WORLD NUCLEAR ASSOCIATION

World Nuclear Performance Report 2021

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Preface

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In 2020, nuclear reactors supplied 2553 TWh of electricity, down from 2657 TWh in 2019. In any other year an almost four percent decline in nuclear generation would be an unequivocal disappointment. However, in 2020, with overall electricity demand falling by around 1% and nuclear reactors increasingly being called upon to provide load-following support to the increased share of variable renewable generation, the resilience and flexibility shown by the global nuclear fleet tell a very positive story.

Despite some reactors curtailing generation to account for reduced demand or to offer load-following services, the global capacity factor in 2020 was still high at 80.3%, down from 83.1% in 2019, but maintaining the high performance seen over the last 20 years.

At the end of 2020 there were 441 operable nuclear reactors, with a combined capacity of 392 GWe. This total capacity has remained almost unchanged for the last three years. Five new reactors started up, but this increase in capacity was countered by the closure of six reactors. Between 2018 and 2020 there have been 26 reactors permanently shutdown with a total capacity of 20.8 GWe, compared to 20 new reactors starting up, with a total capacity of 21.3 GWe.

The IPCC recently published the first part of its Sixth Assessment Report. This report confirmed what we have known for many years - global greenhouse gas emissions need to fall fast if we are to have any chance of limiting the effects of climate change to manageable levels.

With global electricity demand expected to rebound sharply, there is a real risk that greenhouse gas emissions will do so as well, as they did following the recovery from the economic collapse in 2008.

More than half of the reactors permanently shutdown in the last few years have done so not because of technical limitations, but because of political phase-out policies or the failure of markets to adequately recognize the value of low carbon reliable nuclear power. This is a loss of low-carbon generation that the world can ill-afford to squander.

However, there are promising signs for nuclear. Already in 2021 we have seen four new reactors connected to the grid and construction started on seven new reactors, although two reactors have permanently shutdown.

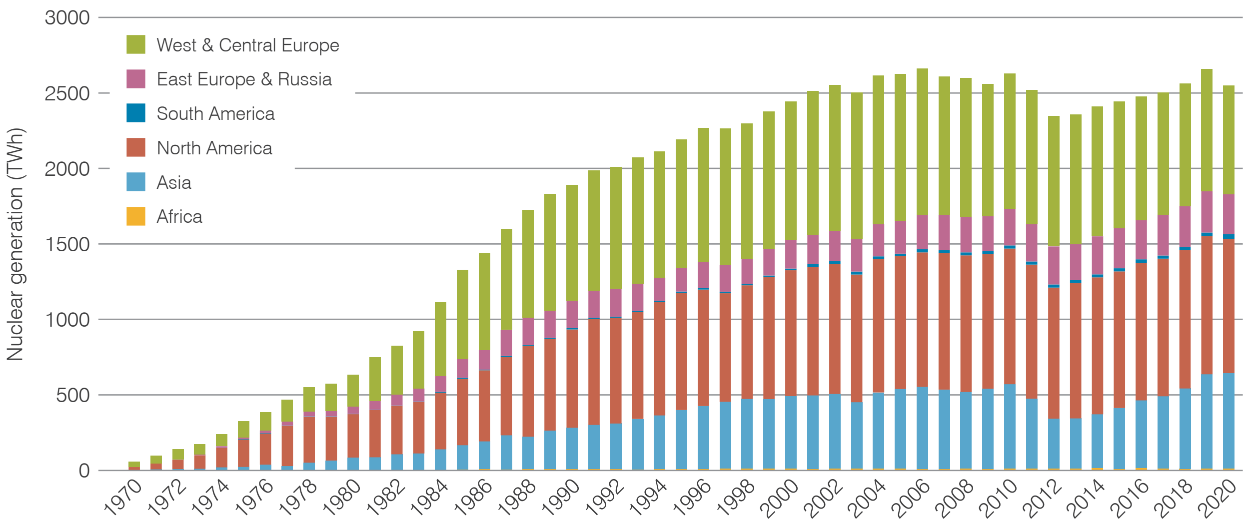
It is vital that nuclear generation bounces back further and faster, helping displace fossil fuels, thus avoiding a sharp rise in greenhouse gas emissions. The operation of the existing nuclear fleet must be maximized and extended as long as feasible, and the pace and scale of new nuclear construction must increase.

1 Nuclear Industry Performance

1.1 Global highlights

Nuclear reactors generated a total of 2553 TWh in 2020, down from 2657 TWh in 2019. Reduced electricity demand resulting from the COVID-19 pandemic saw generators curtail output in response.

