World Nuclear Performance Report 2024

WORLD NUCLEAR ASSOCIATION

Contents

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Preface

Sama Bilbao y León
Director General
World Nuclear Association

In 2023, the global nuclear fleet continued its excellent performance. Nuclear generation supplied more than 2600 TWh, up 58 TWh from 2022, and generating 9% of the world's electricity. This increase was partly due to the return to service of French reactors after extended outages, contributing an additional 42 TWh. The increase in generation is despite a 1 GWe drop in overall capacity, to 392 GWe, of operable nuclear power plants.

The average capacity factor of nuclear reactors increased by 1%, reaching 81.5% in 2023, highlighting the reliability delivered by nuclear energy to the grid. Nuclear energy remains the most reliable means of supplying clean energy to the grid. Nuclear reactors have consistently achieved over 80% capacity factors for the past 20 years.

Nuclear reactors helped avoid 2.1 billion tonnes of carbon dioxide emissions in 2023 from equivalent coal generation - that's more than the annual emissions of almost every individual country, with only China, India, and the USA having higher national CO_2 emissions.

This edition of the World Nuclear Performance Report continues the trend of analyzing generation by the ages of nuclear reactors in each country, showing the excellent performance of nuclear reactors, regardless of age. The case studies illustrate ongoing efforts to generate more electricity from the nuclear fleet, including Holtec's work to return Palisades in the USA to service, KHNP's extension of the operating lifetimes of 10 units in South Korea, and ČEZ's uprating of the power output at the Dukovany and Temelin plants in Czechia.

However, lifetime extensions or restarting shuttered reactors are not substitutes for new builds, particularly as global energy demand continues to rise. At the COP28 climate change conference in Dubai, UAE, in December 2023, 25 countries signed a declaration with the goal of tripling global nuclear capacity by 2050. Achieving this goal will require a significant increase in new nuclear construction.

In 2023, five reactors were shut down, while five reactors were connected to the grid across a diverse set of countries: one each in China, Slovakia, the USA, Belarus, and South Korea. Vogtle 3, the first nuclear power plant to start and complete construction in more than 40 years in the USA, was connected to the grid and began serving customers in 2023, with Vogtle 4 following this year.

Five out of a total of six new construction starts in 2023 were in China, with the other being in Egypt. In Asia, there has been a sustained and significant increase in nuclear generation over the last decade. Of the total 64 reactors under construction today, more than two-thirds are in Asia, with 30 reactors under construction in China alone. Eastern Europe and Russia are second to Asia in terms of the number of units under construction.

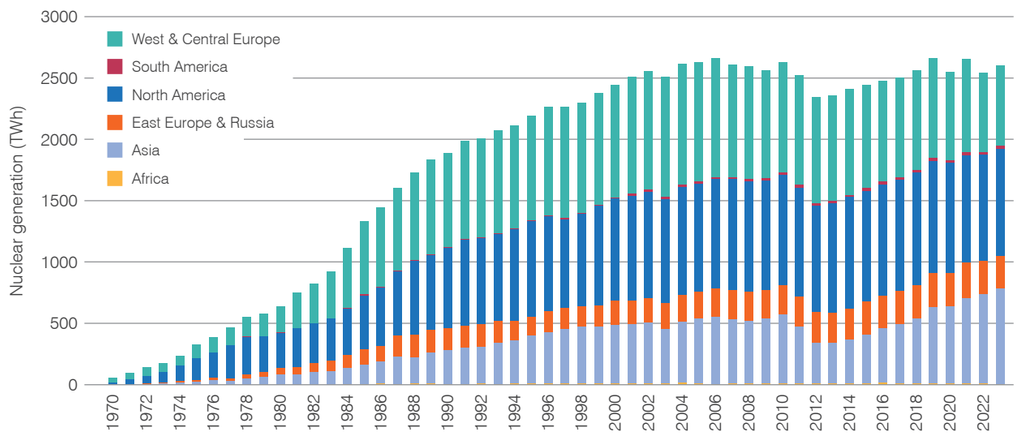
While more concerted efforts are needed to rapidly increase carbon-free generation to meet global decarbonization goals, nuclear energy is now being recognized across an ever-growing number of countries as a reliable answer to the world's demand for clean, secure and affordable energy.

1 Nuclear industry performance

1.1 Global highlights

Nuclear reactors generated a total of 2602 TWh of electricity in 2023, up 58 TWh from 2544 TWh in 2022, but still down 51 TWh on the 2653 TWh generated in 2021. A key contributor to the recovery in 2023 was the 42 TWh increase in generation in France, recovering around half of the reduction in output that was caused by extended outages the previous year.

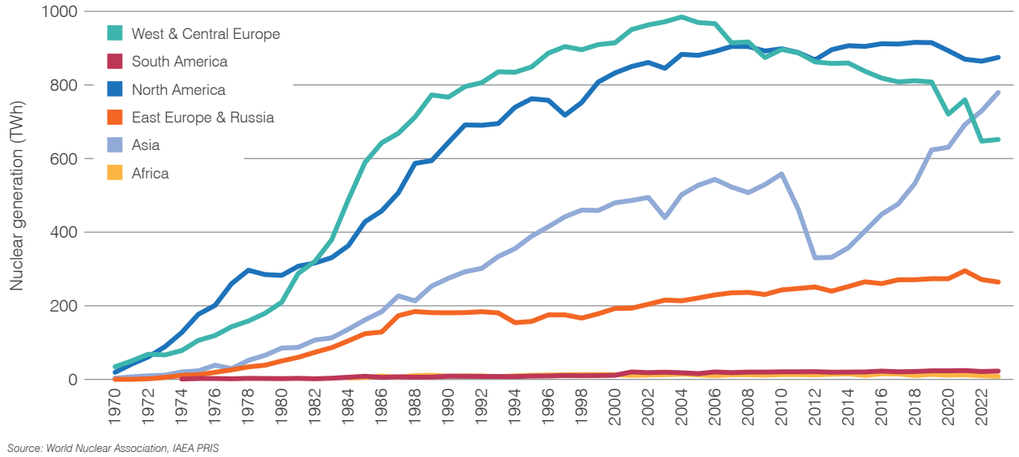
Figure 1. Global nuclear electricity production



Source: World Nuclear Association and IAEA Power Reactor Information Service (PRIS)

Generation continued to rise strongly in Asia, with new reactors connected to the grid since the start of 2023 in China, UAE, South Korea and Pakistan contributing to this increase. In other regions total generation in 2023 was broadly similar to the previous year.

Figure 2. Nuclear electricity generation by region



Source: World Nuclear Association, IAEA PRIS

In 2023 the end-of-year capacity of operable nuclear power plants was 392 GWe, down one gigawatt on 2022. This includes 20 GWe of capacity in Japan and less than 1 GWe capacity in India where the status is categorized as 'Suspended Operation' by the International Atomic Energy Agency (IAEA).

The total number of operable reactors at the end of 2023 was 437, unchanged from 2022.

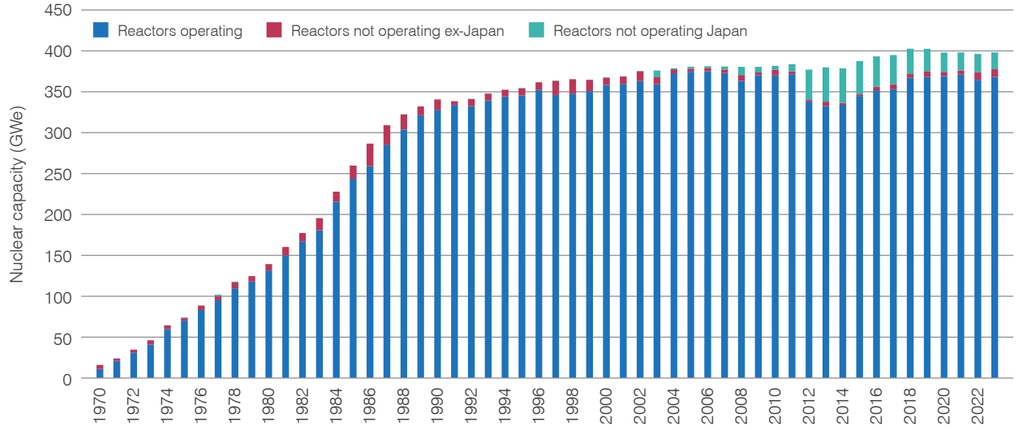
Table 1. Operable nuclear power reactors at year-end 2023 (change from 2022)

	Africa	Asia	East Europe & Russia	North America	South America	West & Central Europe	Total
BWR		19 (-1)		33		8	60 (-1)
FNR			2				2
GCR						8	8
HTGR		1					1
LWGR			11				11
PHWR		23		19	3	2	47
PWR	2	106 (+2)	41 (+1)	62 (+1)	2	95 (-3)	308 (+1)
Total	2	149 (+1)	54 (+1)	114 (+1)	5	113 (-3)	437

Source: World Nuclear Association, IAEA PRIS

The total capacity of reactors that produced electricity in 2023 was 368 GWe, up 3 GWe on 2022. In addition to the 21 GWe of reactor capacity in Japan and India, a further 9 GWe of operable reactors did not produce electricity in 2023, a similar total to 2022. The six reactors at Zaporizhzhia in Ukraine comprise nearly 6 GWe of this, but this is largely countered by the increase in generation from nuclear reactors in France.

Figure 3. Status of operable nuclear capacity

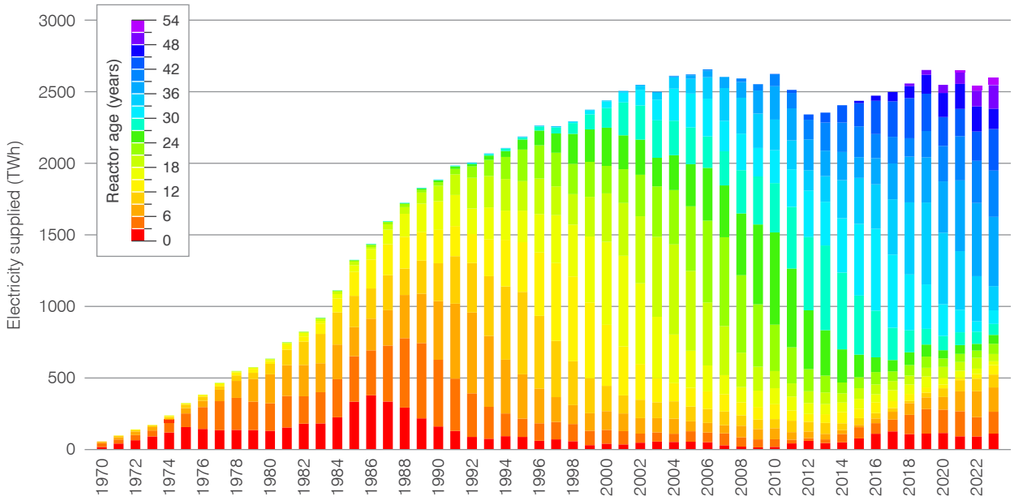


Source: World Nuclear Association, IAEA PRIS

Figure 4 shows total global electricity generation from nuclear power plants by age in each year since 1970, with generation from reactors of different ages shown in different colours.

During the 1970s and '80s the rapid expansion of nuclear generation globally was a consequence of many new reactors coming online, indicated by the growth of redder hues in the chart. As those reactors enter their second and third decades of operation, and the pace of new reactor start-ups declines in the 1990s, the proportion of red in each year's bar reduces, reaching a minimum around 2013. Over the last decade, with increases in the number of reactors being commissioned, the amount of electricity generated by younger reactors has started to increase again, shown by the increasing amount of red in the bars over the last decade.

Figure 4. Total global nuclear electricity generation by age of reactor

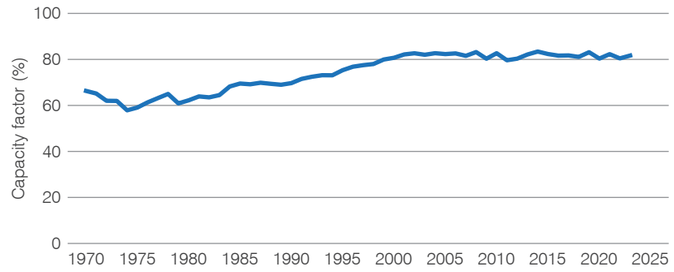


Source: World Nuclear Association, IAEA PRIS

1.2 Operational performance

In 2023 the global average capacity factor was 81.5%, up from 80.4% in 2022, continuing the trend of high global capacity factors seen since 2000. Capacity factors in this section are based on the performance of those reactors that report electricity generation in any one calendar year.

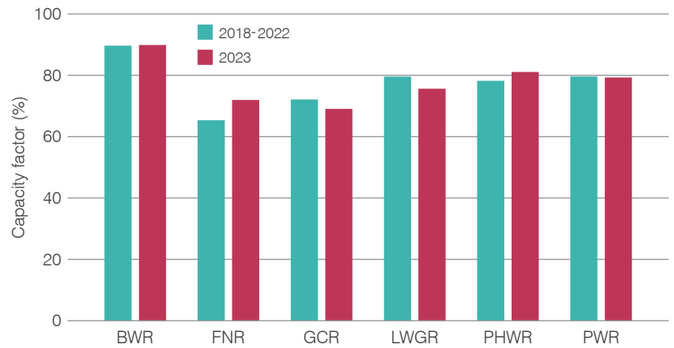
Figure 5. Global average capacity factor



Source: World Nuclear Association, IAEA PRIS

In 2023, capacity factors for different reactor types were broadly consistent with those achieved in the previous five years. On average, boiling water reactors (BWRs) achieve the highest capacity factors.

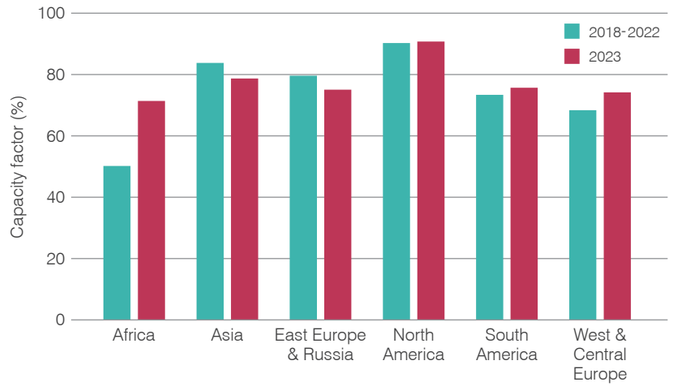
Figure 6. Capacity factor by reactor type



Source: World Nuclear Association, IAEA PRIS

Capacity factors in 2023 for reactors in most geographical regions were also broadly consistent with the average achieved in the previous five years, with North America maintaining the highest average capacity factors. In Africa, the sole nuclear power plant operating there, South Africa's Koeberg, underwent extensive outages in 2022 and 2023 for steam generator replacements.

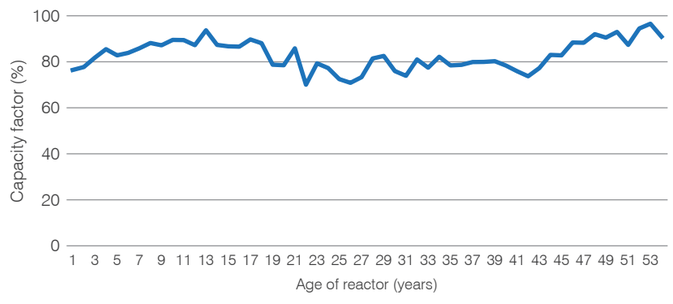
Figure 7. Capacity factor by region



Source: World Nuclear Association, IAEA PRIS

There is no overall age-related decline in nuclear reactor performance, although there is some variation, with lower average capacity factors for those reactors between 25 and 35 years of operation and higher than average capacity factors for those reactors exceeding 45 years of operation.

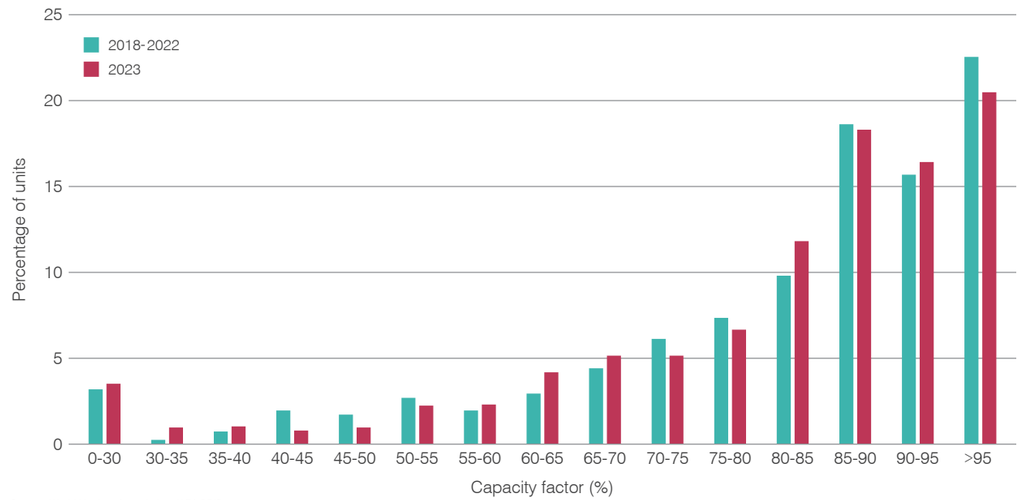
Figure 8. Mean capacity factor 2019-2023 by age of reactor



Source: World Nuclear Association, IAEA PRIS

The spread of capacity factors in 2023 is broadly similar to the average of the previous five years. Two-thirds of reactors have a capacity factor over 80%.

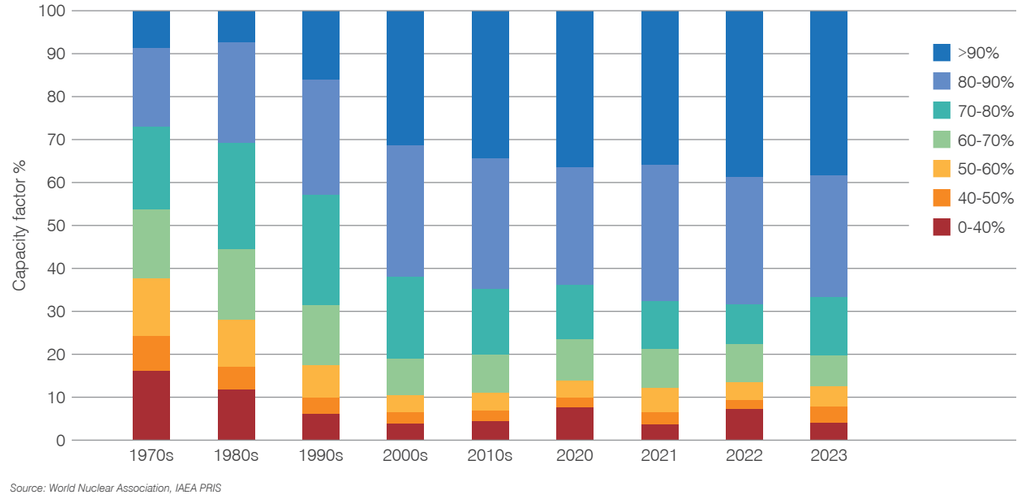
Figure 9. Percentage of units by capacity factor



Source: World Nuclear Association, IAEA PRIS

There has been a steady improvement in average capacity factors in each decade since the 1970s. The high capacity factors achieved in the 2010s have continued from 2020 onwards.

Figure 10. Long-term trends in capacity factor



Source: World Nuclear Association, IAEA PRIS

1.3 New construction

In 2023 construction began on six large pressurized water reactors (PWRs), five in China and one at the El Dabaa site in Egypt.

Table 2. Reactor construction starts in 2023

	Location	Model	Process	Design net capacity (MWe)	Construction start date
Sanmen 4	China	CAP1000	PWR	1163	22 March 2023
Haiyang 4	China	CAP1000	PWR	1161	22 April 2023
El Dabaa 3	Egypt	VVER-1200	PWR	1100	3 May 2023
Lufeng 6	China	Hualong One	PWR	1116	26 August 2023
Lianjiang 1	China	CAP1000	PWR	1224	27 September 2023
Xudabao 1	China	CAP1000	PWR	1000	3 November 2023

Source: World Nuclear Association, IAEA PRIS

With six construction starts in 2023, and five reactor connections to the grid, the total number of units under construction at the end of 2023 was 61, one more than at the end of 2022.

Table 3. Units under construction year-end 2023

	BWR	FBR	PHWR	PWR	Total
Argentina				1	1
Bangladesh				2	2
Belarus				0 (-1)	
Brazil				1	1
China		2		24 (+4)	26 (+4)
Egypt				3 (+1)	3 (+1)
France				1	1
India		1	3	4	8
Iran				1	1
Japan	2				2
Russia		1		2	3
Slovakia				1 (-1)	1 (-1)
South Korea				2 (-1)	2 (-1)
Turkey				4	4
Ukraine				2	2
United Arab Emirates				1	1
United Kingdom				2	2
United States of America				1 (-1)	1 (-1)
Total	2	4	3	52 (+1)	61 (+1)

Source: World Nuclear Association, IAEA PRIS

Five reactors were connected to the grid for the first time in 2023. This included Mochovce 3 in Slovakia, where construction had started in 1987, before being halted in 1990, and resuming in 2015.

