochbaum and Susan Q. Stranahan) of the book "Fukushima: The Story of a Nuclear Disaster" (*The New Press*, 2014). He is the recipient of the 2018 Leo Szilard Lectureship Award from the American Physical Society.

Arnaud Martin, webdesigner and full-stack developer, initiated the development of the CMS SPIP in 2000, and launched the social network Seenthis.net in 2009. His work can be seen on 23FORWARD.

Friedhelm Meinaß, born in 1948, is a visual artist and painter based in the Frankfurt area, Germany. His characteristic pieces including his cover art for Nina Hagen, are on display in the German History Museum in Berlin, and his work is internationally acclaimed. Amongst others, Meinaß has cooperated with Leonard Bernstein, The Byrds, Johnny Cash, Vladimir Horowitz and Billy Joel. He is collaborating with the Designer Constantin E. Breuer, who congenially implements his ideas. Meinaß held a professorship at the University of Design in Darmstadt in the early 1970s.

M.V. Ramana is the Simons Chair in Disarmament, Global and Human Security and Professor at the School of Public Policy and Global Affairs, University of British Columbia, Vancouver, Canada. He received his Ph.D. in theoretical physics from Boston University. Ramana is the author of "The Power of Promise: Examining Nuclear Energy in India" (*Penguin Books*, 2012), "Nuclear is not the Solution: The Folly of Atomic Power in the Age of Climate Change" (*Verso Books*, 2024), and co-editor of "Prisoners of the Nuclear Dream" (*Orient Longman*, 2003). He is a member of the International Panel on Fissile Materials (IPFM), the International Nuclear Risk Assessment Group (INRAG) and the Canadian Pugwash Group. He is the recipient of a Guggenheim Fellowship and a Leo Szilard Award from the American Physical Society.

Mycle Schneider is an independent international analyst on energy and nuclear policy based in Paris. He is the Coordinator and Publisher of the World Nuclear Industry Status Reports (WNISR). He is a founding board member of the International Energy Advisory Council (IEAC) and served as the Coordinator of the Seoul International Energy Advisory Council (SIEAC). He is a member of the International Panel on Fissile Materials (IPFM), based at Princeton University, the International Nuclear Security Forum (INSF), both in the U.S, and the International Nuclear Risk Assessment Group (INRAG), Austria. He provided information and consulting services, amongst others, to the Austrian Ministry for Climate Action, Environment, Energy, the Belgian Energy Minister, the French and German Environment Ministries, the U.S. Agency for International Development, the International Atomic Energy Agency (IAEA), the European Commission, and the French Institute for Radiation Protection and Nuclear Safety (IRSN). Schneider has given evidence and held briefings at national Parliaments in 16 countries and at the European Parliament. He has given lectures at over 20 universities and engineering schools around the globe.

Nina Schneider is a freelance proofreader and translator with Coopaname, Paris, France. Her involvement with the World Nuclear Industry Status Report dates back to 2014 and has been evolving ever since, adding fact checking, background research, and various production tasks to her responsibilities.

Andy Stirling is a Professor in the Science Policy Research Unit (SPRU) and was co-director of the STEPS (Social, Technological and Environmental Pathways to Sustainability) Centre at the University of Sussex. He has a background in the natural sciences, a master's degree in archaeology and social anthropology (Edinburgh) and a doctorate in science and technology policy (Sussex). An interdisciplinary researcher on the politics of science and technology, Andy formerly worked in the environment and peace movements and has also collaborated with a range of governmental, business and civil society organizations. A fellow of the U.K. Academy of Social Science, he has served on several U.K. and E.U. policy advisory committees on issues around energy, chemicals, biotechnology, environment and science policy.

Sebastian Stier is a European patent attorney who has been working for the Munich-based law firm Betten&Resch since 2012. He represents clients before the European Patent Office (EPO) in patent prosecution, opposition, and appeal proceedings. His clients include large international tech firms mainly from the telecom, computer, and electronics industries. He has a diploma in physics from the University of Heidelberg (1985) and obtained a PhD in artificial intelligence from the University of Hamburg (1990). At corporate research of Siemens AG in Munich, he worked as a research engineer and held various positions in technology and innovation management. In the Mobile Phones Division, he was responsible for the integration of a newly acquired mobile phone company in Aalborg/Denmark. In 2005, he joined a patent law firm and qualified as European patent attorney in 2009.

Agnès Stienne is a freelance artist, cartographer and graphic designer. She worked for over ten years as a cartographer for the French newspaper *Le Monde Diplomatique*. For several years now, she has been leading a research project focusing on agricultural practices, "land grabbing" and other fundamental issues related to agriculture and food. This work takes the form of "geo-poetic" narratives published on the cartographic experimentation website Visioncarto.net. Among these, she produced a series of paintings based on satellite images from Google Earth as a continuation of "Géographie du palmier à huile" exhibited in Le Mans (France) in 2020 and 2021. In 2023, she published "Bouts de bois - Des objets aux forêts", a free and sensitive essay with *Éditions La Découverte, Zones collection*.

Tatsujiro Suzuki is Professor at the Research Center for Nuclear Weapons Abolition at Nagasaki University (RECNA), Japan. Before joining RECNA, he was a Vice Chairman of Japan Atomic Energy Commission (JAEC) of the Cabinet Office from January 2010 to March 2014. Until then, he was Associate Vice President of the Central Research Institute of Electric Power Industry (CRIEPI) in Japan (1996–2009) and Visiting Professor at the Graduate School of Public Policy, University of Tokyo (2005–2009), an Associate Director of MIT's International Program on Enhanced Nuclear Power Safety from 1988–1993 and a Research Associate at MIT's Center for International Studies (1993–1995). He is a member of the Advisory Board of Parliament's Special Committee on Nuclear Energy since June 2017. He is also a Council Member of Pugwash Conferences on Science and World Affairs (2007–2009 and from 2014~), Co-Chair of the International Panel on Fissile Materials (IPFM) and a Board member of Asia Pacific Leadership Network for Nuclear Non-Proliferation and Disarmament (APLN). Dr. Suzuki has a PhD in nuclear engineering from Tokyo University (1988).

Alexander James Wimmers is a research associate in the AT-OM research group at the Workgroup for Economic and Infrastructure Policy (WIP) at the Berlin University of Technology (TU Berlin), and guest researcher at the German Institute for Economic Research (DIW Berlin), Germany. Before joining WIP, he worked as a consultant for renewable energy markets at a renowned energy consulting firm in Berlin. He holds an MSc in Business Administration and Engineering (Wirtschaftsingenieurwesen) from RWTH Aachen University. His current research focuses on the political economy of nuclear power, from new build, operation, decommissioning and nuclear waste management. He is a member of a long-term research project on nuclear decommissioning in cooperation with the University of Basel.

Hartmut Winkler is a Professor in the Department of Physics of the University of Johannesburg in South Africa. After completing his PhD in Astronomy at the University of Cape Town, he joined the Soweto Campus of the former Vista University, where he started engaging on air quality research, which led to an interest in solar irradiance studies, solar energy potential and later energy studies in the broader sense. After a stint in the University administration as Dean of Science, he returned to scientific work after joining the new University of Johannesburg. In recent years, he has been one of South Africa's most visible television and radio commentators on the country's electricity crisis. His contributions include numerous media articles on various nuclear energy issues in South Africa.