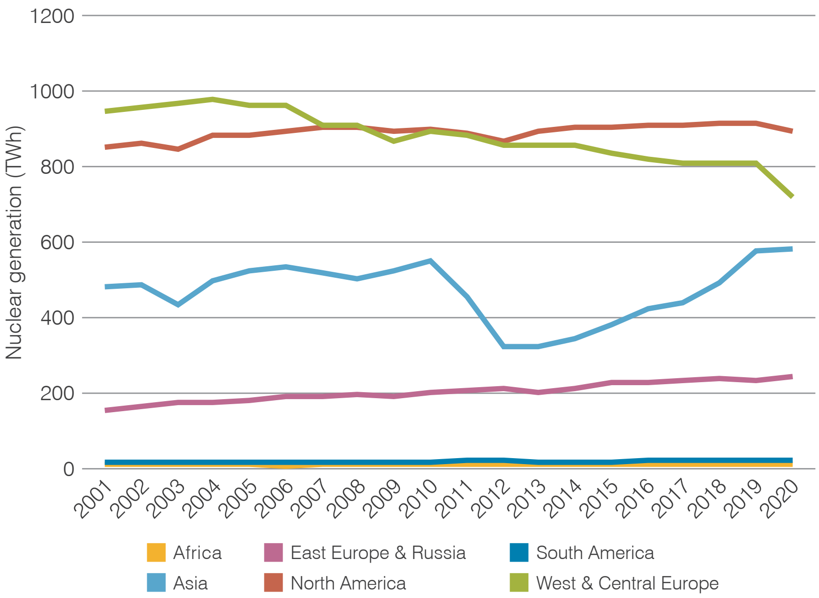
Figure 1. Nuclear electricity production



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

In 2020 generation declined in Africa, North America and in West & Central Europe. Generation rose in Asia, although by a much smaller amount than in recent years. Generation was almost unchanged in East Europe & Russia, and South America.

Figure 2. Regional generation



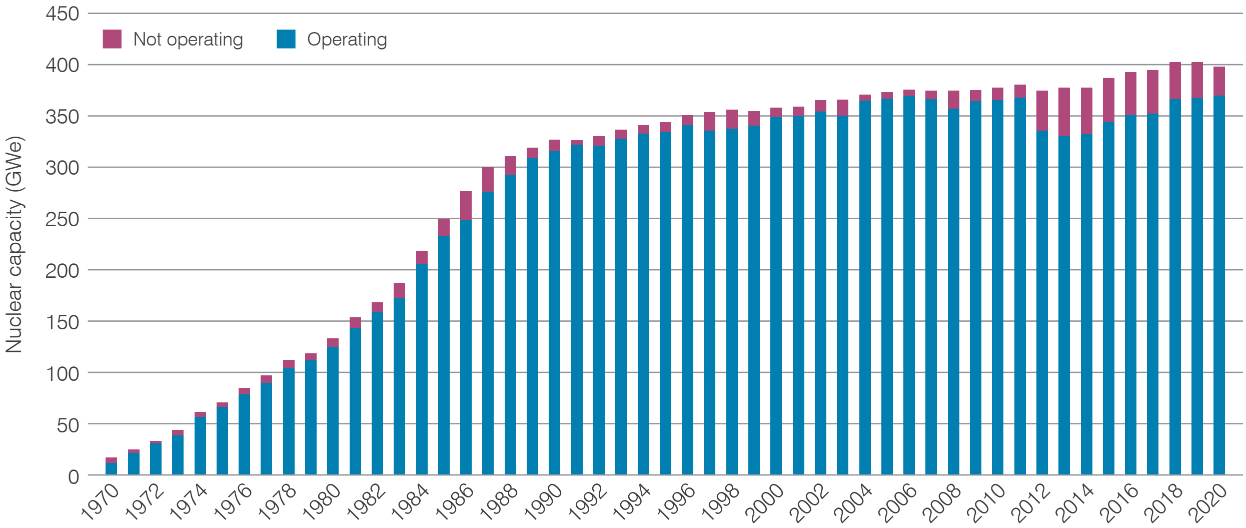
Source: World Nuclear Association, IAEA PRIS

In 2020 the end of year capacity of operable nuclear power plants was 392 GWe.

In most years, a small number of operable reactors do not generate electricity. However, in the years following the Fukushima Daiichi Accident in 2011, all reactors in Japan were closed down pending approval to restart. As more reactors in Japan restart, and the decision is made to permanent shutdown other reactors, the number of reactors operable, but not generating, has gradually reduced. The total capacity of reactors producing electricity in 2020 was 369 GWe, which is the highest ever total capacity of reactors generating electricity in one year.