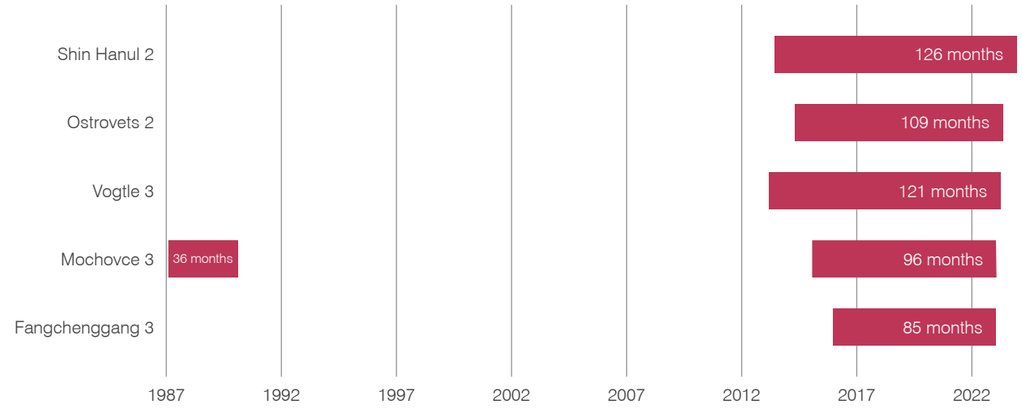
Table 4. Reactor grid connections in 2023

	Location	Reference unit power (MWe)	Model	Reactor type	Construction start	First grid connection
Fangchenggang 3	China	1105	Hualong One	PWR	24 December 2015	10 January 2023
Mochovce 3	Slovakia	440	VVER-440/V-213	PWR	27 January 1987	31 January 2023
Vogtle 3	USA	1117	AP1000	PWR	2 March 2013	31 March 2023
Ostrovets 2	Belarus	1110	VVER V-1200/V-491	PWR	27 April 2014	13 May 2023
Shin-Hanul 2	South Korea	1340	APR-1400	PWR	19 June 2013	21 December 2023

Source: World Nuclear Association, IAEA PRIS

The average construction times for those five reactors is considerably higher than in recent years, with a median time of 121 months, compared to 88 months in 2021 and 89 months in 2022, and a mean construction time of 115 months. Construction times for Shin Hanul 2 and Ostrovets 2 both took longer than the first units at each site.

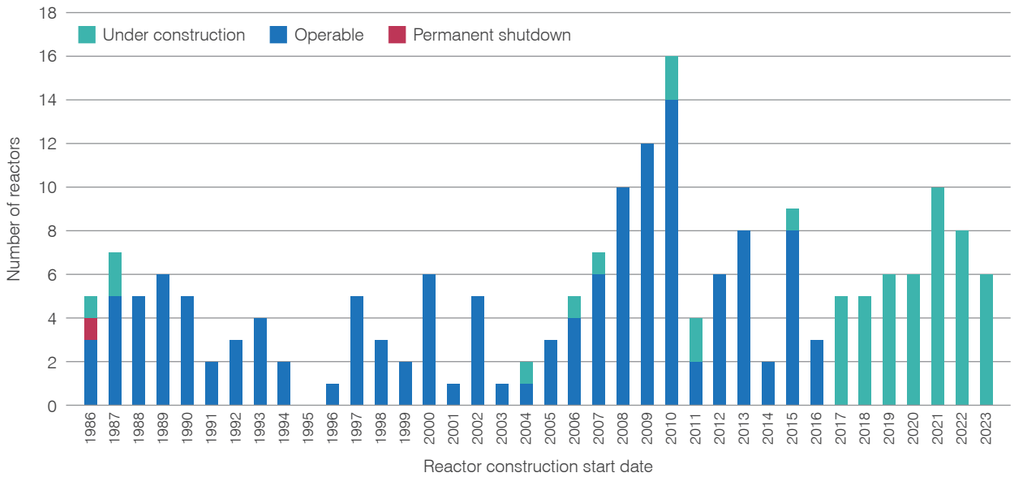
Figure 11. Construction times of units grid-connected in 2023



Source: World Nuclear Association, IAEA PRIS

Most reactors under construction today started construction in the last seven years. The small number that have taken longer are either pilot plants, first-of-a-kind (FOAK) reactors, or projects where construction was suspended before being restarted. Construction on Khmelnitski 3&4, in Ukraine, started in 1986 and 1987, respectively, before being halted in 1990. In 2021 Energoatom signed an agreement with Westinghouse that might see completion of unit 4. In Slovakia, construction started in 1987 on Mochovce 3&4. Construction was halted in 1990, before recommencing in 2015. Mochovce 3 was connected to the grid in in January 2023, and work is continuing to bring unit 4 into service.

Figure 12. Operational status of reactors with construction starts since 1986



Source: World Nuclear Association, IAEA PRIS

1.4 Reactor shutdowns

Five reactors were permanently shut down in 2023. These include the final three reactors operating in Germany, Kuosheng 2 in Taiwan, China, and Tihange 2 in Belgium, which were all shut down as part of phaseout policies.

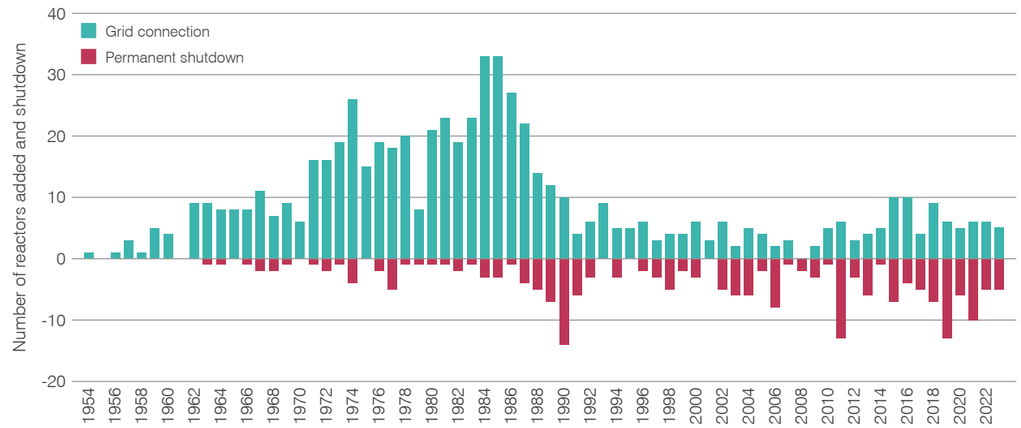
Table 5. Shutdown reactors in 2023

	Location	Model	Process	Capacity (MWe)	Grid connection	Permanent shutdown
Tihange 2	Belgium	WH 3-loop	PWR	1008	13 October 1982	1 February 2023
Kuosheng 2	Taiwan, China	BWR-6	BWR	985	29 June 1982	14 March 2023
Emsland	Germany	Konvoi	PWR	1335	19 April 1988	15 April 2023
Isar 2	Germany	Konvoi	PWR	1410	22 January 1988	15 April 2023
Neckarwestheim 2	Germany	Konvoi	PWR	1310	3 January 1989	15 April 2023

Source: World Nuclear Association, IAEA PRIS

In 2023 as five reactors closed and five were grid connected, there was no net change in the number of operable reactors worldwide.

Figure 13. Reactor first grid connection and shutdown 1954-2023



Source: World Nuclear Association, IAEA PRIS

2 Case studies

Returning Palisades to service

The Palisades nuclear power plant in Covert Township, Michigan, USA, consists of a single 805 MWe pressurized water reactor that was acquired by Holtec from its then-owner and operator, Entergy, in June 2022. Just over a month before its acquisition, the plant was shut down, having generated more than 230 TWh over the course of its 50 years of service.

At that time, it was intended to dismantle, decontaminate and remediate the plant by 2041. However, following strong local, state and federal support, Holtec announced plans to apply for federal funding to enable it to reopen the plant. In March 2024 the US Department of Energy (DOE) Loan Programs Office conditionally committed up to $1.52 billion for a loan guarantee. Holtec has to satisfy certain technical, legal, environmental, and financial conditions before the DOE enters into definitive financing documents and funds the loan, which is anticipated to occur in the summer of 2024.

As part of the steps towards the restart of the plant, Holtec has increased staffing by over 225 professionals, including both new hires and returning former plant employees. Holtec is also reconstituting training facilities, including rebuilding the control room simulator, submitting regulatory documents, securing a power purchase agreement and is ordering new fuel and long-lead components.

Plant work is also underway, including the offsite refurbishment of the generator exciter and restoration of reactor vessel's operational integrity in preparation for a deep chemical cleaning of the plant's reactor cooling system. Upcoming actions include inspection of the reactor vessel internals and steam generators.

Holtec is currently targeting a late 2025 restart of the reactor, with generation until 2051 under consideration – which would require applying for a subsequent licence renewal.

Lifting the Exciter (Image: Holtec)

Interview with Patrick O'Brien

Director, Government Affairs and Communications

What benefits would the repowering of Palisades offer the local community?

There are many benefits of repowering the facility. When online the facility supports roughly 600 full-time, high-paying jobs during regular operation, with a large union workforce. Additionally, it brings an additional 1000+ specialty workers to southwest Michigan for regularly scheduled refuelling and maintenance outages every 18 months.

The facility is one of the region's largest taxpayers supporting local public schools and libraries, public safety, transport, veterans and senior services. A 2023 study by the Economic Growth Institute at the University of Michigan determined that the premature shutdown of Palisades resulted in an annual loss of $259 million in labour, income, and value added for the tri-county region alone. Bringing this economic benefit to the area is essential. For Michigan it provides carbon-free generation to achieve its climate goals, maintain reliability, and attract future employers, which will further increase the economic benefits for the region.

What are the main challenges in restarting Palisades and how are they being addressed?

The restart process has been quite complex. Initially the main challenge was gaining the support to resume operations, and for Palisades this was actually something the state of Michigan pushed hard for and allowed us the look at the concept of repowering, which has never occurred for a plant that had been shut down prior to being decommissioned. There have been instances of plants having multi-year shutdowns before a restart so, from a physical plant perspective, that challenge has been overcome at other sites in the USA.

Identifying the funding – a mix of federal, state, and Holtec – was vital, and was initially rejected when we failed to get the DOE's Civil Nuclear Credit funding, before turning to the DOE Loan Program Office.

Rehiring or hiring up to 400 people back to the site to assist the 220 that had remained for decommissioning continues to be a challenge in ensuring that we have the best staff to accomplish the goal.

Securing a power offtaker was the next challenge and working with our partners at Wolverine and Hoosier Power this was accomplished at a price that ensures our ability to repay the DOE loan.

Another ongoing challenge is developing the correct scope of work and ensuring the systems and material condition of the plant will be ready for the restart, and to allow for a long-continued operation of the facility.

Finally, we continue to work through the challenge of obtaining a licence from the Nuclear Regulatory Commission (NRC) to restart the facility. With the regulatory oversight and public input processes, we expect this to continue into 2025, but ultimately we expect to have a success path with the proper oversight and public input.

When do you plan for the reactor to re-enter service, and for how long could it operate?

Our target is to have the facility back online producing clean power by October 2025. The facility is currently licensed to 2031, with an option for an additional 20-year extension, which will be pursued after we recommence operation.

Holtec intends to build its first two small modular reactors (SMRs) at Palisades. What are the pros and cons of constructing those SMRs on a site with an active reactor, rather than one that is being decommissioned?

The benefits of building at an existing plant, either operating or undergoing decommissioning are the same. You have an educated local community on the benefits of nuclear power and a trained workforce to support the plant operations. Additionally, the sites have pre-existing security plans, known environmental impacts/studies, and energy infrastructure like interconnection to the grid.

We don't see many downsides and feel the long history of nuclear power at these sites is a major benefit to initial deployment. The biggest potential downside would be to let the infrastructure and highly skilled personnel go to waste by not continuing generation at these sites.

KHNP targets long-term operation

Inspections at Kori (Image: KHNP)

In South Korea, the initial operating permits of ten out of the 26 operable nuclear reactors are set to expire by 2029. Korea Hydro & Nuclear Power (KHNP), the owner and operator of those plants, is pursuing continued operation for these ten units. Their total capacity is 8323 MWe, accounting for 32% of South Korea's nuclear power generation capacity of 25,825 MWe .

South Korea conducts comprehensive safety evaluations for long-term operation, including life management assessment of major equipment, radiological environmental impact assessments, and periodic safety assessments, according to International Atomic Energy Agency (IAEA) standards.

The procedure for securing continued operation of a reactor involves KHNP submitting a periodic safety evaluation every 10 years. Separately, KHNP must submit an application to the Nuclear Safety and Security Commission (NSSC) for changes in the operating permit, including a radiological environmental impact assessment, reflecting public opinion. Upon review and approval, continued operation is permitted.

For Kori 2-4, the periodic safety evaluations and applications for operating permit changes have been submitted to the NSSC, and the review process is ongoing.

For Hanbit 1&2 and Hanul 1&2, the periodic safety evaluations have been submitted to the NSSC and are under review while public opinion comments are collected for the radiological environmental impact assessment.

For Wolsung 2-4, the periodic safety evaluations have been submitted to the NSSC and are undergoing compatibility review.

The Korean government has included the continued operation of these ten nuclear reactors in its 10th Basic Plan for Electricity Supply and Demand (2022), to ensure stable power supply and achieve the country’s nationally determined contribution (NDC) for 2030.

Interview with Jung Won-Soo

Vice President / Head of Plant Improvement Department

The push for continued operation of ten nuclear reactors seems challenging. What are the key strategies for successfully implementing the project?

The key strategy is prioritizing nuclear safety while aiming for timely restart of the ten refurbished units. We are maximizing the recruitment of experienced personnel for continued operation. We have established dedicated organizations for long-term operation and research, and are promoting close collaboration with domestic specialized companies, like KEPCO E&C.

By integrating domestic and international business experience and operational experience of the same reactor models, as well as utilizing the latest technical standards, we aim to establish an optimal continued operation project schedule that is compact and thorough.

KHNP has already carried out the long-term operation review process for two units. Have lessons learned led to improvements in the ongoing projects?

We have analyzed and incorporated lessons learned from the operational experience and know-how from the refurbishment projects of Kori 1 and Wolsung 1. Notably, by improving the methodology for evaluating operational environments of safety-related cables that have reached the end of their design lifetime, we have significantly reduced project costs and schedule, in addition to increasing reliability of the components compared to previous ‘test and replace’ methods.

Additionally, we developed an environmental fatigue monitoring system to predict and prevent environmental fatigue for key equipment of the reactor coolant system, enhancing the safety and integrity of critical facilities.

Furthermore, efforts are being made to maximize actual plant output and optimize capacity factors by identifying optimal areas for facility equipment and proactively replacing components.

What does KHNP aim to achieve through the ongoing long-term operation projects?

As the largest power company in Korea, holding over 30% of the nation's total power generation capacity, KHNP plays a crucial role in ensuring stable energy supply and achieving carbon neutrality. The current long-term operation projects are essential to the government's energy policy.

By smoothly implementing the long-term operation projects for ten nuclear reactors, including both pressurized water reactors (PWRs) and pressurized heavy water reactors (PHWRs), we aim to accumulate engineering experience and capabilities, enhancing our competitiveness and standing as a global energy leader.

Second phase of uprates at Dukovany

The Dukovany plant (Image: ČEZ, a. s.)

In early April 2024 the operator of the Czech nuclear power plants Dukovany and Temelín, ČEZ, achieved the increased power of 1475 MWt for the first time at unit 3 of the Dukovany nuclear plant. This corresponds to 511 MWe and represents a 2.3% power uprate achieved without increasing fuel consumption or associated emissions.

When they were commissioned between 1985 and 1987, the Dukovany VVER-440 reactors had an original gross capacity of 440 MWe. After a nine-year modernization programme, the power of each reactor was increased to almost 500 MWe in 2013. Similarly, both VVER-1000 units at the Temelín nuclear power plant were modernized in stages between 2005 and 2024, reaching gross capacities of 1086 MWe – an increase of over 10% on their original capacity of 981 MWe each.

The preparation for the latest power uprate at Dukovany started in 2020, as part of the 'design margins utilization' programme, which includes the transition from a 12-month to a 16-month fuel cycle. This programme involved only limited modernization of some systems and adjustment of some basic parameters. The steam pressure was increased to transfer the increased reactor power. Consequently, the reactor coolant outlet temperature increased from 298.4 °C to 300.4 °C.

The power uprate will also be implemented at units 1&2 in 2024, and unit 4 in early 2025 to fit in with outage schedules.

The capacity uprate at Dukovany is part of the B32T (*Bezpečně 32 terawatthodin*, '32 TWh safely') programme, which aims to achieve combined annual production from Dukovany and Temelín of 32 TWh by 2030, while planning to operate both plants for at least 60 years.

Interview with Bohdan Zronek

Director of the Nuclear Energy Division, ČEZ

The increase in thermal power by 2.3% might seem modest to some, so could you provide some context on the impact of this increase?

This is already the second phase of power uprating at Dukovany. The first phase took place from 2004 to 2013. ČEZ increased the reactor power by 5% and through the modernization of turbines, generators, unit transformers, along with several other minor steps to enhance operating efficiency, increased the power by an additional 8.5%. In total, during this first step the power of each unit was increased by 13.5% from the original 440 MWe to almost 500 MWe. The second phase of the power uprate utilized the design margins of the main equipment without the need for their replacement or modernization. The increase of reactor thermal power by another 2.3% on all four units will bring an annual production increase of approximately 300,000 MWh.

Do any of the changes, such as the higher water outlet temperature from the reactor, have any impact on the potential operating lifetime of the reactor?

The fundamental condition for all changes and modifications carried out at Dukovany and Temelín is to be aligned with ČEZ's priorities. This means they must not have any negative impact on the safe, reliable, and long-term operation of all units, which is currently planned to be at least 60 years. From this perspective, ČEZ thoroughly and extensively analyzed all significant changes and modifications, especially for power uprates and fuel cycle extensions. A modification gets the green light to proceed only when all these preconditions are met.

Is there potential for any of the changes implemented at Dukovany to be applied to other power plants operated by ČEZ or elsewhere?

Power uprates and fuel cycle extensions are standard modifications that have been carried out or are being planned at many nuclear power plants. At Temelín, the first phase of reactor power uprates was implemented in 2013 and 2014. Together with turbine island modifications, the output power of each reactor was increased from 981 MWe to 1086 MWe. Another uprate phase, based on equipment design margins similar to Dukovany, is planned around 2030 and will include the replacement of high-pressure turbine parts. Regarding the fuel cycle extension, Temelín has just got final regulatory approval and is currently in transition from a 12-month to an 18-month cycle. This transition should be completed at both units in 2026.

ČEZ has also introduced data-driven techniques to reduce electricity consumption at its Temelín plant. Could these adjustments be applied at Dukovany as well?

Specifically, this modification is maximizing grid delivery by optimization of turbine operation and power consumption of the tertiary circuit pumps (which pump cooling water from the turbine condensers to the cooling towers). These are the largest pumps, and largest power consumers, at the plant. The water flow and power consumption are controlled by adjusting the pump blades based on the processing (including AI integration) of numerous data such as cooling water temperature, air temperature and humidity, and weather prediction.

At Dukovany, the operation of these pumps has been optimized based on similar principles since 2012. Various operating modes of the pumps with different blade angles were tested when changing water and air temperatures. All of these operation modes were evaluated, and optimal operating modes were determined. Based on this obtained 'library' of operating modes, the pumps are operated according to water and air parameters.

3 Country pages

This chapter's Country Pages present summaries of recent developments and performance data for countries with reactors in operation, and updates on those new entrant countries with their first nuclear reactors under construction.

The information for the numbers of operable reactors and reactors under construction is correct as of 31 July 2024.

The lifetime CO_2 avoided data is calculated on the basis of the emissions of carbon dioxide that would have been released had the electricity supplied by nuclear generation in each country to 31 December 2023 been generated by coal-fired power plants instead. The values for emissions avoided annually since 2019 are derived from equivalent electricity generation from coal-fired or gas-fired plant.

The nuclear share of generation figures refer to the percentage of electricity generated from nuclear for 2023.

As in Chapter 1, capacity factors are calculated based only on those reactors that generated electricity in each calendar year. The electricity generation charts show total electricity generation for each year and subdivide this into electricity generation by reactors of different ages, based on the date of first grid connection.

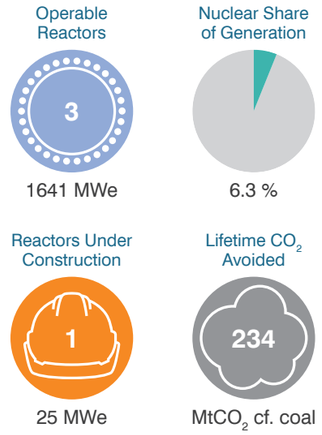
Argentina

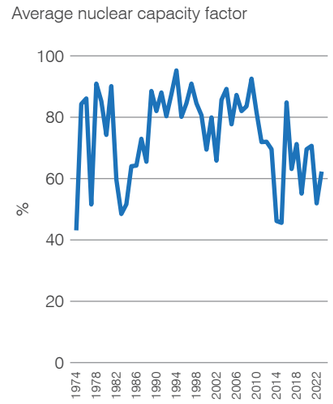
Argentina has two nuclear power plants: Atucha, about 100 km northwest of Buenos Aires; and Embalse, about 100 km south of Córdoba. The Atucha plant comprises two Siemens-designed pressurized heavy water reactors (PHWRs), unique to Argentina; and Embalse, a single Candu 6 PHWR unit from Atomic Energy of Canada Ltd (AECL).

A long-term operation project at Atucha 1, Latin America's first nuclear power reactor, is due to commence this year. The shutdown is expected to last two-to-three years and would allow the unit, which began operation in 1974, to operate for a further two decades. Nucleoeléctrica Argentina has said that 2000 jobs will be created during the extension project.

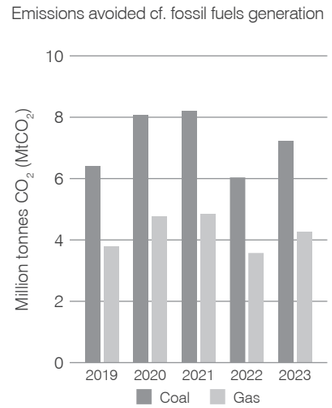
Atucha 2 returned to service in August 2023. The unit had been offline since October 2022, when a routine inspection revealed that one of the four internal supports of the reactor had become detached. August 2024 the unit received a renewed operating licence for a further 10 years of operation.

Construction of the CAREM25 prototype SMR – also at the Atucha site – began in early 2014 but has been suspended several times. The new president of the National Atomic Energy Commission (CNEA) ordered a 'critical design review' in May 2024 to identify aspects of the project that might require review or redesign.

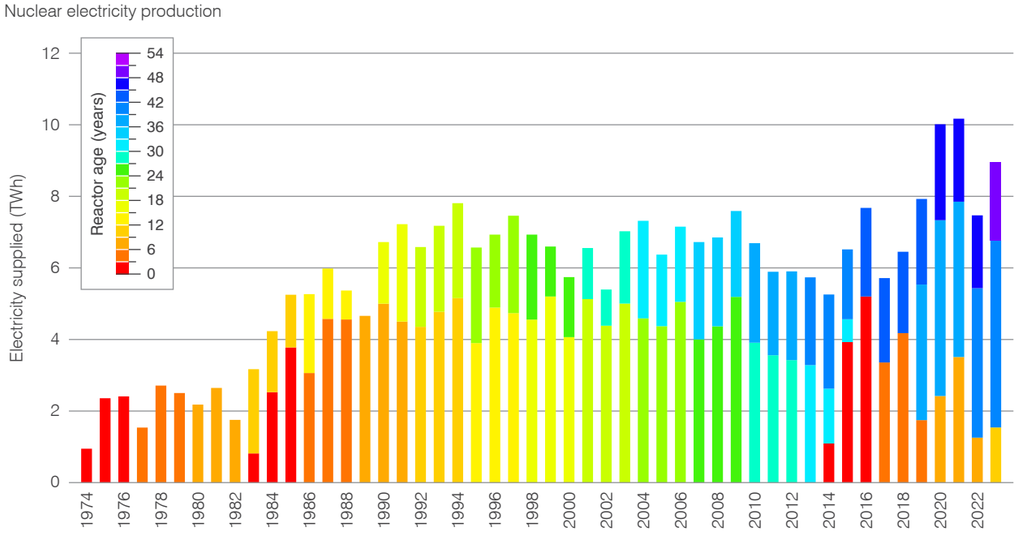




Source: World Nuclear Association, IAEA PRIS



Source: World Nuclear Association, IAEA PRIS

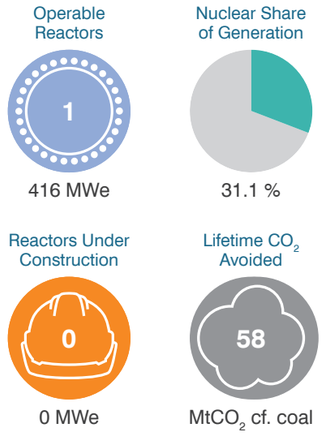


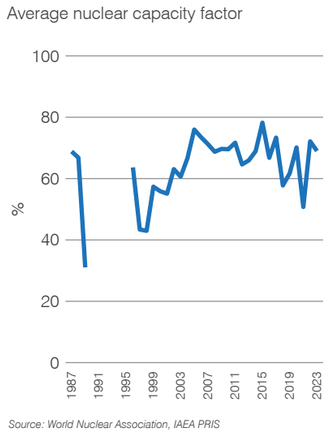
Source: World Nuclear Association, IAEA PRIS

Armenia

Armenia has one nuclear power plant at Metsamor, 30 km west of the capital Yerevan, consisting of two VVER-440 units. Unit 1 was connected to the grid in 1976, followed by unit 2 in 1980. Both units were taken offline in 1988 due to safety concerns following a major earthquake in the region earlier that year. Unit 2 was restarted in 1995 in the face of severe energy shortages.

In December 2023 Armenia and Russia signed a contract to modernize and extend the operating lifetime of the Metsamor plant. The work is expected to be completed in 2026 and would allow the plant to generate electricity until 2036. The Armenian government intends to build a new nuclear unit at Metsamor.





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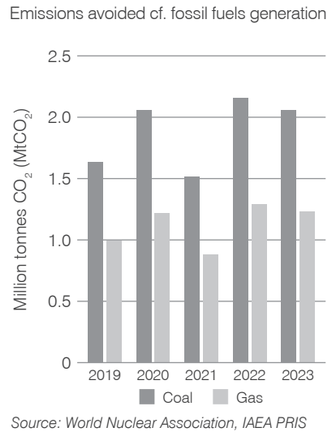
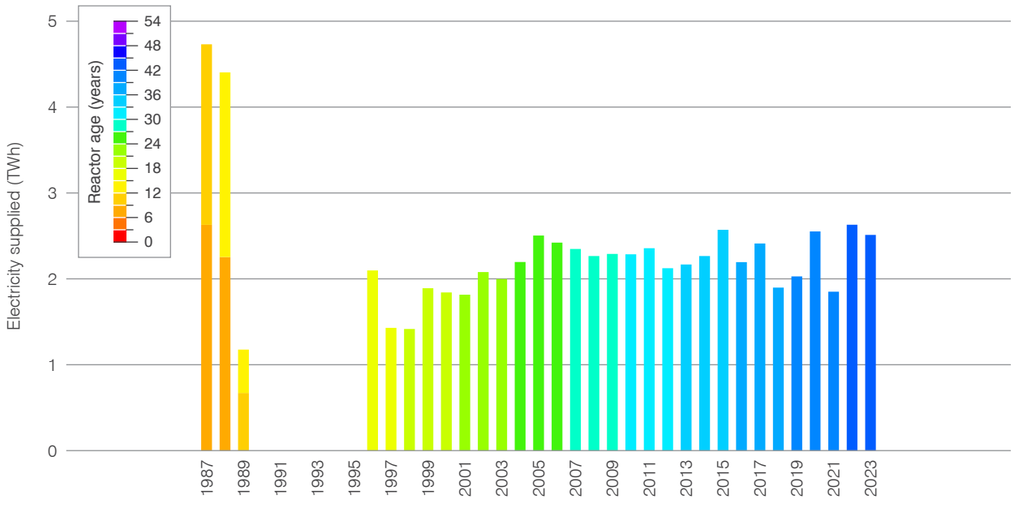


Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Bangladesh

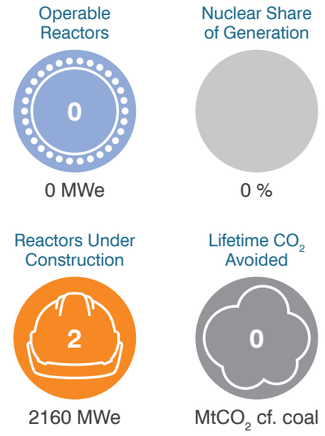
Two VVER-1200 units are under construction in Bangladesh at Rooppur, on the east bank of the Padma River, about 160 km northwest of Dhaka.

Construction of unit 1 began in November 2017, followed by unit 2 in July 2018. The reactors are designated as V-523, which are based on the V-392M reactors at Novovoronezh II in Russia. Once completed, the two-unit plant is expected to provide about 9% of the country's electricity.

In October 2023 Bangladesh received its first delivery of nuclear fuel, marking the point when the Rooppur site became a nuclear facility.

Construction at the site continues to progress, with concreting of the outer containment shells of the two units achieved in March 2023 and January 2024, respectively. Earlier, in October 2022 the government announced that the construction of Rooppur was running approximately one year behind schedule due to issues stemming from the COVID-19 pandemic and Russia's invasion of Ukraine. Unit 1 is now expected to start providing electricity to Bangladesh's national grid in 2025.

In April 2024 Bangladesh's prime minister Sheikh Hasina said the country intends to build two more units at the Rooppur site.



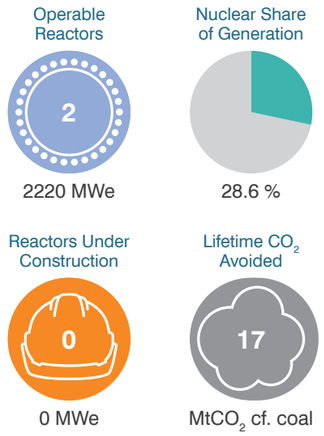
Belarus

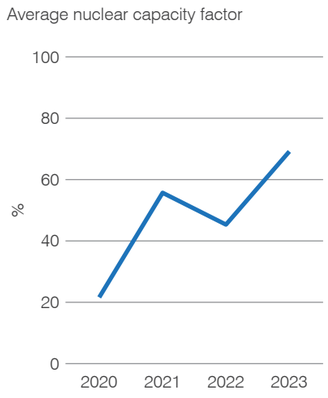
Belarus has two VVER-1200 reactors, located at Ostrovets, about 120 km northwest of Minsk. These reactors were the first VVER-1200s to be built outside of Russia. Unit 1 was connected to the grid in November 2020 and unit 2 in May 2023.

Unit 2 began commercial operation in November 2023. The plant will now provide about 40% of the country's electricity needs.

In December 2023 the energy minister Viktor Karankevich said that the country was considering building either a second nuclear power plant or a third unit at Ostrovets.

In October Russia's TVEL and the Belarusian Organisation for Radioactive Waste Management entered into an agreement to develop infrastructure for radioactive waste in Belarus, and to train personnel for the operation of a near-surface waste disposal facility.





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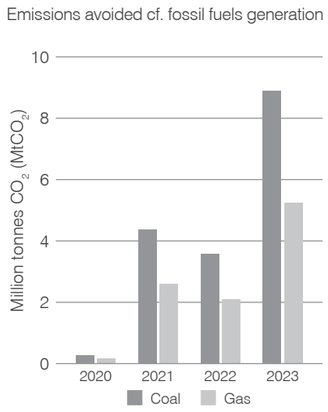
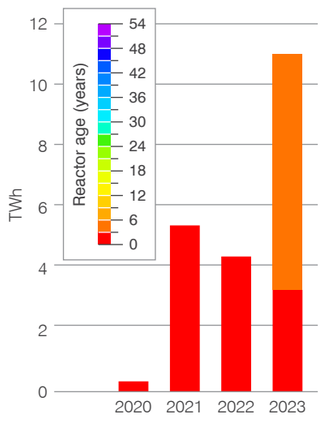


Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



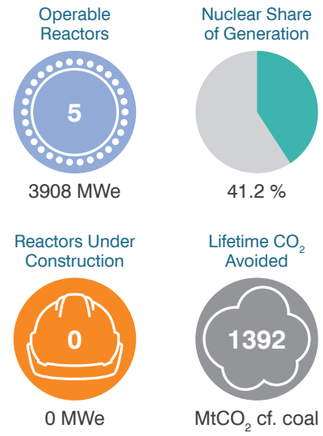
Source: World Nuclear Association, IAEA PRIS

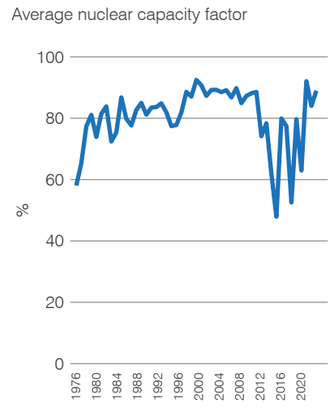
Belgium

Belgium has two nuclear power plants: Doel, a four-unit plant located 15 km northwest of Antwerp; and Tihange, a three-unit plant located about 25 km west-southwest of Liège.

A decision was made in March 2022 to extend the operation of Doel 4 and Tihange 3 to 2035. The final agreement between the Belgian government and French utility Engie was signed in December 2023.

In February 2023 the government asked Engie to investigate whether Doel 1&2 and Tihange 1 could operate beyond their current 2025 shutdown date, due to concerns about electricity supply in 2025 and 2026. Belgium's regulator has since ruled out an extension to the operating lifetimes of these three units.





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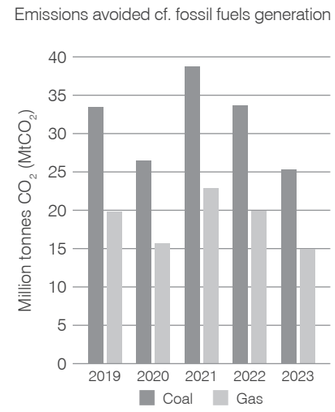
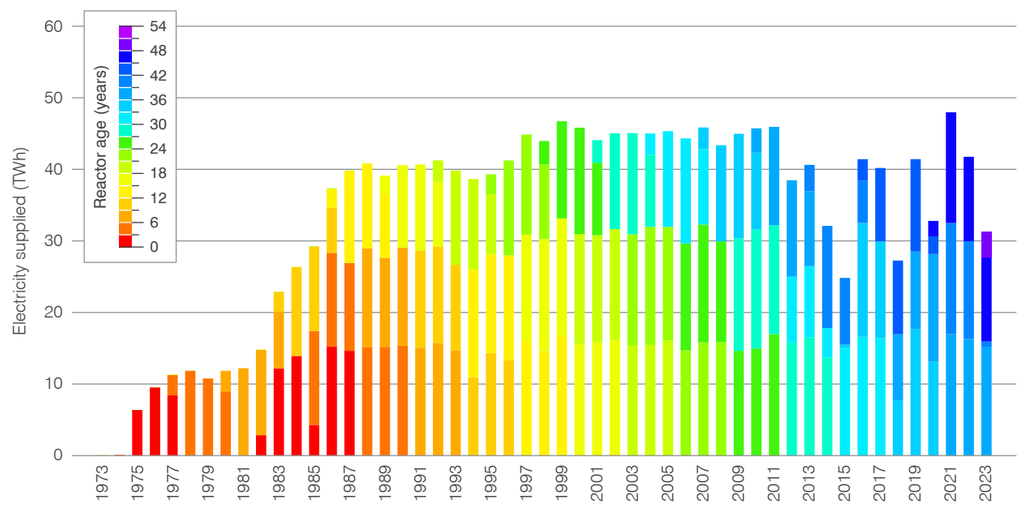


Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Brazil

Brazil has two operating reactors with a combined capacity of 1884 MWe at Angra, 200 km west of Rio de Janeiro. A third unit is being constructed at the same site.

Eletronuclear is seeking a lifetime extension from 40 to 60 years for Angra 1.

Construction of the much-delayed Angra 3 unit was once again stopped in April 2023 following orders from the municipal government of Angra dos Reis and a related embargo imposed by the Rio de Janeiro Court of Justice. In June 2024 the Rio de Janeiro Court of Justice removed the embargo. On the same day Eletronuclear unilaterally terminated its construction contract with the Ferreira Guedes, Matricial and ADtranz consortium that was signed in February 2022 for restarting Angra 3 civil works.

Earlier, in April 2024 the project's costs came under scrutiny following an analysis from the Federal Audit Court, which concluded: "The charges to consumers will be much higher if the construction of Angra 3 continues than if the project is abandoned." Eletronuclear responded by saying that the price of electricity from Angra 3 would be competitive for a clean and reliable energy source.

Operable Reactors

1884 MWe

Nuclear Share of Generation

2.2 %

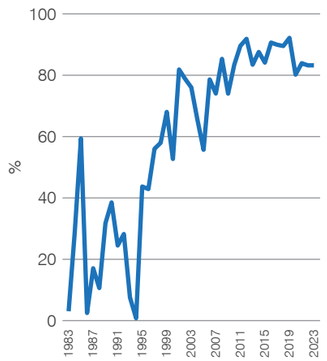
Reactors Under Construction

1340 MWe

Lifetime CO_2 Avoided

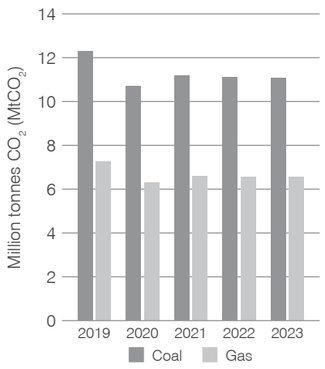
$MtCO_2$ cf. coal

Average nuclear capacity factor



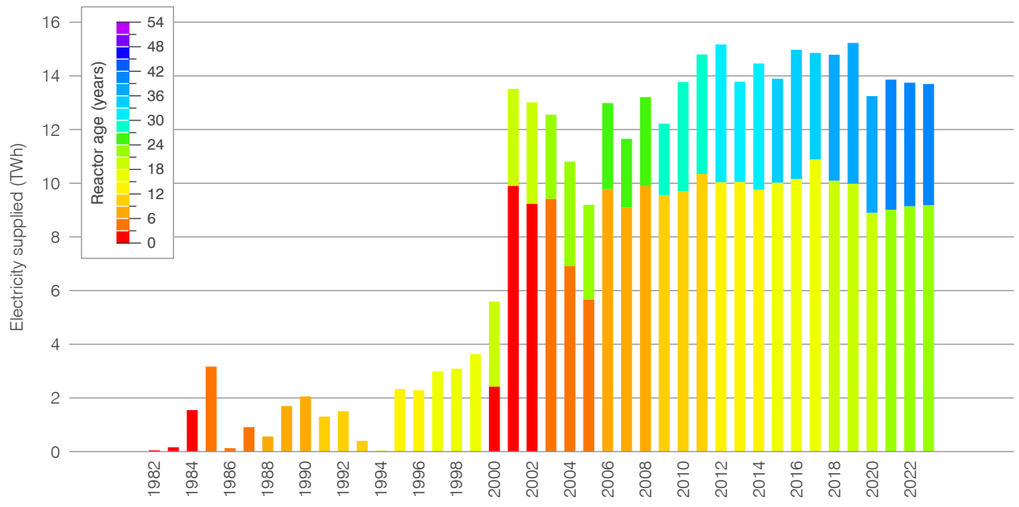
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Bulgaria

Bulgaria has one nuclear power plant, Kozloduy, located on the river Danube about 110 km north of Sofia. It has two operating VVER-1000 reactors, with a combined capacity of 2006 MWe. Four VVER-440 units were shut down in the 2000s as a condition of the country joining the European Union.

In January 2023 the energy minister set out an energy strategy that includes plans for two new reactors at Kozloduy and two at Belene. The strategy outlines the continued use of coal until 2030 before reducing its use to zero by 2038.

The same month, the National Assembly voted by 112 to 45, with 39 abstentions, in favour of a draft decision asking ministers to negotiate with the US government for a new AP1000 unit at Kozloduy.

In October 2023 the Council of Ministers in Bulgaria gave the go-ahead for construction of two AP1000 units at Kozloduy. In January 2024 companies interested in being involved in the plant construction were invited to express their interest. In February it was announced that five companies had done so.

In December 2022 Bulgaria signed a 10-year deal with Westinghouse to supply fuel for Kozloduy 5. The first batch of Westinghouse VVER fuel was loaded into the reactor in May 2024, and the unit restarted from its annual scheduled shutdown in June.

Operable Reactors

2006 MWe

Nuclear Share of Generation

40.4 %

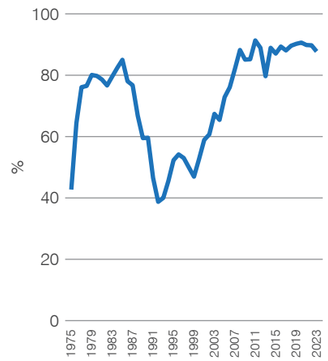
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

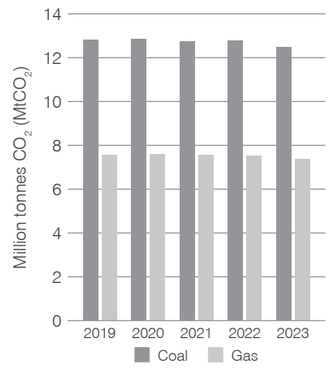
$MtCO_2$ cf. coal

Average nuclear capacity factor



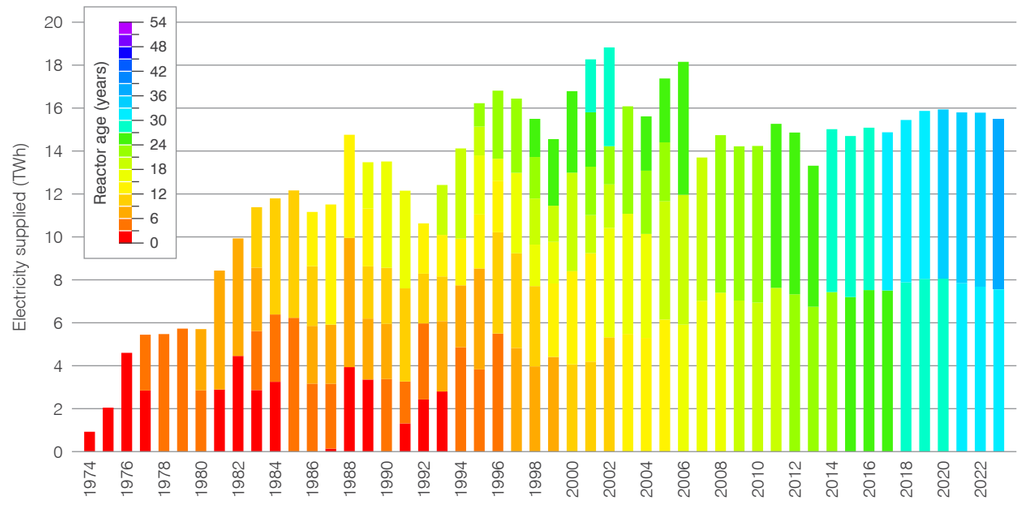
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Canada

Nineteen reactors operate at four plants in Canada, 18 of which are in Ontario at Bruce, Darlington and Pickering, and one in New Brunswick.