369 GWe of nuclear capacity produced electricity in 2020, the highest ever

Figure 3. Nuclear generation capacity operable (net)



Source: World Nuclear Association, IAEA PRIS

At the end of 2020 there were 441 operable reactors, down one on 2019. Of the 392 GWe total operable capacity, nearly three quarters was comprised of PWRs.

Table 1. Operable nuclear power reactors at year-end 2020

	Africa	Asia	East Europe & Russia	North America	South America	West & Central Europe	Total
BWR		21		33 (-1)		9 (-1)	63 (-2)
FNR			2				2
GCR						14	14
LWGR			12 (-1)				12 (-1)
PHWR		24		19	3	2	48
PWR	2	95 (+3)	40 (+2)	63 (-1)	2	100 (-2)	302 (+2)
Total	2	140 (+3)	54 (+1)	115 (-2)	5	125 (-3)	441 (-1)

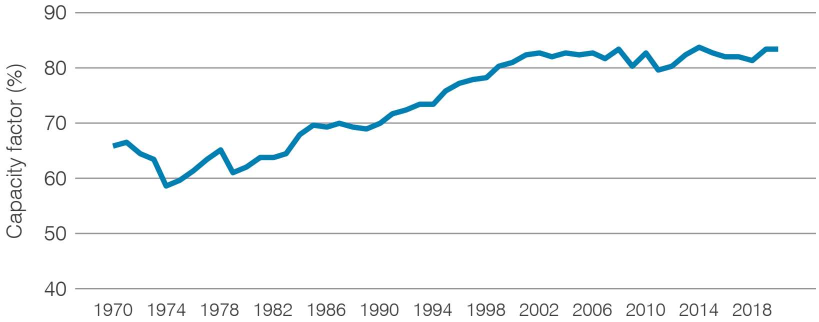
Source: World Nuclear Association, IAEA PRIS

1.2 Operational performance

Capacity factors in this section are based on the performance of those reactors that generated electricity during each calendar year. From this edition, we also report capacity factors taking account of a reactor's start-up or closure dates.

In 2020 the global average capacity factor was 80.3%, down from 83.1% in 2019. This continues the trend of high global capacity factors seen since 2000, even though some reactors were required to operated more in a load-following mode in 2020 due to suppressed demand for electricity during the COVID-19 pandemic.

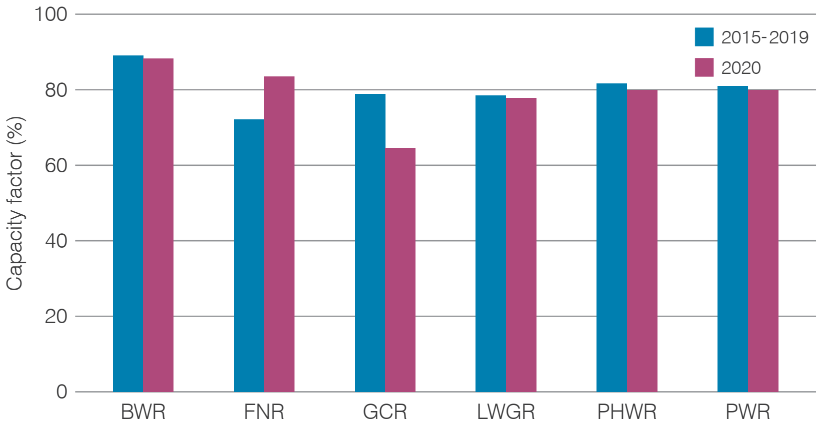
Figure 4. Global average capacity factor



Source: World Nuclear Association, IAEA PRIS

Capacity factors for different reactor types in 2020 were broadly consistent with those achieved in the previous five years. Capacity factors show the greatest variation where there are relatively few reactors of that type in operation.