Refurbishment programmes are underway at Bruce and Darlington. Six of the eight units at Bruce are being refurbished, with the first, unit 6, returned to service in 2023. At Darlington units 2&3 have been returned to service, with units 1&4 due to restart in 2025 and 2026, respectively.

The Ontario government is supporting OPG's plans to refurbish units 5-8 at the Pickering plant, with the schedule anticipating completion of the programme by the mid-2030s.

In July 2023 the Ontario government announced it was working with OPG to begin planning and licensing three additional GE Hitachi BWRX-300 small modular reactors (SMRs) at Darlington, building on a contract signed earlier in the year for the first unit. Also in July, the province's government announced it is starting pre-development work to build up to 4800 MWe of new nuclear capacity at Bruce.

In New Brunswick, NB Power, in partnership with ARC Clean Technology Canada, has submitted an application for a site preparation licence for an SMR.

SaskPower in June 2024 said it has identified two potential sites for deployment of a BWRX-300 unit, both in the Estevan area of the uranium mining province of Saskatchewan. Separately SaskPower, Westinghouse and Cameco signed an agreement in June 2024 to evaluate deploying Westinghouse reactor technology.

Operable Reactors

13,699 MWe

Nuclear Share of Generation

13.7%

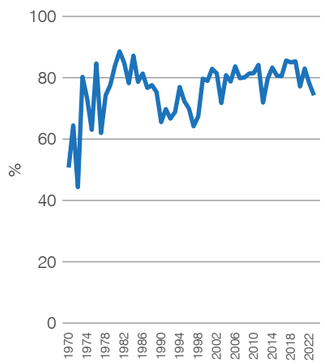
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

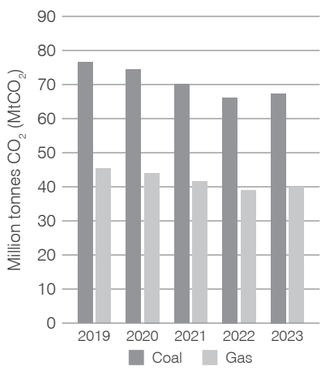
$MtCO_2$ cf. coal

Average nuclear capacity factor



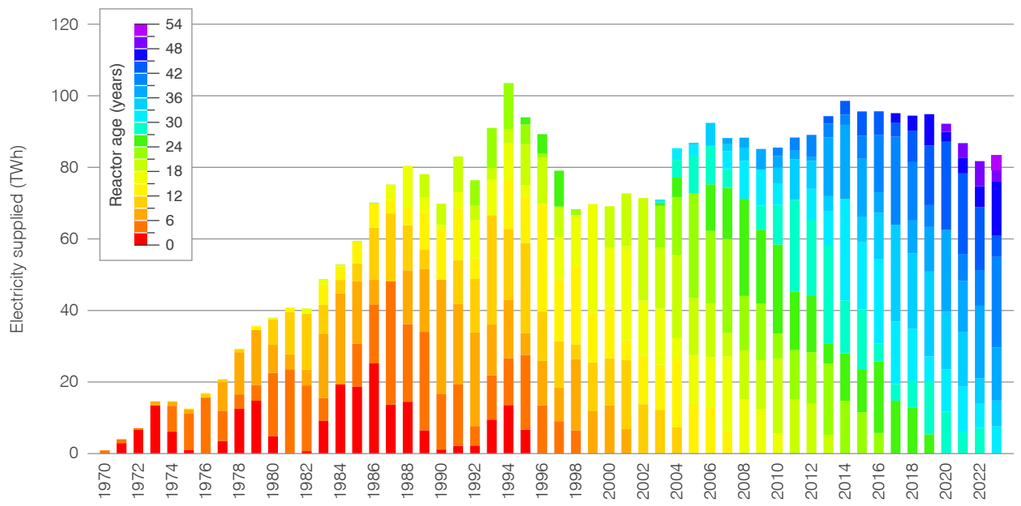
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

China, mainland

Mainland China has 56 operable reactors with a total capacity of 54 GWe, primarily at sites along its southeast coastline. It also had 30 reactors under construction as of 31 July 2024, totalling 32 GWe.

In April 2024 a CGN Hualong One reactor in China, unit 4 at Fangchenggang, was connected to the grid.

Five reactors commenced construction during 2023 (Haiyang 4, Lianjiang 1, Lufeng 6, Sanmen 4, Xudabao 1). Six units were approved by China's state council in August 2023 for construction: Xudabao 1&2 in Liaoning, Ningde 5&6 in Fujian, and Shidaowan 1&2 in Shandong. The State Council approved a further four reactors in January 2024: Taipingling 3&4 in Guangdong and Jinqimen 1&2 in Zhejiang.

In November 2023 the country's first project to bring nuclear-generated heat to prefecture-level cities began operation in Shandong. Heat is supplied from the Haiyang nuclear power plant to the cities of Haiyang and Rushan through a 23 km pipeline. In June 2024 China's first industrial-use nuclear energy steam supply project entered operation. The project, using steam from the Tianwan nuclear power plant, supplies steam to a nearby petrochemical plant.

Nuclear heat is also being supplied to residents of Shandong province from the demonstration High Temperature Gas-Cooled Reactor Pebble-bed Module (HTR-PM), which entered commercial operation in December 2023.

Operable Reactors

54,362 MWe

Nuclear Share of Generation

4.9 %

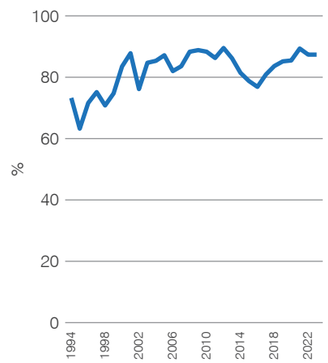
Reactors Under Construction

32,523 MWe

Lifetime CO_2 Avoided

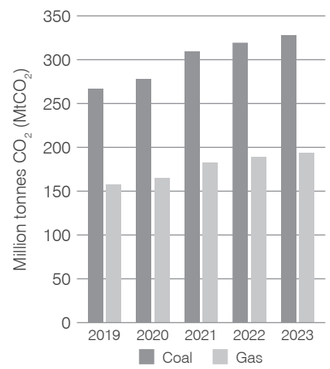
$MtCO_2$ cf. coal

Average nuclear capacity factor



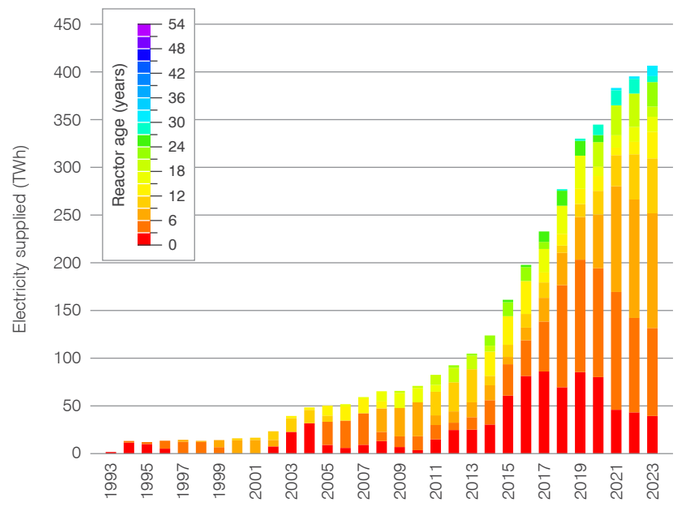
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



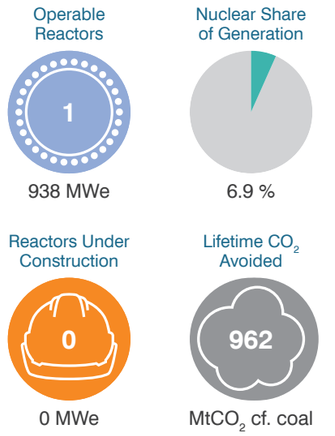
Source: World Nuclear Association, IAEA PRIS

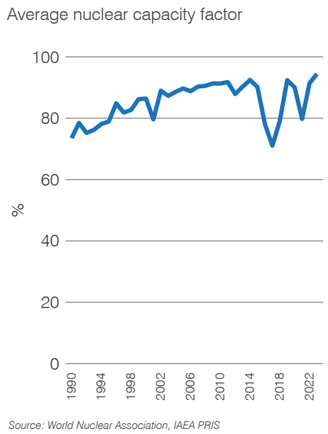
Taiwan, China

Taiwan has one remaining operable reactor with a capacity of 938 MWe located at Maanshan, on the southern coast of the island. The unit is expected to shut down when its operating licence expires on 17 May 2025. Maanshan 1 was shut down in July.

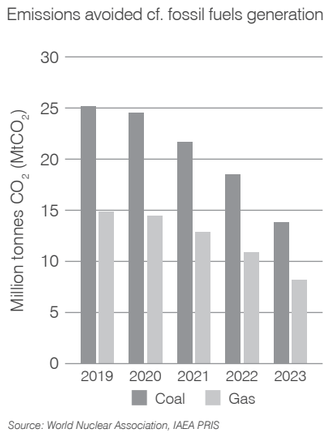
Taiwan's Democratic Progressive Party (DPP) was elected to government in January 2016 with a policy of creating a "nuclear-free homeland" by 2025. Under this policy, the island's six power reactors that were then operable would be decommissioned as their 40-year operating licences expire. Shortly after taking office, the government passed an amendment to the Electricity Act, bringing its phase-out policy into law.

A referendum held in November 2018 called for the government to cancel the amendment, but the policy has remained in effect.

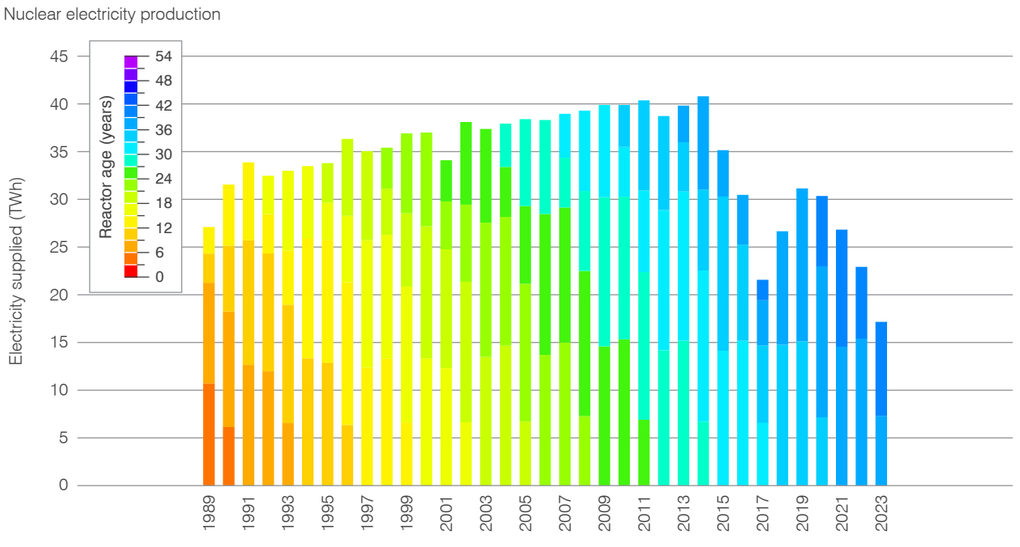




Source: World Nuclear Association, IAEA PRIS



Source: World Nuclear Association, IAEA PRIS



Source: World Nuclear Association, IAEA PRIS

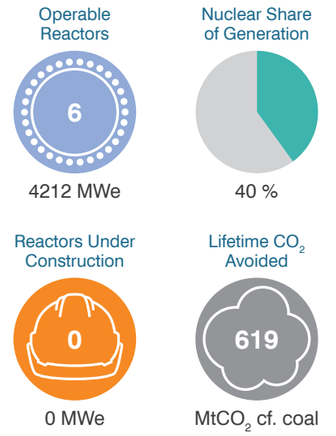
Czechia

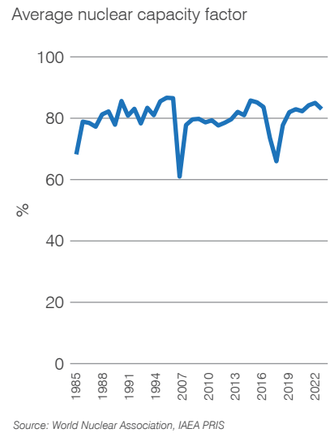
Czechia has six operable reactors: two VVER-1000 units at Temelin, 100 km south of Prague; and four VVER-440 units at Dukovany, 30 km west of Brno.

The government's long-term energy strategy of 2015 forecasts the need to increase the share of nuclear power in the country's electricity mix to 50-55% by 2050. In September 2023 the Czech prime minister said the country would need at least four nuclear power reactors to achieve this aim.

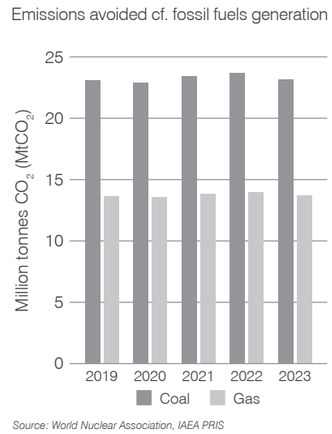
In October 2022 three vendors – EDF, Westinghouse and Korea Hydro and Nuclear Power (KHNP) – submitted initial bids to national utility ČEZ for a binding offer to build a new reactor at Dukovany plus a non-binding offer for three more. In February 2024 the tender was changed to binding offers for up to four reactors – units 5&6 at Dukovany and units 3&4 at Temelin – and EDF and KHNP were invited to submit bids. In April 2024 KHNP and EDF submitted their updated bids.

In April 2024 ČEZ highlighted the benefits of its fleet modernization programme, stating these changes had added extra capacity equivalent to that of a large coal-fired power plant. Changes at Dukovany include extending the duration of fuel cycles. At Temelin, fuel is now cycled every 18 months, rather than every 12, and parameters like air temperature, humidity and cooling water temperature are analyzed to optimize plant performance. ČEZ said that Temelin's electricity consumption was reduced by 5400 MWh in 2023 as a result.

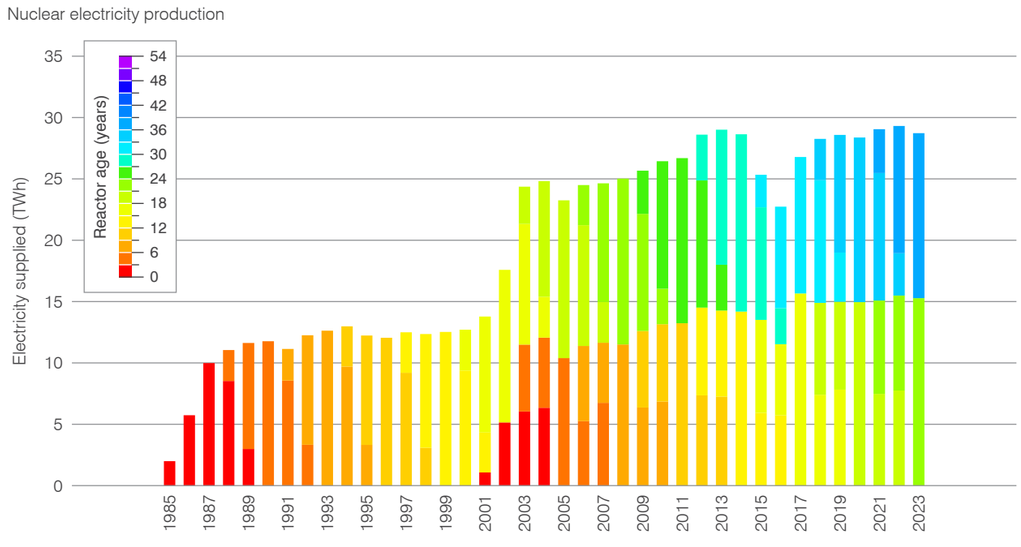




Source: World Nuclear Association, IAEA PRIS



Source: World Nuclear Association, IAEA PRIS



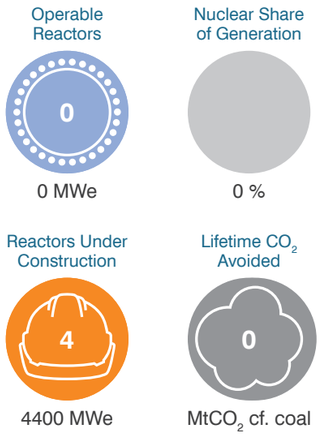
Source: World Nuclear Association, IAEA PRIS

Egypt

Four VVER-1200 units are under construction in Egypt at El Dabaa, on the north Mediterranean coast, 140 km west of Alexandria.

In November 2015 an intergovernmental agreement was signed with Russia to build and operate the four reactors, including fuel supply, used fuel management, training and development of regulatory infrastructure. In April 2019 the Nuclear Power Plants Authority (NPPA) received a site approval permit for the El Dabaa site from the Egyptian Nuclear Regulation and Radiological Authority (ENRRA).

Construction of El Dabaa 1 commenced in July 2022, followed by unit 2 in November 2022, unit 3 in May 2023, and unit 4 in January 2024.

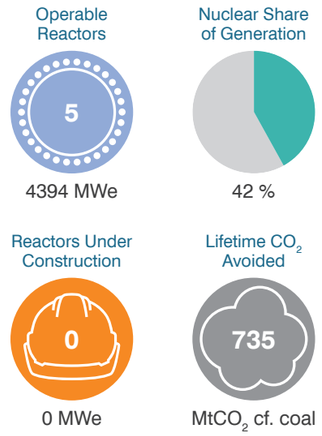


Finland

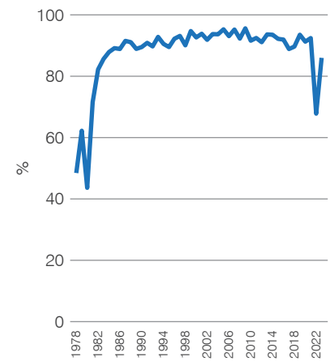
Finland has two nuclear power plants: Loviisa, a two-unit VVER-440 plant, located 80 km east of Helsinki; and Olkiluoto, about 220 km northwest of the capital, with twin BWR units and an EPR.

In February 2023 the Finnish government approved Fortum's operating lifetime extension request for an additional 20-year term, which would extend the operation of Loviisa 1&2 until the end of 2050. The units started up in 1977 and 1980, respectively. In May 2024 Fortum awarded a contract to Doosan Škoda Power to modernize the low-pressure turbines at Loviisa as part of its modernization programme.

Teollisuuden Voima Oyj (TVO) is making preparations to extend the operational lifetimes and uprate units 1&2 at its Olkiluoto plant. In January 2024 it submitted an environmental impact assessment to the Ministry of Economic Affairs and Employment.

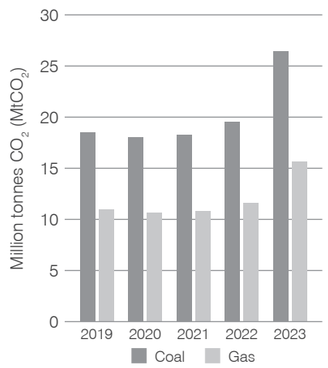


Average nuclear capacity factor



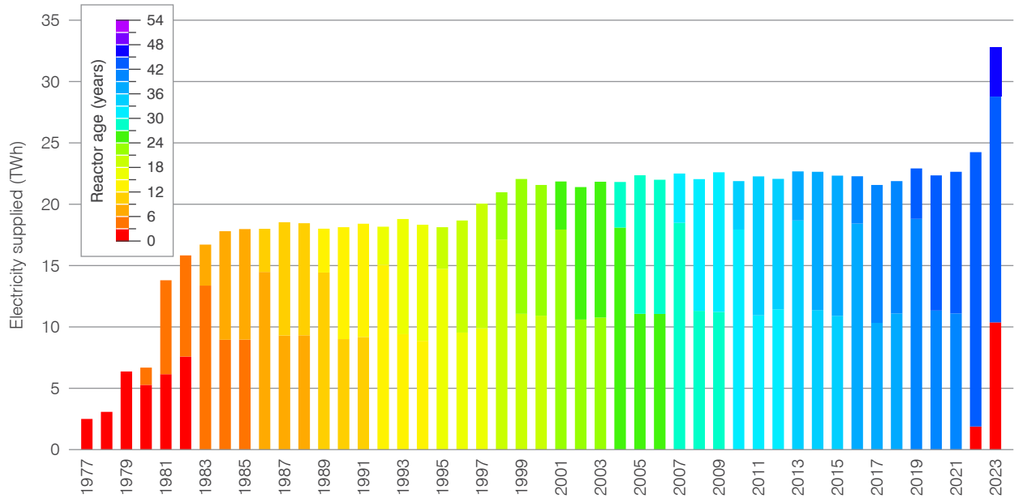
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

France

France has 56 operable reactors with a total capacity of 61.4 GWe at a variety of coastal and inland sites. An EPR is under construction at the Flamanville plant in Normandy on the northwest coast.

In March 2023 France's parliament formally approved the government's nuclear investment plan to construct six EPR2 units at three sites at an estimated cost of €52 billion. In June 2023 EDF announced that it was seeking the necessary authorizations to construct two EPR2 reactors at the Penly nuclear plant in Normandy. In July it was announced that the Bugey plant in eastern France would host the third pair of EPR2 units, with the second pair to be constructed at Gravelines on the north coast.

France's nuclear regulator authorized commissioning of Flamanville 3 in May 2024. Fuel loading was completed in May 2024 and the unit is targeting startup in summer 2024.

In August 2023 Tricastin 1 was approved to operate for a further ten years. It is the first French power reactor licensed to operate beyond 40 years.

EDF has set a production target for its fleet of 315-345 TWh for 2024. The company said in April 2024 that problems linked to stress corrosion, first discovered at Civaux 1 in December 2021, will continue to weigh on output until the end of 2025.

Operable Reactors

61,370 MWe

Nuclear Share of Generation

64.8 %

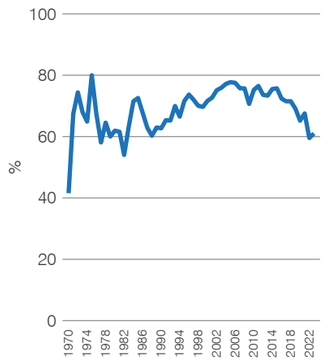
Reactors Under Construction

1630 MWe

Lifetime CO_2 Avoided

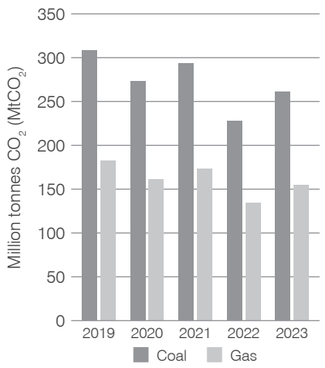
$MtCO_2$ cf. coal

Average nuclear capacity factor



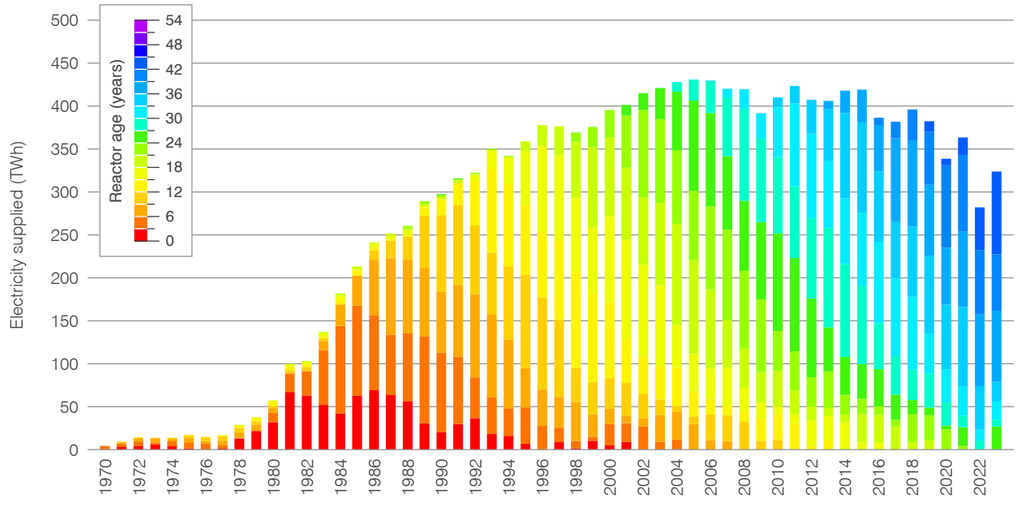
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Germany

Germany closed its last three reactors – Neckarwestheim 2, Isar 2 and Emsland – in April 2023, a result of a political phase-out decision. In the last full calendar year of generation (2022) nuclear plants achieved a capacity factor of 90%.

Over the course of 62 years, nuclear plants in Germany supplied more than 5200 TWh of electricity, avoiding the emission of more than 4200 million tonnes of carbon dioxide, compared to coal-fired generation.

Germany still uses coal-fired power plants to meet around a quarter of its electricity needs. It has a phase-out date for coal-fired electricity generation of 2038, later than many of its European counterparts.

Operable Reactors

0 MWe

Nuclear Share of Generation

1.4 %

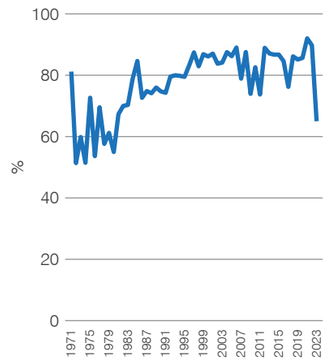
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

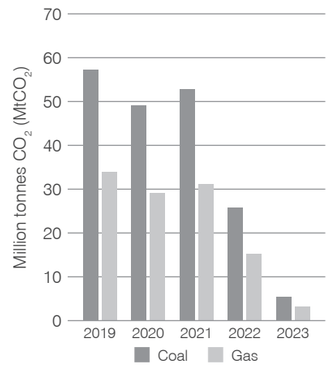
$MtCO_2$ cf. coal

Average nuclear capacity factor



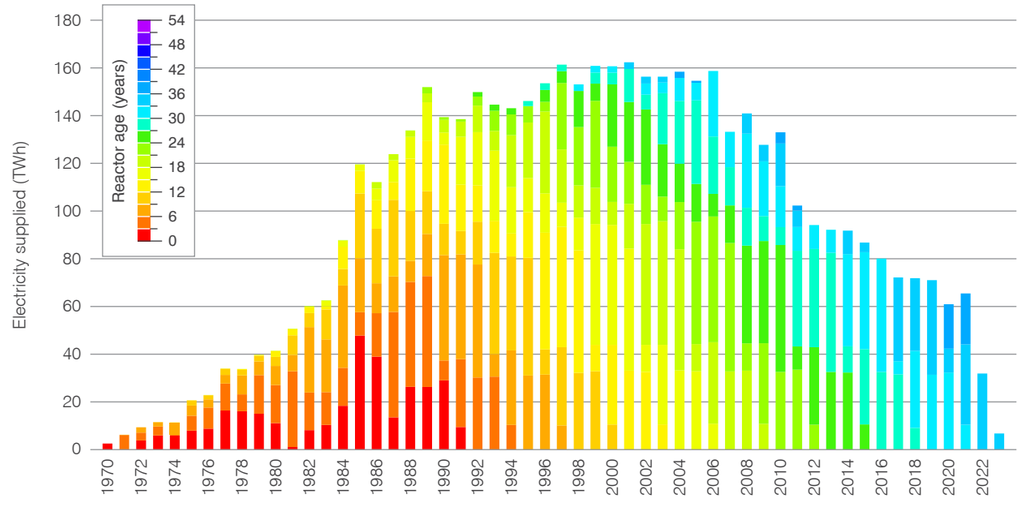
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Hungary

Four VVER-440 reactors operate at the Paks nuclear power plant, 100 km south of Budapest, with a combined capacity of 1916 MWe. The plant generates around half of the electricity produced in Hungary, but supplies around one-third of electricity demand as the country relies heavily on imported electricity.

The four units at Paks started up between 1982 and 1987. Their design lifetime was for 30 years but that was extended in 2005 by 20 years, to between 2032 and 2037. In December 2023 the operator of the plant notified the European Union of the country's intention to further extend the operating lifetime of the four units to 70 years. This follows the overwhelming support for the plan shown by the Hungarian parliament in December 2022.

In August 2022 the Hungarian Atomic Energy Authority (HAEA) issued a construction licence for two VVER-1200 units at Paks II, to be built by Rosatom. In April 2023 the government announced its intention to continue with the project, despite the conflict in Ukraine and the European Union's sanctions against Russia. In May 2023 the European Union approved an amended contract with Rosatom. Preparatory groundworks began at the Paks II site in July 2023, and a construction schedule was agreed in November 2023, which targets first nuclear concrete in 2024.

Operable Reactors

1916 MWe

Nuclear Share of Generation

48.8 %

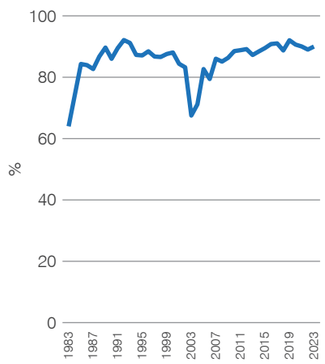
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

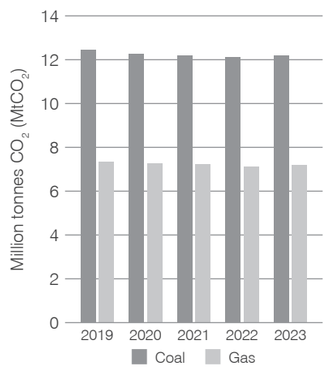
$MtCO_2$ cf. coal

Average nuclear capacity factor



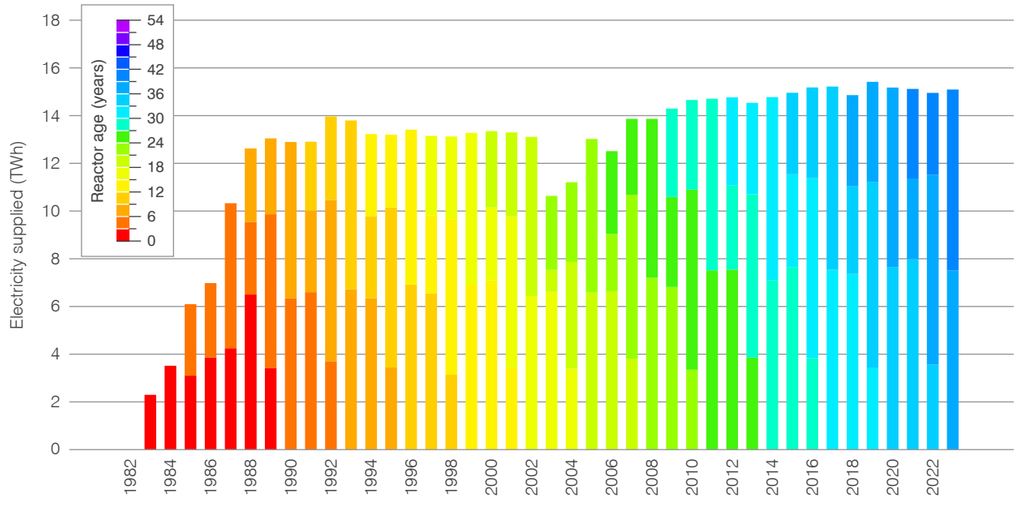
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

India

India has 23 reactors at seven nuclear power plants located both inland and along the coast. The majority of reactors are indigenously designed pressurized heavy water reactors (PHWRs).

In July 2023 the first Indian-designed 700 MWe pressurized heavy water reactor (PHWR), Kakrapar 3, entered commercial operation. In February 2024 the second 700 MWe PHWR at the site, Kakrapar 4, was connected to the grid. India has a further two 700 MWe PHWR units under construction at Rajasthan, and the government has sanctioned construction of a further ten: Kaiga 5&6 in Karnataka; Gorakhpur 3&4 in Haryana; Chutka 1&2 in Madhya Pradesh; and Mahi Banswara 1-4 in Rajasthan.

In April 2023 the government announced plans to increase nuclear capacity, with nuclear accounting for nearly 9% of India's electricity by 2047, up from around 3% currently. In August 2023 the Minister of State said the government is exploring options for small modular reactors but that large-size plants remain the mainstay of the country's plans to expand capacity.

Operable Reactors

7425 MWe

Nuclear Share of Generation

3.1 %

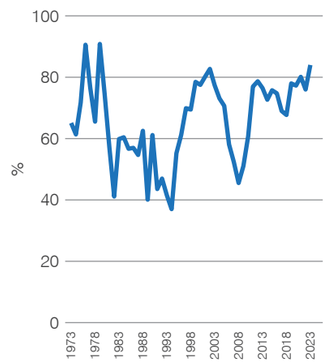
Reactors Under Construction

5398 MWe

Lifetime CO_2 Avoided

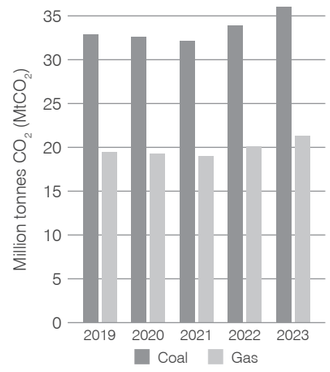
$MtCO_2$ cf. coal

Average nuclear capacity factor



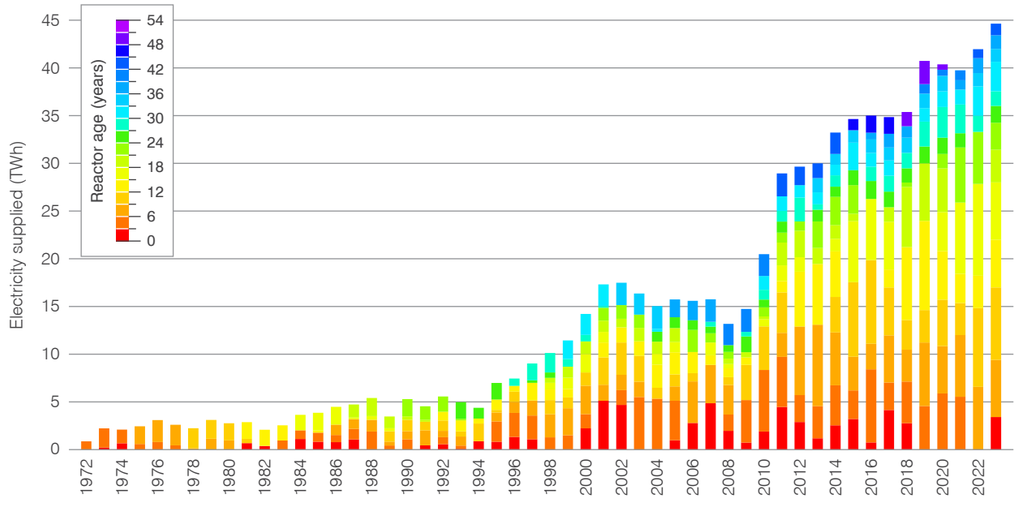
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Iran

A single VVER-1000 unit is in operation in Iran on the Persian Gulf coast at the Bushehr site, about 180 km southwest of Shiraz.

Construction commenced on a second VVER-1000 at Bushehr in 2019. A further VVER-1000 is planned at the site, and in April 2024 the head of the Atomic Energy Organization of Iran (AEOI) said that first concrete would be poured in May, although as of July it was not clear whether this had taken place.

Earlier, in August 2023 the head of the AEOI announced that the country aims to increase its nuclear power generation capacity to 20 GWe over the next 20 years. This announcement was followed up by the start of site work in Hormozgan, which the AEOI said will host four reactors.

Since 2002 Iran has been the subject of International Atomic Energy Agency (IAEA) inquiries concerning its possible development of nuclear weapons. In June 2024 the IAEA board of governors adopted a resolution calling on Iran to fully cooperate with the agency, including giving it access to locations and material for nuclear safeguards verification activities.

Operable Reactors

915 MWe

Nuclear Share of Generation

1.7 %

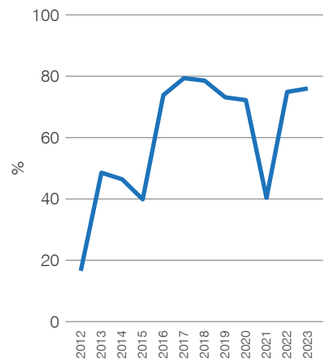
Reactors Under Construction

974 MWe

Lifetime CO_2 Avoided

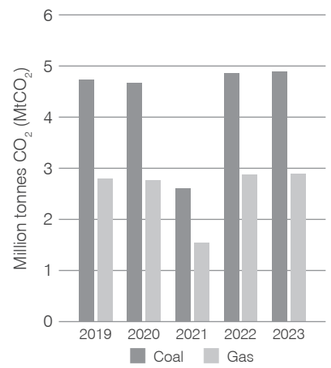
$MtCO_2$ cf. coal

Average nuclear capacity factor



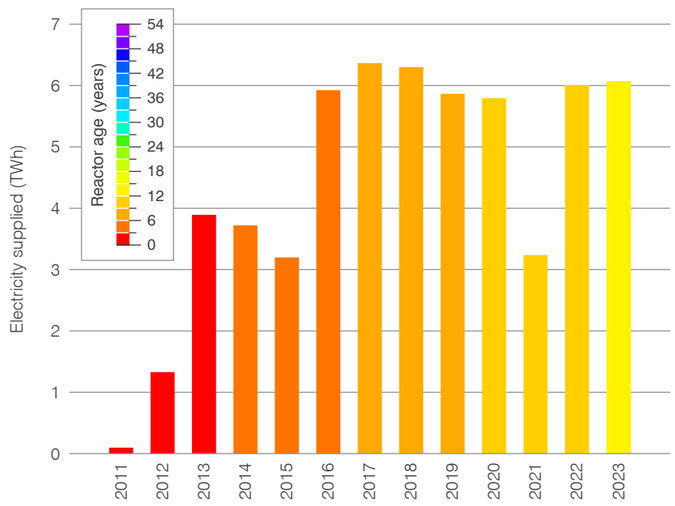
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Japan

Following the March 2011 tsunami and subsequent accident at the Fukushima Daiichi plant, all reactors in Japan have had to get regulatory approval to restart.

In December 2022 the government adopted a policy maximizing the use of existing reactors by restarting as many of them as possible, whilst also developing advanced reactors to replace those that are shut down.

In July 2023 and September 2023 respectively, Takahama 1&2 became the 11th and 12th Japanese reactors to resume operation. Takahama 1 had entered a regular inspection outage in January 2011, two months before the accident at the Fukushima Daiichi plant; Takahama 2 was taken offline in November 2011.

In April 2024 Tepco said it planned to begin loading fuel into unit 7 of the Kashiwazaki-Kariwa plant following approval by Japan's Nuclear Regulatory Authority (NRA). The unit is expected to be restarted in October 2024. Onagawa 2 was due to restart in May, but this date has now been pushed back to September.

In November 2023 the NRA approved the operation of Sendai 1&2 for a further 20 years. The NRA approved the same for Takahama 3&4 in May 2024.

Operable Reactors

31,679 MWe

Nuclear Share of Generation

5.6 %

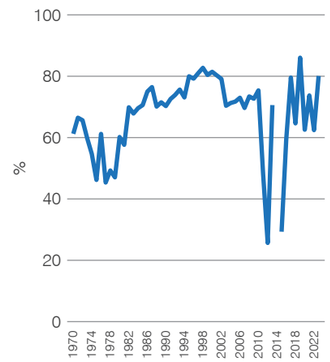
Reactors Under Construction

2653 MWe

Lifetime CO_2 Avoided

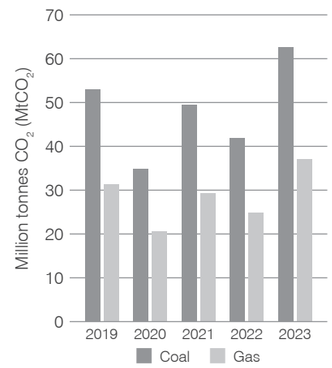
$MtCO_2$ cf. coal

Average nuclear capacity factor



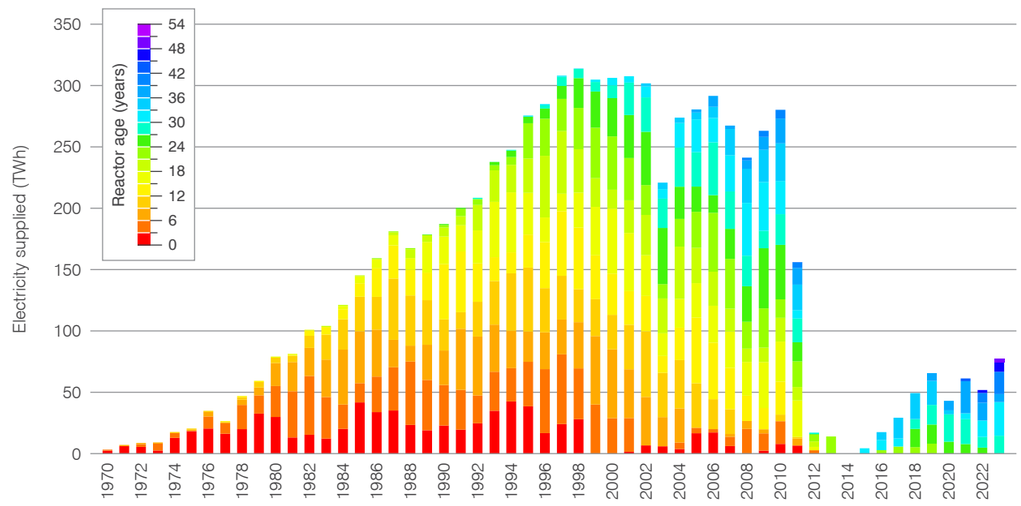
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production

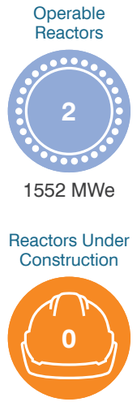


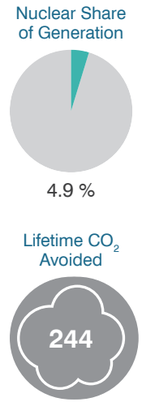
Source: World Nuclear Association, IAEA PRIS

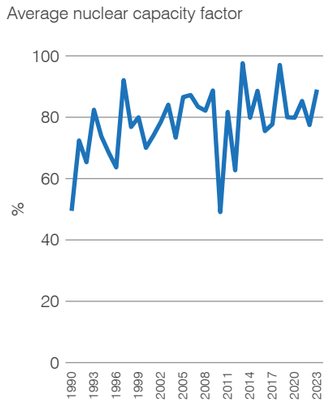
Mexico

Mexico has two operable nuclear reactors located on the east coast of the country, 300 km east of the capital, Mexico City. Laguna Verde 1 began commercial operation in 1990 and unit 2 in 1995.

In July 2020 the Mexico energy ministry approved a 30-year extension of the operating licence for Laguna Verde 1. This would allow the reactor to operate until 2050. In August 2022 Laguna Verde 2 was granted an extension to its operating licence, to April 2055.