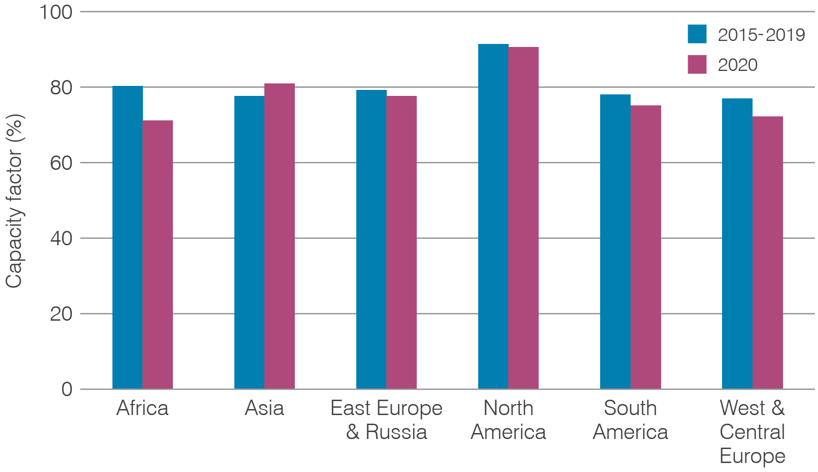
Figure 5. Capacity factor by reactor type



Source: World Nuclear Association, IAEA PRIS

Capacity factors in 2020 were also broadly consistent with the average achieved in the previous five years for reactors in different geographical regions.

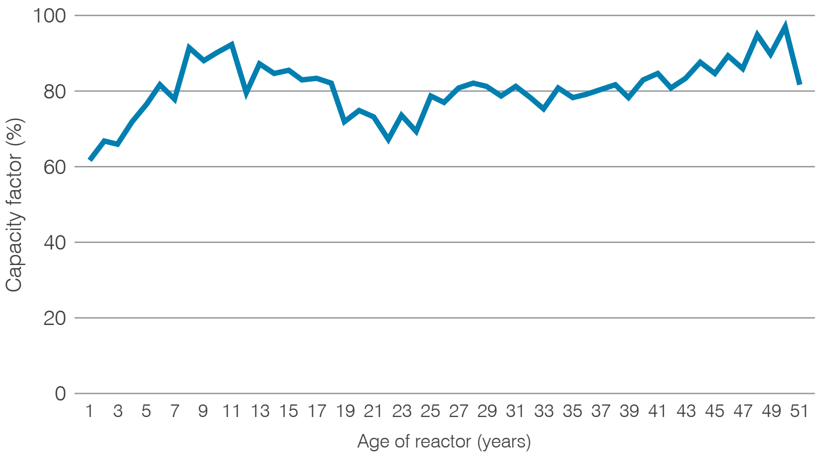
Figure 6. Capacity factor by region



Source: World Nuclear Association, IAEA PRIS

There is no age-related trend in nuclear reactor performance. The mean capacity factor for reactors over the last five years shows no significant overall variation with age. With some reactors now being licensed to operate for 80 years the consistency in performance of reactors regardless of age is notable. It is also notable that the improvements in average global capacity factor have been achieved in reactors of all ages, not just new reactors of more advanced design.