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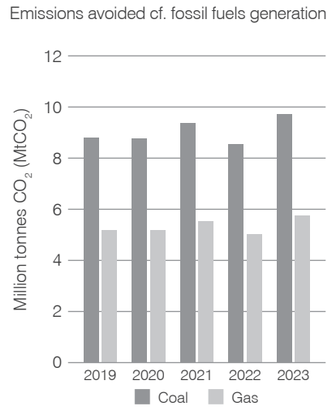
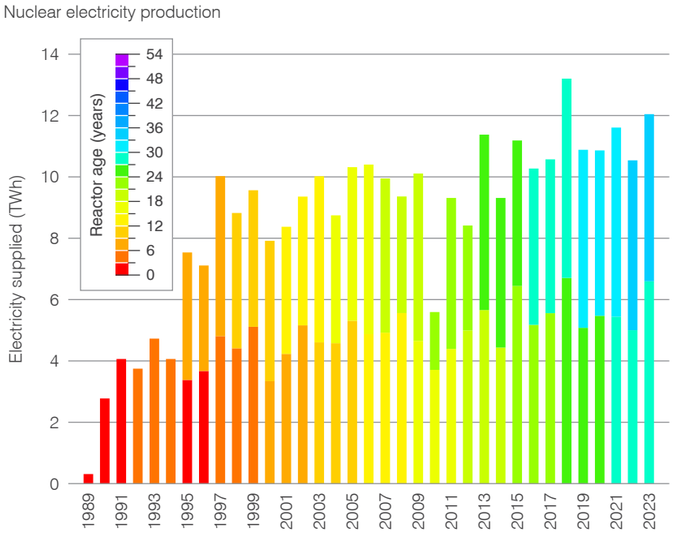


Source: World Nuclear Association, IAEA PRIS



Source: World Nuclear Association, IAEA PRIS

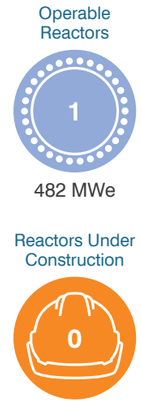
Netherlands

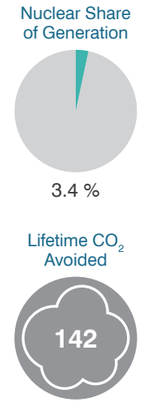
A single 485 MWe PWR is operating at Borssele, about 70 km southwest of Rotterdam.

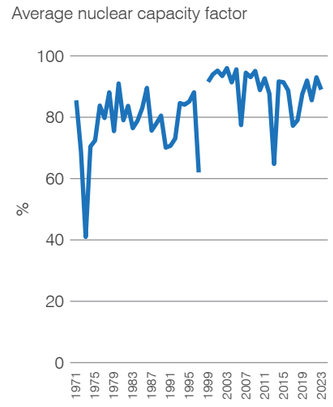
In April 2023 the government announced its draft Climate Fund for 2024, which included €320 million for the development of nuclear energy. Of this funding, €10 million would go towards studies over the period 2023-2025 regarding the operating lifetime extension of the Borssele plant; €117 million was allocated for studies on the construction of two new reactors; €65 million would go towards investment in nuclear skills; and €65 million would be used to support the development of SMRs.

The government has earmarked the Borssele site as the most suitable location for the construction of two new large reactors, but a final decision on the location is not due to be made before the end of 2024. Preliminary plans suggest that the reactors would have a capacity of 1000-1650 MWe each, providing 9-13% of the country's electricity, and could be completed by around 2035.

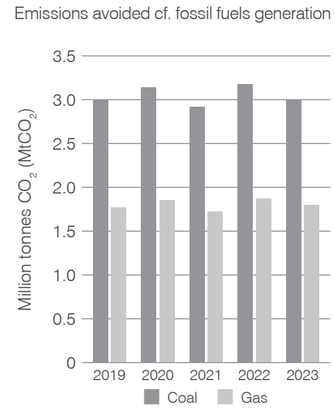
In February 2024 Westinghouse was awarded a contract to conduct a technical feasibility study on the deployment of two AP1000 reactors at Borssele. In the same month the Ministry of Economic Affairs and Climate announced its 'proposal for participation' in the construction of the two new reactors at Borssele was open.



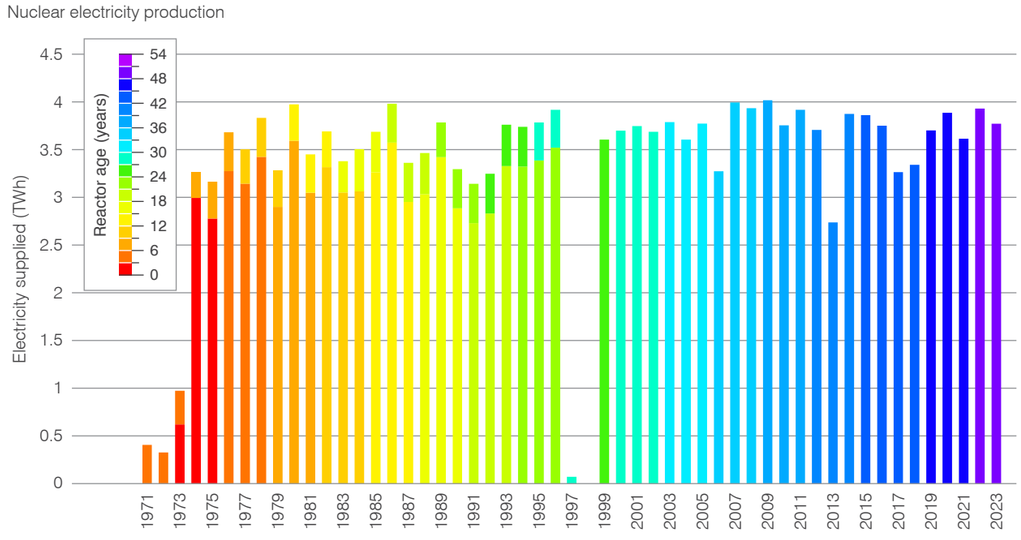




Source: World Nuclear Association, IAEA PRIS



Source: World Nuclear Association, IAEA PRIS



Source: World Nuclear Association, IAEA PRIS

Pakistan

Pakistan has six operating nuclear power reactors supplied by China at two sites: Chashma, inland 200 km southwest of Islamabad; and Karachi, on the coast about 30 km west of the city of Karachi.

The four units at Chashma are CNP300 models, based on the Qinshan 1 reactor in China. The first reactor was connected to the grid in 2000 and the fourth unit in 2017.

The Karachi nuclear plant is the site of the country's first nuclear power reactor, a 90 MWe (net) Canadian PHWR that operated between 1971 and 2021. The two operating units at Karachi are HPR1000 models, also known as Hualong one. Unit 2 at the plant was connected to the grid in 2021, followed by unit 3 in 2022.

Also, in June 2023 it was announced that the Pakistan Atomic Energy Commission had signed a $4.8 billion deal with China National Nuclear Corporation (CNNC) to construct an HPR1000 reactor as unit 5 at Chashma. The reactor would be built by CNNC, which would also supply 85% of the estimated $3.7 billion required for the construction. In July 2023 a ceremonial groundbreaking ceremony took place.

Operable Reactors

3262 MWe

Nuclear Share of Generation

17.4 %

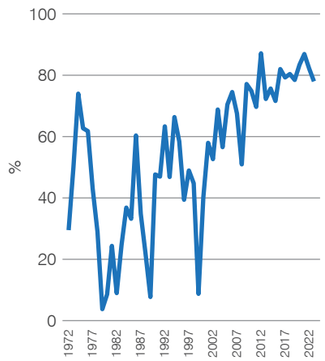
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

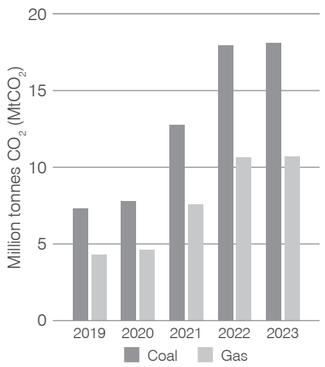
$MtCO_2$ cf. coal

Average nuclear capacity factor



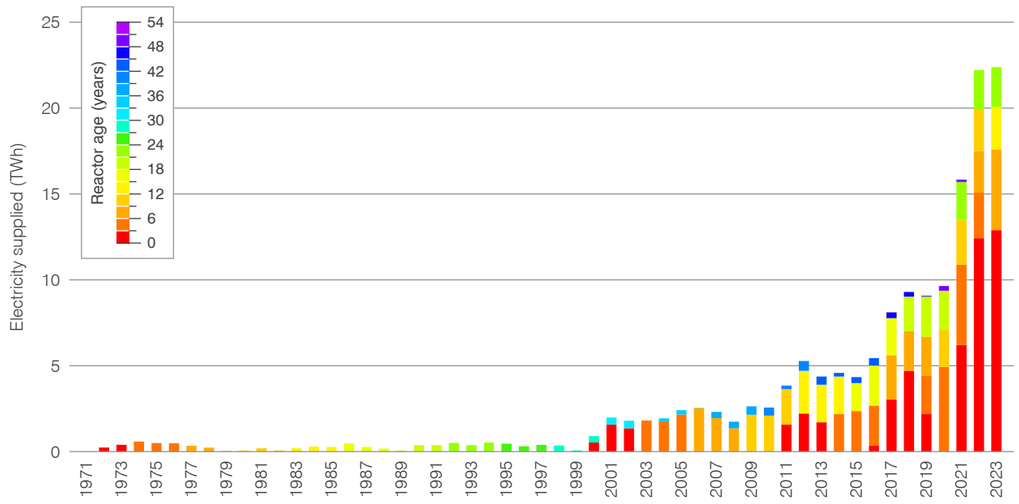
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Romania

Two CANDU-6 PHWRs operate at the Cernavoda plant, 150 km east of Bucharest. In addition to electricity, the plant provides district heating to the adjacent town of Cernavoda.

Cernavoda was originally planned to be a five-unit plant. In December 2022 the Romanian government adopted a draft law covering a state support agreement with Societatea Nationala Nuclearelectrica (SNN) subsidiary EnergoNuclear relating to the estimated €7 billion ($7.4 billion) project to complete Cernavoda 3&4. In June 2023 the Romanian government and Nuclearelectrica signed a support agreement that allows for the restart of the project to construct the two units. Nuclearelectrica now expects the two units to enter commercial operation in 2030 and 2031 respectively.

Cernovoda 1, which started operation in 1996, is to be upgraded to allow the reactor to operate for an additional 30 years, to 2060. In October 2023 Korea Hydro & Nuclear Power announced it had signed an agreement with Canada's Candu Energy and Italy's Ansaldo Nucleare to jointly carry out the refurbishment works. Separately, in June 2024, Nuclearelectrica signed an agreement with Canadian Nuclear Partners for the provision of project management services and technical assistance during the refurbishment.

A NuScale small modular reactor plant is planned for a site at Doicești in Romania's Muntenia region. In May 2023 the USA, along with multinational public-private partners from Japan, South Korea and the United Arab Emirates, announced funding for the project.

Operable Reactors

1300 MWe

Nuclear Share of Generation

18.9 %

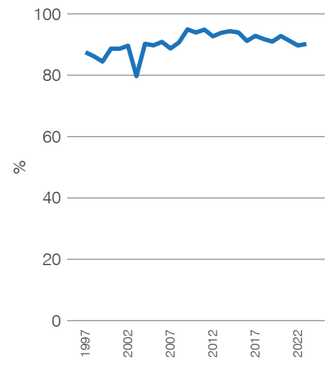
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

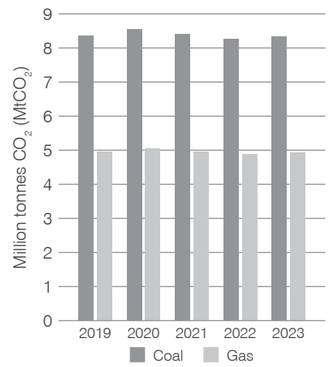
$MtCO_2$ cf. coal

Average nuclear capacity factor



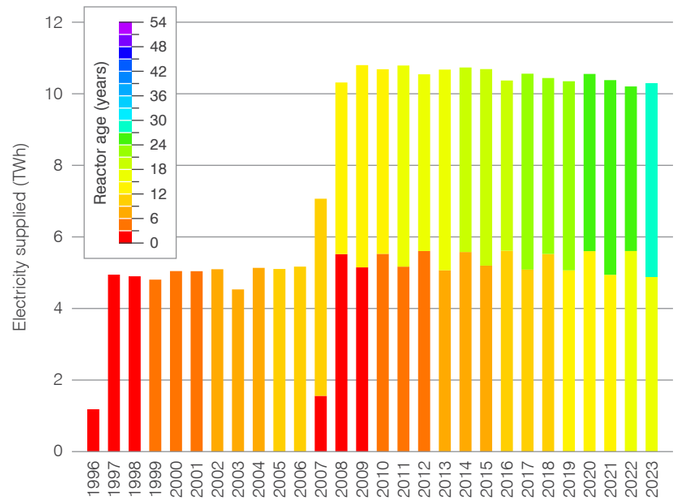
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Russia

There are 36 operable reactors in Russia, with the majority in the west of the country. Four reactors are under construction: two VVER-1200 units at the Kursk power plant; one VVER-1200 unit at Leningrad; and a demonstration lead-cooled fast reactor, BREST-OD-300, in Seversk.

As of July 2024, a total of 20 VVER reactors were under construction outside of Russia in Bangladesh (2), China (4), Egypt (4), India (4), Iran (1), Slovakia (1), and Turkey (4). Rosatom has agreements in place with Hungary and India for the construction of further reactors, and is in discussion with other countries.

In January 2024 Russia's nuclear regulator, Rostekhnadzor, issued construction licences for Lengingrad 7&8. Construction commenced on unit 7, also known as Leningrad II-3, in March 2024, the first domestic reactor construction start since 2021. The two reactors at Leningrad are expected to be grid connected in 2030 and 2031 respectively.

In November 2023 Russia completed the first refuelling of the world's first floating nuclear power plant, *Akademik Lomonosov*. In June 2023 Rosatom signed an agreement with TSS Group to construct a series of floating power units "with a capacity of at least 100 MWe and an assigned service life of up to 60 years for foreign markets and the subsequent sale of electricity from the floating power unit in the countries of presence." Rosatom has identified target markets for its floating units in the Middle East, southeast Asia, and Africa.

Operable Reactors

26,802 MWe

Nuclear Share of Generation

18.4 %

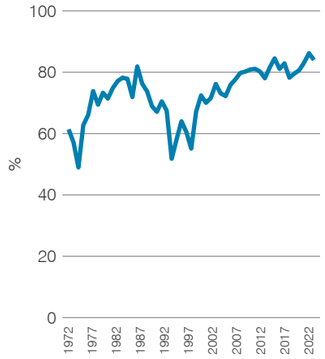
Reactors Under Construction

3702 MWe

Lifetime CO_2 Avoided

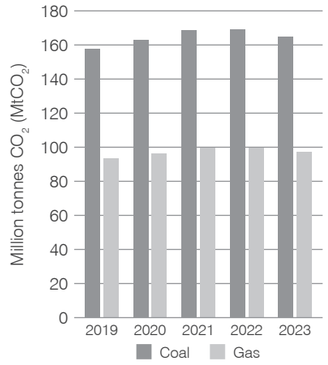
$MtCO_2$ cf. coal

Average nuclear capacity factor



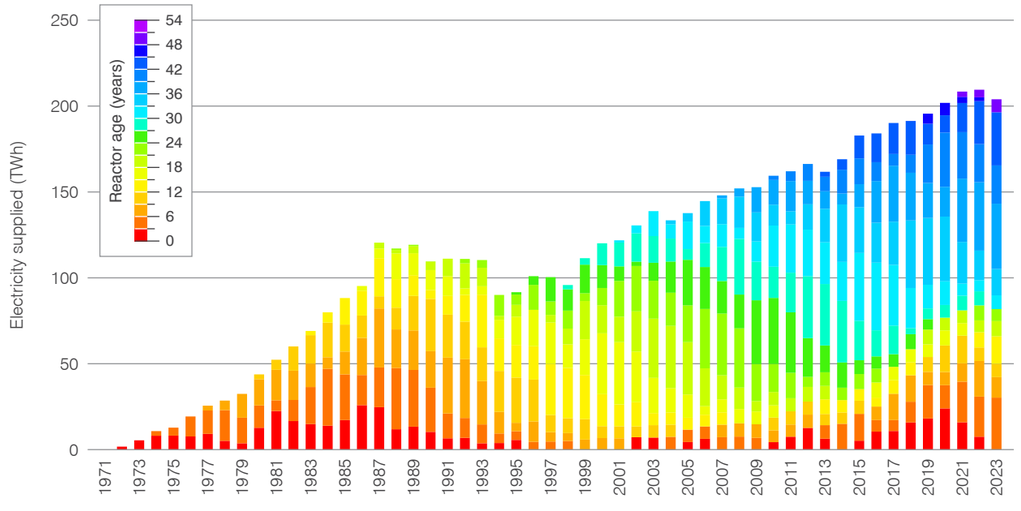
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Slovakia

Slovakia has five operable VVER440/V-213 nuclear reactors: two at Bohunice V2, 140 km northeast of Bratislava; and three at Mochovce, 100 km east of Bratislava. Mochovce 3 was grid connected in January 2023, and unit 4 at that site is still under construction.

In June 2023 Slovenské Elektrárne signed a memorandum of understanding with Framatome on the development of European nuclear fuel for VVER-440 reactors. In August 2023 the utility signed a long-term agreement with Westinghouse for the licensing and supply of VVER-440 fuel assemblies.

In May 2024 the government approved a plan for a new 1.2 GWe unit near the existing Bohunice plant. Detailed plans are being developed, and France, South Korea and the USA are among the potential project partners.

Slovakia signed a memorandum of understanding in June 2023 with a range of partners – US Steel Košice, the Slovak Electricity Transmission System, VUJE, the Office of Nuclear Supervision and the Slovak Technical University in Bratislava – to support development of SMRs.

Slovakia is one of the first recipients of support through the US-funded Project Phoenix, announced at the COP27 conference on climate change held in Sharm el-Sheikh, Egypt in 2022. The initiative aims to support energy security and climate goals by creating pathways for coal-to-SMR plant conversions. In February 2024 Slovenské Elektrárne said that staff from Project Phoenix implementation partner Sargent & Lundy had visited its Bohunice and Mochovce nuclear power plants and the Nováky and Vojany coal-fired plants to carry out field surveys.

Operable Reactors

2308 MWe

Nuclear Share of Generation

61.3%

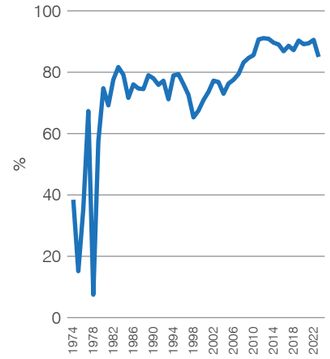
Reactors Under Construction

440 MWe

Lifetime CO_2 Avoided

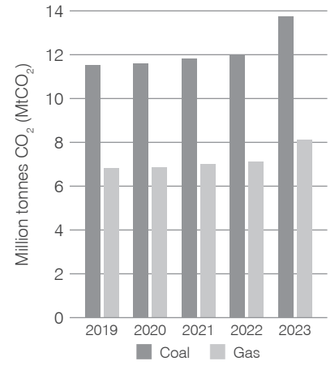
$MtCO_2$ cf. coal

Average nuclear capacity factor



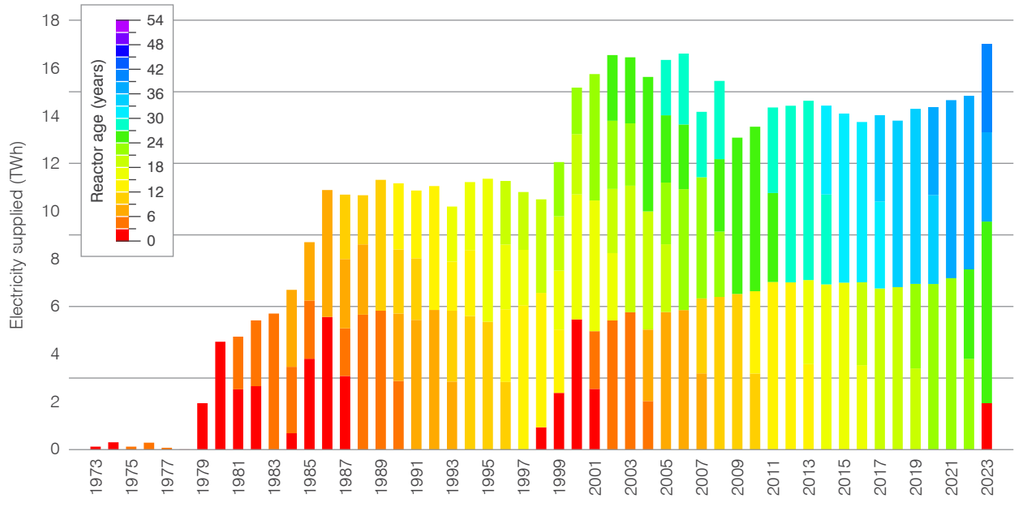
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Slovenia

Slovenia has a single reactor operating at Krško, about 40 km northeast of Zagreb. It is a two-loop Westinghouse PWR with a net capacity of 688 MWe. The plant's operating company Nuklearna Elektrarna Krško (NEK) is jointly owned by Slovenian state-owned company Gen-Energija and Croatian state-owned company Hrvatska Elektroprivreda (HEP).

In October 2023 the Krško plant was shut down after discovery of a leak in the primary circuit connection system. NEK said that following investigation, a decision was made to replace the complete pipeline segment from the reactor vessel to the first valve. While the shutdown took place, activities for the scheduled shutdown in 2024 were brought forward. The unit returned to service at the end of November.

Slovenia has plans to build a new nuclear power plant – the JEK2 project – with a capacity of up to 2400 MWe. It is to be sited near the existing plant at Krško. In January 2024 the country's prime minister held a meeting with opposition party leaders and members of parliament from Hungary and Italy stating that Slovenia's long-term use of nuclear energy "requires the broadest national and political consensus." The cross-party summit agreed on the need for both renewables and nuclear energy as part of the "path to a carbon-free future." A referendum on nuclear energy will now take place later in 2024, with a final investment decision on JEK2 targeted for 2028.

Operable Reactors

688 MWe

Nuclear Share of Generation

36.8 %

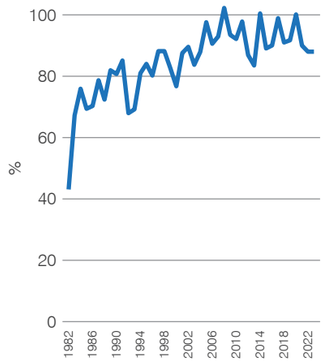
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

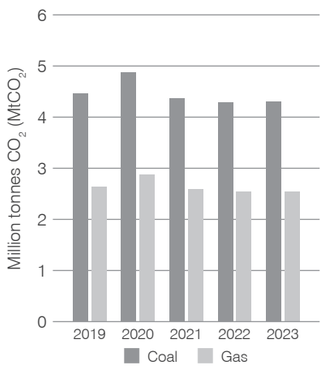
$MtCO_2$ cf. coal

Average nuclear capacity factor



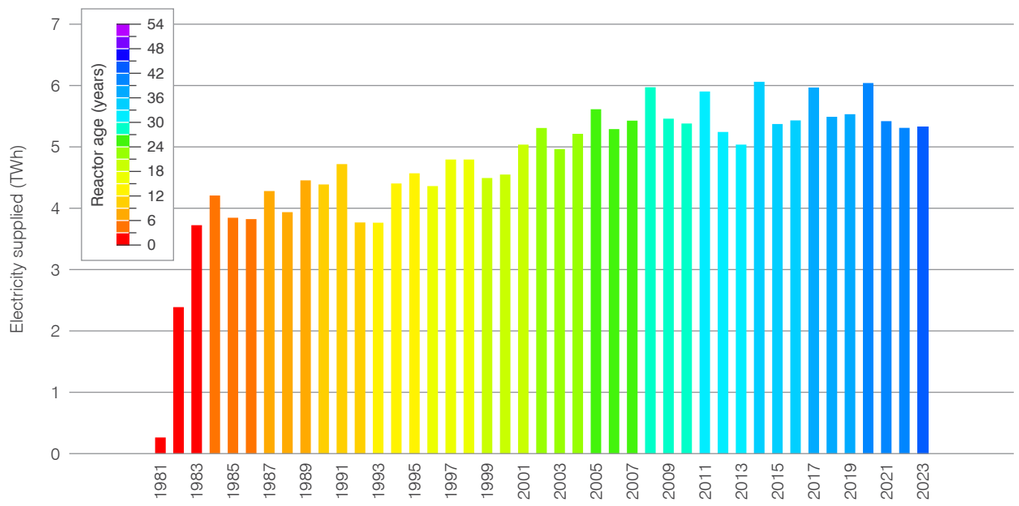
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

South Africa

South Africa has a single nuclear power plant at Koeberg, 30 km north of Cape Town. The plant's two reactors, connected to the grid in 1984 and 1985, have a combined capacity of 1854 MWe.

To allow for the long-term operation of Koeberg the plant's steam generators have to be replaced. The replacement work at unit 1 had originally been scheduled to take place in the first half of 2021, with similar work at Koeberg 2 the following year. However, the schedule was put back due to concerns about the tight supply of electricity in South Africa. Koeberg 1's maintenance outage began on 10 December 2022 and to allow for the replacement of steam generators had been expected to last about six months. In the event the unit returned to service in November 2023, after nearly a year offline.

Unit 2 was taken offline in December 2023. In February 2024 Eskom said it expected the unit to return to service in September 2024.

South Africa's Department of Mineral Resources and Energy (DMRE) confirmed in December 2023 that it is proceeding with the procurement of 2500 MWe of new nuclear capacity.

Operable Reactors

1854 MWe

Nuclear Share of Generation

4.4 %

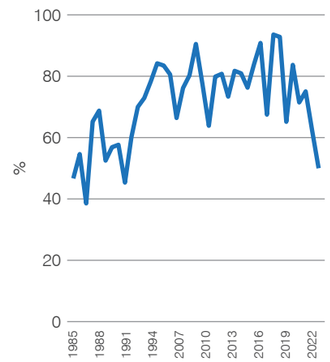
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

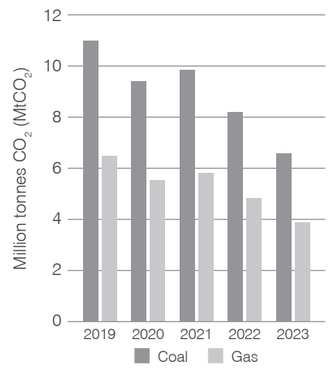
$MtCO_2$ cf. coal

Average nuclear capacity factor



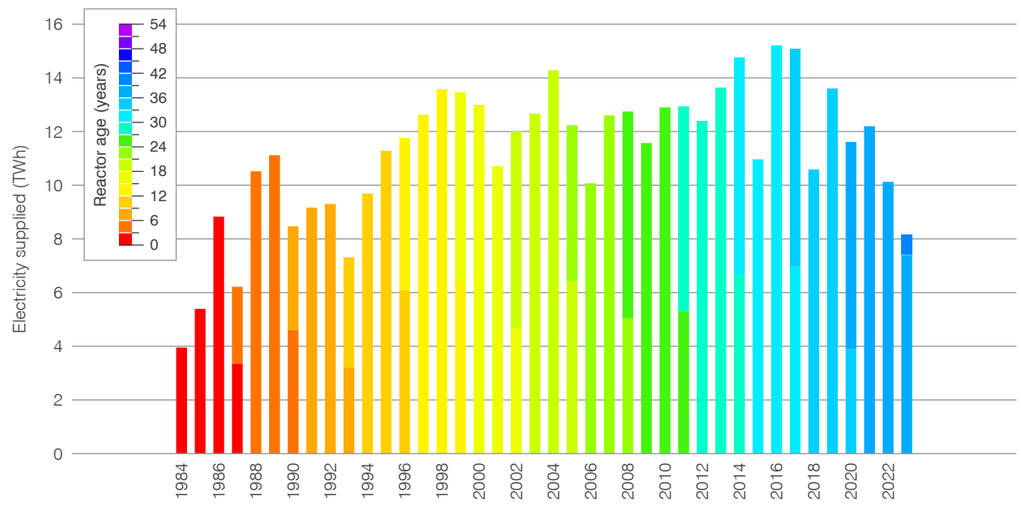
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

South Korea

There are 26 reactors operating in South Korea, providing more than a quarter of the country's electricity. Two APR-1400 units are under construction, with further units planned.

In March 2022 a new President, Yoon Suk-yeol, was elected on a platform that rejected his predecessor's nuclear phase-out policy.

In June 2023 the government approved the project implementation plan for Shin Hanul 3&4, allowing Korea Hydro & Nuclear Power (KHNP) to restart preliminary construction. In December 2023 a consortium led by Hyundai Engineering & Construction was selected as the contractor for the construction of the main facilities of the two units. First nuclear concrete is expected later in 2024.

In July 2023 it was announced that the country's Ministry of Trade, Industry and Energy is to review the need for new nuclear power. The committee noted the "recent mid- to long-term changes in power supply and demand conditions" with the need for growing capacity fuelled by the increase in electric vehicles, expansion of data centres and investment in semi-conductor and battery manufacture.

In July 2023 a public-private partnership comprising 42 entities was created to advance Korea's small modular reactor (SMR) sector, including 11 government and public institutions. In June 2024 President Yoon Suk-yeol announced plans to create an SMR hub in the city of Gyeongju in the southeastern corner of the country's North Gyeongsang province.

Operable Reactors

25,825 MWe

Nuclear Share of Generation

31.5 %

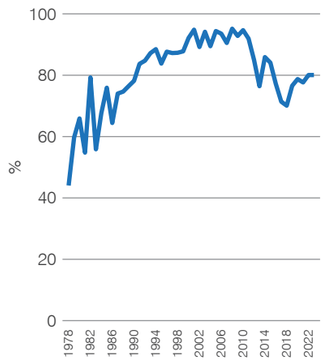
Reactors Under Construction

2680 MWe

Lifetime CO_2 Avoided

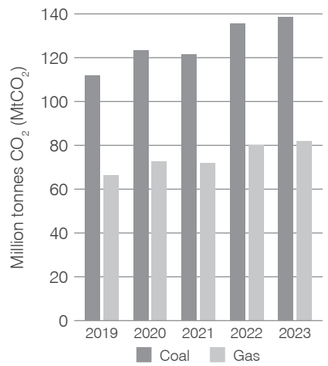
$MtCO_2$ cf. coal

Average nuclear capacity factor



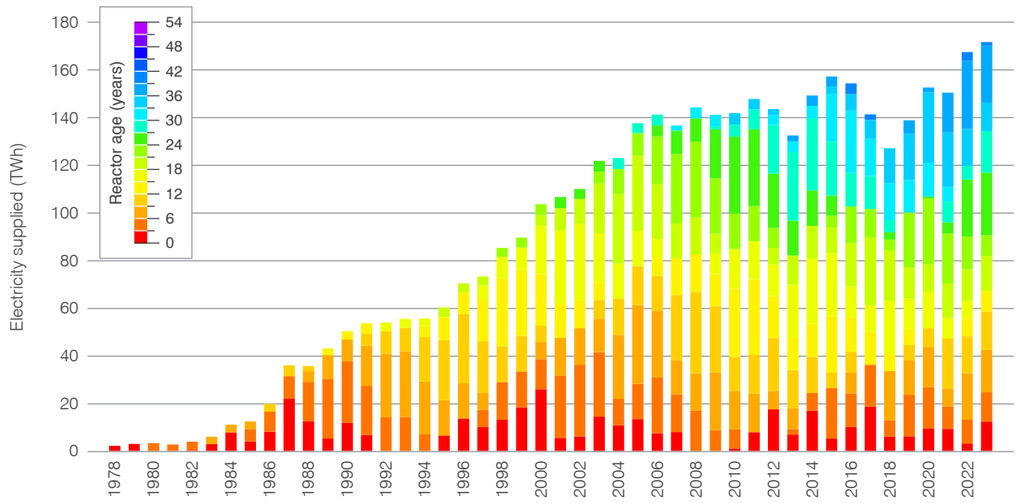
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Spain

Spain has seven operable nuclear reactors at five sites across the country, all of which started up in the 1980s. With a combined capacity of 7123 MWe, the units generate over 20% of the country's electricity.

Until 2011 it was planned that operation of Spain's reactors would end in the 2020s as operating lifetimes would be limited to 40 years. That restriction has since been removed; however, at the end of 2023 the new government confirmed that it would phase out nuclear power between 2027 and 2035.

In July 2023 dismantling of the Santa María de Garoña nuclear power plant began following the transfer of ownership from Nuclenor to decommissioning and waste management firm Enresa. Decommissioning is expected to take about 10 years.

Operable Reactors

7123 MWe

Nuclear Share of Generation

20.3 %

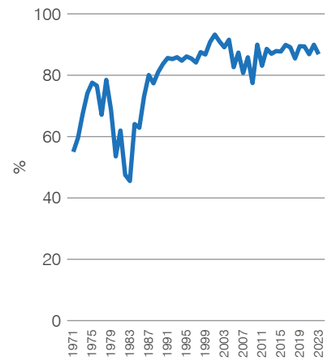
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

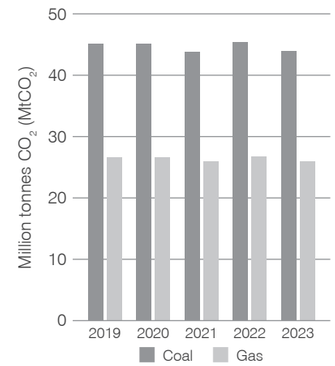
$MtCO_2$ cf. coal

Average nuclear capacity factor



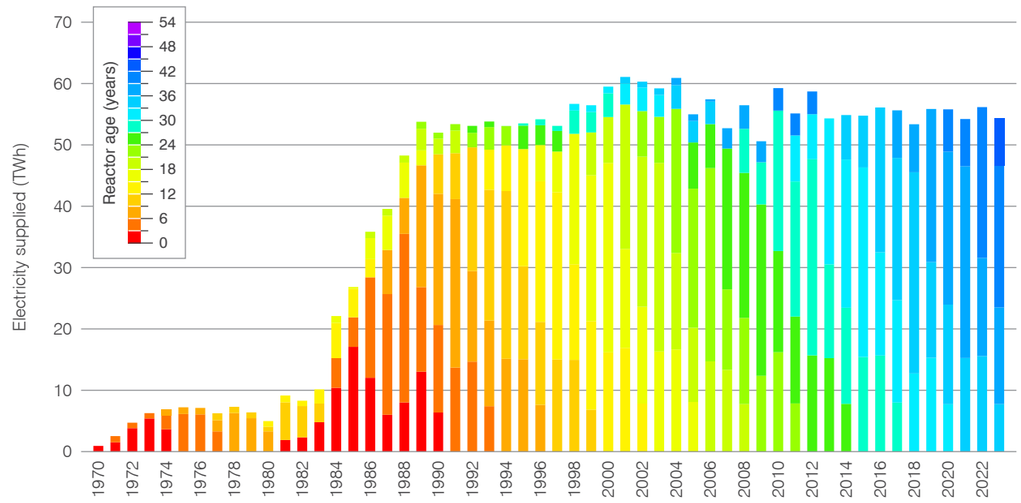
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Sweden

There are six reactors operating in three locations in Sweden: Ringhals, 50 km south of Gothenburg; Oskarshamm, 220 km south of Stockholm; and Forsmark, 120 km north of Stockholm.

In October 2022 a pro-nuclear centre-right coalition government took office. In January 2023 the government announced that it was preparing legislation that would scrap both the country's limit of ten reactors and the requirement to only build new nuclear reactors at locations where they already exist. The bill was passed by parliament in November 2023.

Earlier, in August 2023, Sweden's Radiation Safety Authority (SSM) presented its final report to the government on how the regulatory framework should be developed for nuclear power to be expanded in the country. This followed a government request a year earlier for SSM to review the regulatory framework to ensure there are conditions for using both existing and future nuclear power.

In November 2023 the government announced plans to construct two large-scale reactors by 2035 and the equivalent of 10 new reactors, including small modular reactors, by 2045. Also in November, Vattenfall sought planning permission to enable construction of new reactors on the Värö Peninsula at its Ringhals site.

In June 2024 the owners of the Forsmark and Ringhals nuclear power plants announced they are assessing the possibility of extending the operating lifetimes of the plants' reactors from 60 to 80 years.

Operable Reactors

6944 MWe

Nuclear Share of Generation

28.6 %

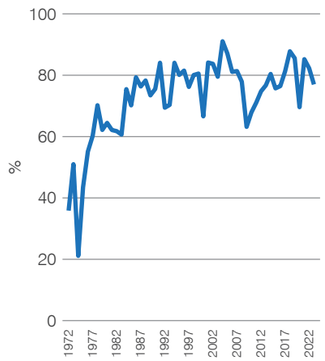
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

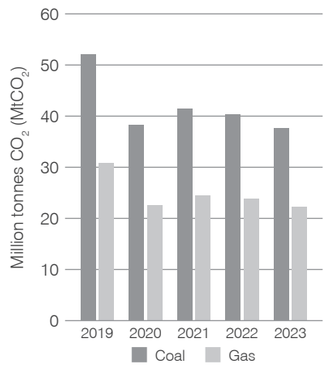
$MtCO_2$ cf. coal

Average nuclear capacity factor



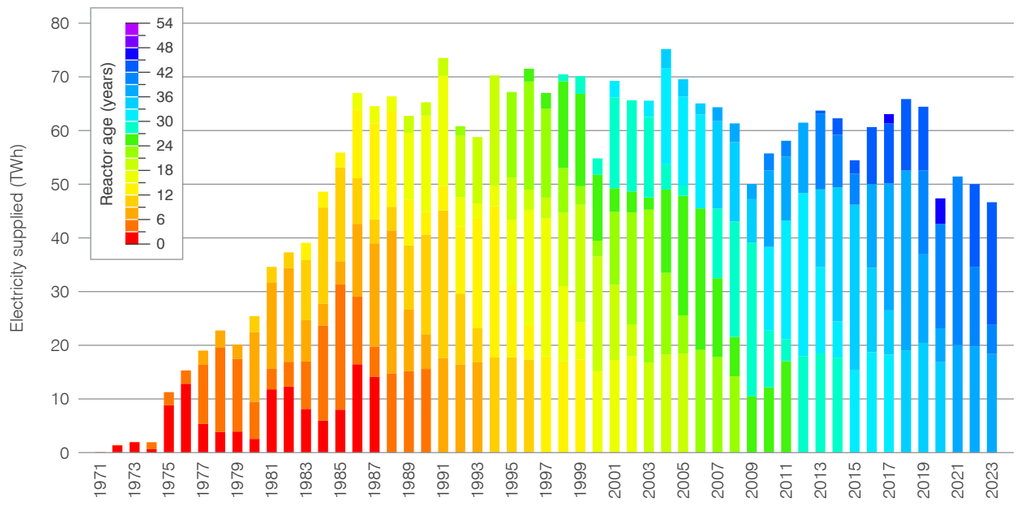
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Switzerland

Switzerland has two reactors at Beznau, 30 km southwest of Zurich, one at Gösgen, 40 km southwest of Zurich and one at Leibstadt, 40 km northwest of Zurich. Together they generate up to 40% of the country's electricity. The country has a policy of gradual withdrawal of nuclear power: no new reactors are to be built, but existing reactors may remain in operation as long as the regulator considers them safe.

In September 2022 following a 14-year site selection process for a deep geological repository, Switzerland's national radioactive waste disposal cooperative Nagra proposed the Nördlich Lägern site in northern Switzerland. The repository for low-level and intermediate-level waste is planned to be in operation by 2050, with the high-level waste facility planned to be operational ten years later.

Operable Reactors

2973 MWe

Nuclear Share of Generation

32.4 %

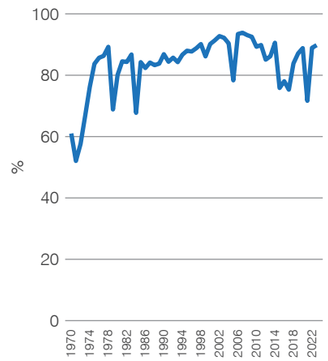
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

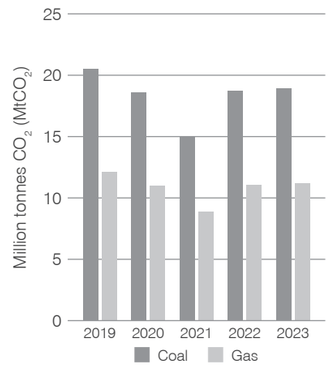
$MtCO_2$ cf. coal

Average nuclear capacity factor



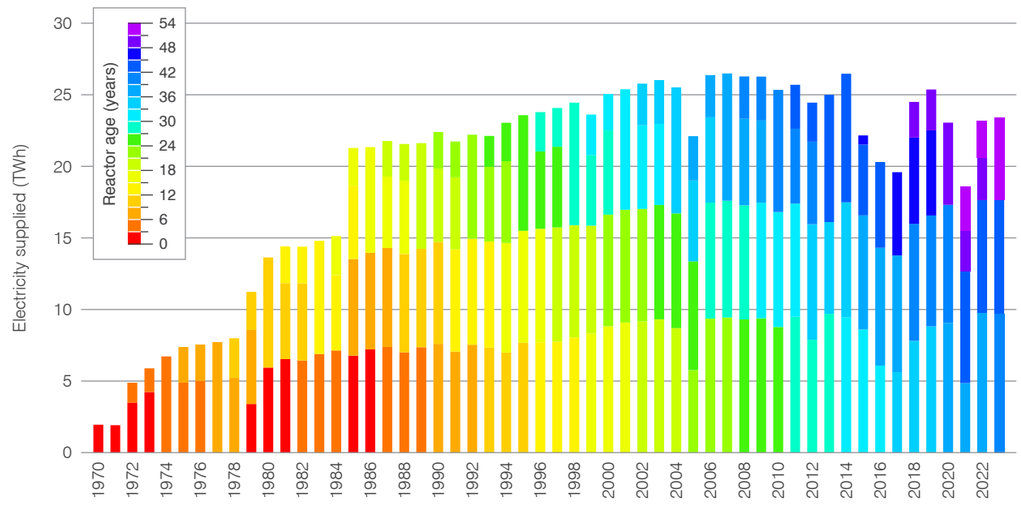
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production

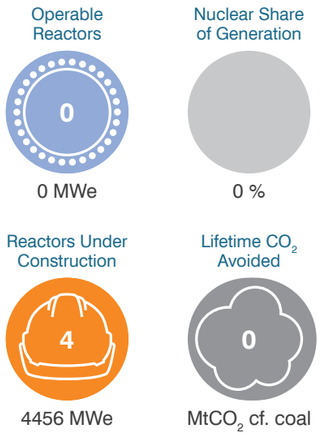


Source: World Nuclear Association, IAEA PRIS

Turkey

The Akkuyu nuclear plant, under construction on Turkey's southern coast, 120 km southwest of Mersin, will comprise four 1114 MWe VVER-1200 reactors. Construction of the fourth unit commenced in August 2023, and commissioning work for unit 1 began in April 2024. The reactors are expected to come online between 2025 and 2028.

Turkey has been in talks with Russia, China and South Korea over its planned second and third nuclear power plants. In comments made in July 2023 Turkey's energy minister also revealed the country is talking to organizations in the USA and UK regarding small modular reactors (SMRs). He said that with the country's energy demand continuing to grow, "our first priority is to ensure security of supply in a sustainable manner."



Ukraine

All 15 reactors in Ukraine are VVER units. Rovno and Khmelnitski are in the west of the country, and South Ukraine and Zaporizhzhia in the south.

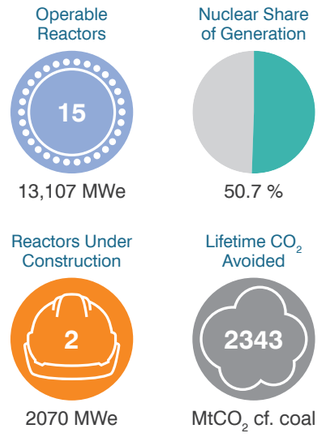
In February 2022 Russia launched a military offensive against Ukraine. The war has had an impact on energy systems across Ukraine, with all six units at Zaporizhzhia – which is occupied by Russian military forces – having not generated electricity since September 2022. Output from Ukraine's other reactors has been less affected.

Since January 2023 teams of nuclear safety and security experts from the International Atomic Energy Agency (IAEA) have been stationed at Ukraine's nuclear power plants and the Chernobyl site.

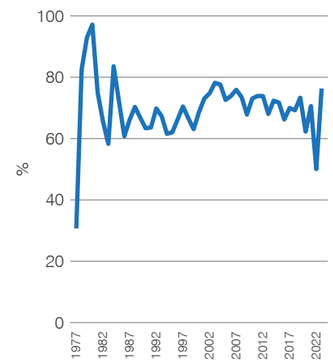
All units at Zaporizhzhia have been in cold shutdown since April 2024, following the installation of four diesel steam generators for liquid waste treatment at the site, and the end of the heating season. In June 2024 IAEA Director General Rafael Mariano Grossi said there "was an understanding" that the Zaporizhzhia plant's reactors would not be restarted during the conflict.

In October 2023 the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) established a pre-licensing system based on the approach adopted by the Canadian Nuclear Safety Commission.

In November 2023 South Ukraine 1 received a 10-year extension to its operating licence. The reactor entered commercial operation in 1983.

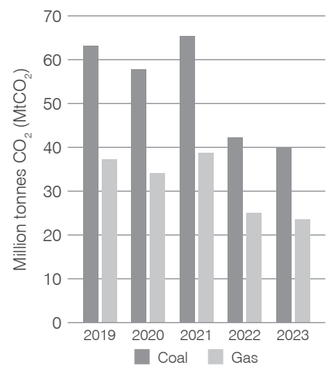


Average nuclear capacity factor



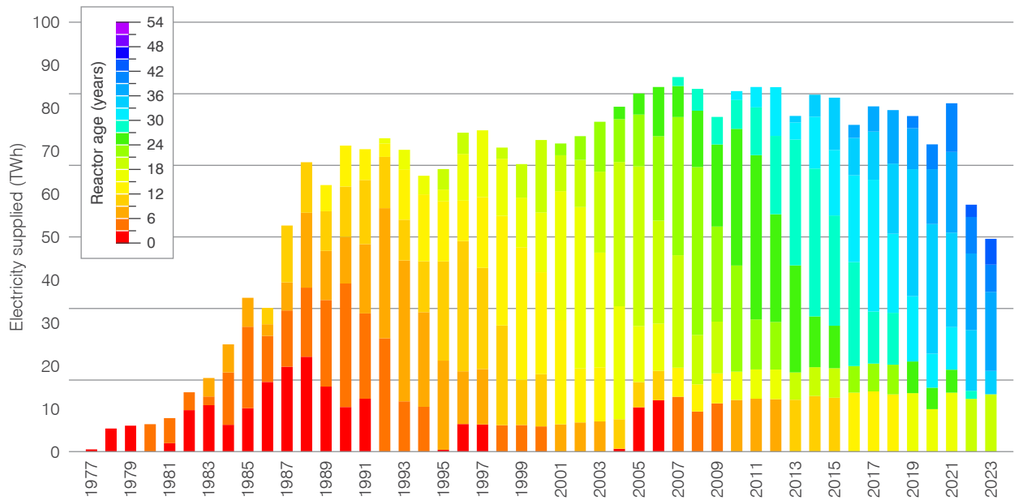
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

United Arab Emirates

The United Arab Emirates (UAE) has four operable nuclear power reactors at its Barakah nuclear power plant, located 230 km west of Abu Dhabi. It is the first nuclear power plant in the Middle East.

Barakah 1 produced first power in August 2020, followed by unit 2 in September 2021, unit 3 in October 2022 and unit 4 in March 2024. Now fully operational, the four units supply some 25% of the UAE's electricity.

The Barakah One Company PJSC – a joint venture between Emirates Nuclear Energy Corporation (ENEC) and Korea Electric Power Corporation (KEPCO) – completed the AED 8.9 billion ($2.4 billion) refinancing of the project in July 2023.

Operable Reactors

5348 MWe

Nuclear Share of Generation

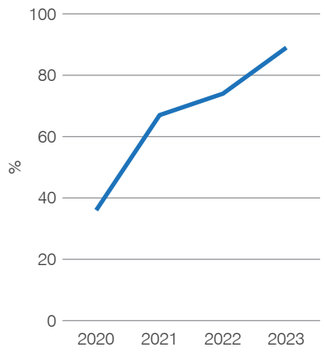
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

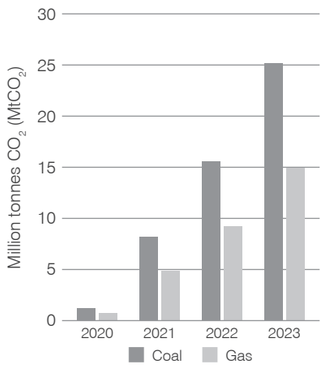
$MtCO_2$ cf. coal

Average nuclear capacity factor



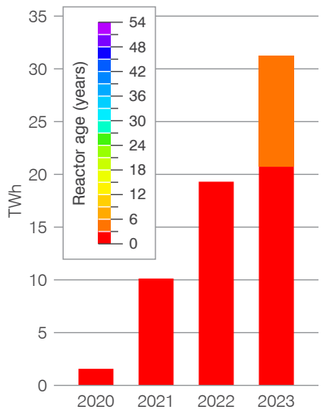
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

United Kingdom

The UK has nine operable reactors at five sites; eight are advanced gas-cooled reactors (AGRs), with one pressurized water reactor (PWR) at Sizewell. In January 2024 EDF announced it would invest a further GBP1.3 billion in the UK's operating plants over the following two years and planned to further extend the lives of the AGR plants.

Two EPR units are under construction at Hinkley Point. In January 2024 EDF said that they are now unlikely to be operational before 2030. In the same announcement EDF said the estimated cost of the project had increased to between GBP31 and 34 billion (in 2015 prices) – up from 26 billion, as estimated in 2022.

Two further EPR units are planned at Sizewell. In May 2024 the country's regulator issued a site licence for Sizewell C. This followed the issuance of a Development Consent Order on 15 January, which paves the way for construction work to begin at the site, and the commitment on 23 January of a further GBP1.3 billion of government funding for infrastructure work at the site ahead of a final investment decision.

The new Labour government, elected in July 2024, has said that new nuclear power stations, such as Sizewell C, and small modular reactors, will play an important role in helping the UK achieve energy security and clean power while securing thousands of good, skilled jobs.

Operable Reactors

5883 MWe

Nuclear Share of Generation

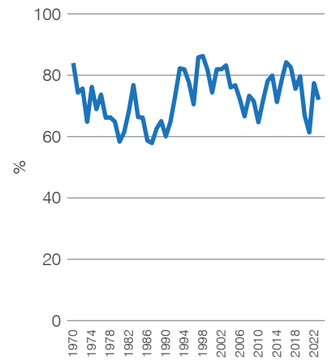
Reactors Under Construction

3260 MWe

Lifetime CO_2 Avoided

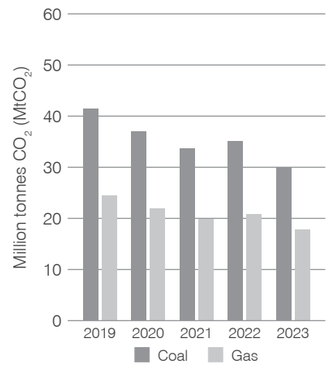
$MtCO_2$ cf. coal

Average nuclear capacity factor



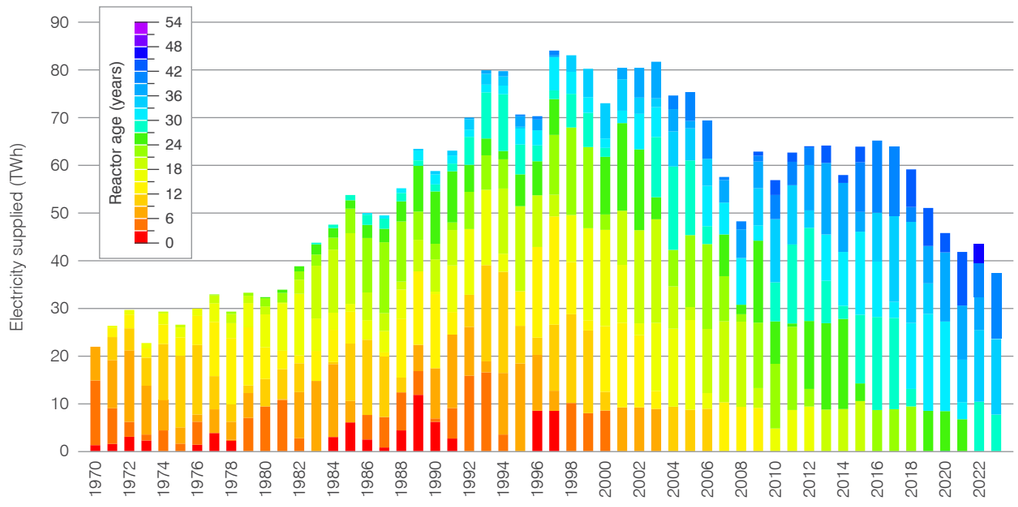
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

United States of America

The USA has 94 operable reactors with a combined capacity of 95,800 MWe, the largest nuclear fleet of any single country.

Vogtle 3, an AP1000, was connected to the grid in April 2023 and began commercial operation in July. Unit 4 was connected to the grid in March 2024 and began commercial operation in April.

In October 2023 Holtec International applied to restart the Palisades plant in Michigan, having purchased the 800 MWe PWR from owner and operator Entergy in June 2022, shortly after the plant was shut down. In March 2024 the US DOE Loan Programs Office committed up to USD1.52 billion for a loan guarantee to support the project.

In December 2023 Californian regulators agreed to extending the operation of Diablo Canyon nuclear plant for an additional five years, to 2030. Pacific Gas & Energy had agreed in 2016 that the plant would close at the end of its current licences - in 2024 for unit 1 and 2025 for unit 2. At that time, it was thought that the plant's output would no longer be required as California focused on an energy policy centred on efficiency, renewables and storage. However, in September 2022 – as California's energy grid saw its highest-ever peak demand during a record-breaking heatwave – the state passed a law allowing the two nuclear units that provide 9% of California's power generation to continue operation.

Operable Reactors

96,952 MWe

Nuclear Share of Generation

18.6 %

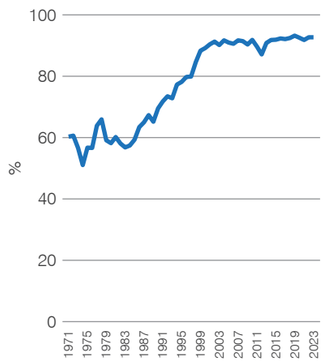
Reactors Under Construction

0 MWe

Lifetime CO_2 Avoided

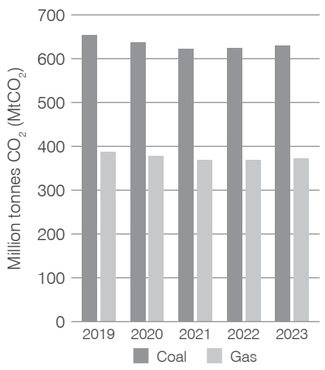
$MtCO_2$ cf. coal

Average nuclear capacity factor



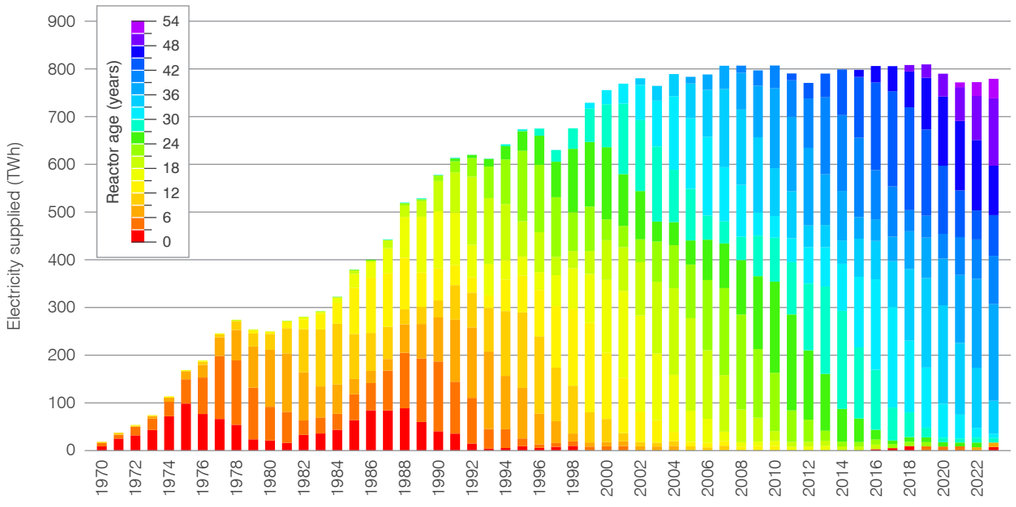
Source: World Nuclear Association, IAEA PRIS

Emissions avoided cf. fossil fuels generation



Source: World Nuclear Association, IAEA PRIS

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

4 Nuclear reactor global status

31 July 2024

Grid Connections 1 January - 31 July 2024

	Location	Model	Net Capacity (MWe)	Grid Connection
Kakrapar 4	India	PHWR-700	630	20 February 2024
Vogtle 4	USA	AP1000	1117	1 March 2024
Barakah 4	UAE	APR-1400	1337	23 March 2024
Fangchenggang 4	China	Hualong One	1105	9 April 2024

Construction Starts 1 January - 31 July 2024

	Location	Model	Net Capacity (MWe)	Construction Start
El Dabaa 4	Egypt	VVER-1200/V-529	1100	23 January 2024
Zhangzhou 3	China	Hualong One	1126	22 February 2024
Leningrad II-3	Russia	VVER-1200/ V-491	1101	14 March 2024
Lianjiang 2	China	CAP1000	1161	26 April 2024
Xudabao 2	China	CAP1000	1160	17 July 2024
Ningde 5	China	Hualong One	1116	28 July 2024
Shidaowan 1	China	Hualong One	1116	28 July 2024

Permanent Shutdowns 1 January - 31 July 2024

	Location	Model	Net Capacity (MWe)	Permanent Shutdown
Kursk 2	Russia	RBMK-1000	925	31 January 2024
Maanshan 1	Taiwan, China	WE 312	936	28 July 2024

5 Director General's concluding remarks

Last year's report noted the ever-growing policy support for nuclear; this year momentum has increased further. At the COP28 climate change conference in Dubai in December 2023, nuclear energy received high-level recognition for the first time. Leaders from 25 governments signed a ministerial declaration committing to the tripling of global nuclear energy capacity to achieve net zero by 2050. Notably, countries currently without nuclear energy, such as Ghana, Jamaica, Mongolia, Morocco, and Poland, signed the declaration alongside long-established nuclear energy countries, such as France, South Korea, the UK, and the USA.

The industry responded to the ministerial declaration with the Net Zero Nuclear pledge, signed by more than 120 companies supporting nuclear energy worldwide. The World Nuclear Performance Report 2023 data and case studies illustrate the work being done to improve operational performance and make the most of the current nuclear fleet. At the same time, a significant increase in new nuclear construction is necessary if the tripling goal is to be achieved. This level of construction depends on the nuclear industry rising above the financing, supply chain and regulatory challenges faced by new projects, particularly in the Western world.

Governments are increasingly creating supportive policy environments to advance nuclear development for both small and large plants with a range of applications, with resurgence in the USA, Canada, and many European countries. Meanwhile, in Asia – particularly in China, India and South Korea – continues to pursue clear energy and industrial growth strategies that include nuclear power. Nuclear has rapidly become a significant component of the UAE energy mix, while the new build programmes of other newcomers such as Bangladesh, Egypt, and Turkey are proceeding well.

Nuclear technologies will have a broader role than traditional grid electricity supply. There is increasing interest from end energy users such as data centres, which have high electricity requirements, and industrial producers, that require heat for chemical and material production applications or desalination. This offers the potential to decarbonize the wider economy, especially hard-to-abate sectors.

The global nuclear reactor fleet has a proven track record of excellent performance. It is now time to build on that track record and significantly accelerate the pace of new nuclear construction. Today, there are 64 reactors under construction around the world, with many more planned and proposed in both new and established nuclear countries. The industry is set for a major expansion, and we can expect more governments and companies to sign the declaration to triple global nuclear energy capacity. Additionally, we anticipate increased collaboration with other industries. Now is the time for the nuclear industry to capitalize on this momentum and deliver the full potential of nuclear energy for people and planet.

Sama Bilbao y León,
Director General
World Nuclear Association
July 2024

Background information

Acknowledgement

World Nuclear Association is grateful to the International Atomic Energy Agency (IAEA) for access to its Power Reactor Information System (PRIS) database, and use of its data in the preparation of this report.

Definition of Capacity Factor

Capacity factors are calculated as the percentage obtained by dividing a reactor's actual electricity output by the output expected if the reactor operated constantly at 100% of its net capacity. When calculating capacity factors, those reactors that do not generate any electricity during the calendar year are not included. For reactors that start-up or shut down during a calendar year the capacity factor for that year is calculated based on the electricity output that would have been generated were they to operate at 100% output for the fraction of the year in which they were in an operable status.

Reactor Statuses

The IAEA PRIS reactor database has a status type – Suspended Operation – differentiated from its Operating status. As of 1 August 2024, this status has been assigned to 21 reactors in Japan, which have not restarted since their outage after the 2011 accident at Fukushima Daiichi. It has also been assigned to four reactors in India: Madras 1, Rajasthan 1, Tarapur 1 and Tarapur 2.

World Nuclear Association uses the Operable status for reactors categorized by IAEA as Suspended Operation or Operable, with the exception of Rajasthan 1, which we consider to be in Permanent Shutdown status.

Ukraine

Performance data for reactors in Ukraine have not been provided to the IAEA PRIS database for 2022 and 2023. Estimates for output from Ukraine reactors are based on other data sources, such as overall electricity output from nuclear power plants in Ukraine published by the International Energy Agency, using Ukrainian electricity transmission system operator (UKRENERGO) data, for the period 1 January 2022 to 27 October 2022, and data published in Energy Institute's 2024 Statistical Review of World Energy.

Abbreviations

AGR	Advanced gas-cooled reactor
BWR	Boiling water reactor
CO_2	Carbon dioxide
COVID-19	Disease caused by the SARS-CoV-2 coronavirus
FNR	Fast neutron reactor
FOAK	First-of-a-kind
g	gram
GWe	Gigawatt (one billion watts of electric power)
IAEA	International Atomic Energy Agency
MWe	Megawatt (one million watts of electric power)
PHWR	Pressurized heavy water reactor
PRIS	Power Reactor Information System database (IAEA)
PWR	Pressurized water reactor
SMR	Small modular reactor
TWh	Terawatt hour (one trillion watt hours of electricity)
VVER	Vodo-Vodyanoi Energetichesky Reaktor (a PWR)

Geographical Categories

Africa
Egypt, South Africa

Asia
Armenia, Bangladesh, China mainland and Taiwan, India, Iran, Japan, Kazakhstan, Pakistan, South Korea, Turkey, United Arab Emirates (UAE)

East Europe & Russia
Belarus, Russia, Ukraine

North America
Canada, Mexico, United States of America (USA)

South America
Argentina, Brazil

West & Central Europe
Belgium, Bulgaria, Czechia, Finland, France, Germany, Hungary, Italy, Lithuania, Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom (UK)

Further Reading

World Nuclear Association Information Library
https://world-nuclear.org/information-library

World Nuclear Association Reactor Database
https://world-nuclear.org/nuclear-reactor-database/summary

World Nuclear News
https://www.world-nuclear-news.org

International Atomic Energy Agency Power Reactor Information System
https://pris.iaea.org/pris/home.aspx

World Nuclear Association is the industry organization that represents the global nuclear industry. Its mission is to promote a wider understanding of nuclear energy among key international influencers by producing authoritative information, developing common industry positions, and contributing to the energy debate, as well as to pave the way for expanding nuclear business.

World Nuclear Association
York House
23 Kingsway
London WC2B 6UJ
United Kingdom

+44 (0)20 7451 1520
www.world-nuclear.org
info@world-nuclear.org

World Nuclear Performance Report 2024