Figure 7. Mean capacity factor 2016-2020 by age of reactor

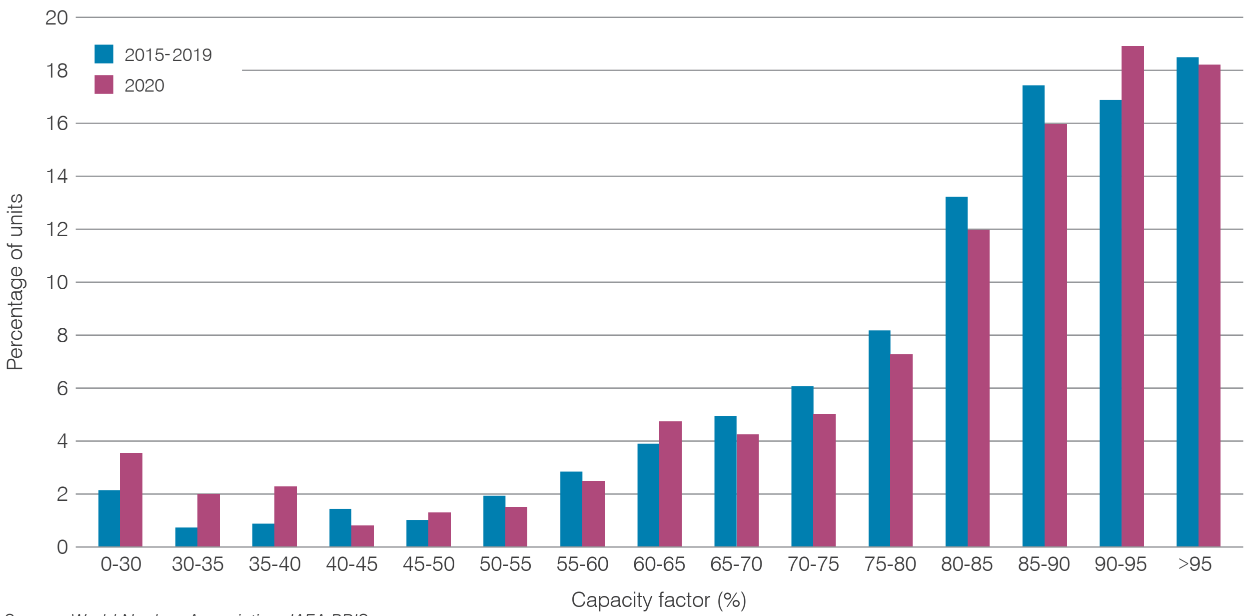


Source: World Nuclear Association, IAEA PRIS

Improvements in capacity factors have been achieved in reactors of all ages

The spread of capacity factors in 2020 is broadly similar to the average of the previous five years. Just under two-thirds of reactors having a capacity factor greater than 80%. The share of reactors with capacity factors less than 40%, although still small, is higher than the previous five-year average.

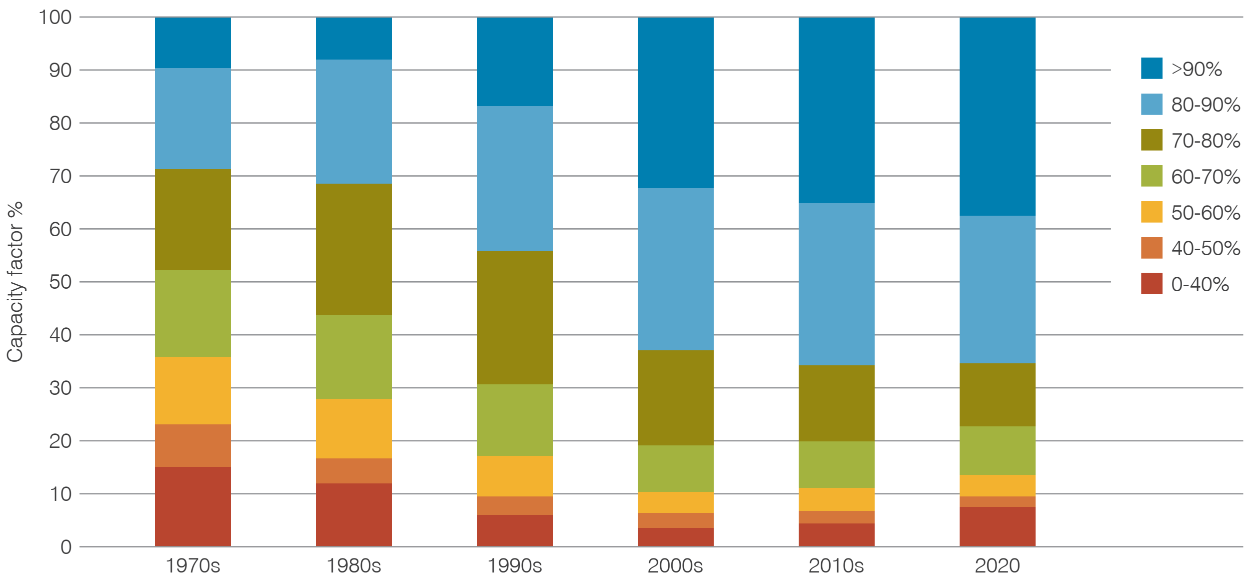
Figure 8. Percentage of units by capacity factor



Source: World Nuclear Association, IAEA PRIS

Even accounting for the revised capacity factor calculations, which show higher capacity factors for reactors in the 1970s and 80s than previously stated, a steady improvement in reactor performance can be seen in the following chart, which presents the average capacity factors in each decade since the 1970s.

Figure 9. Long-term trends in capacity factors



Source: World Nuclear Association, IAEA PRIS

Six reactors were permanently shut down in 2020. The two Fessenheim reactors were closed as a result of a political decision to reduce the share of nuclear generation in the French electricity generation mix. The two US reactors closed because of market conditions. Ringhals 1 closed despite being called on to restart during 2020 to provide voltage stability to the Swedish grid. In Russia, the Leningrad reactor closed as the second of two new reactors at the site started up to replace it.

Table 2. Shut down reactors in 2020

	Location	Capacity (MWe net)	First grid connection	Permanent shutdown date
Fessenheim 1	France	880	06 April 1977	22 February 2020
Indian Point 2	USA	998	26 June 1973	30 April 2020
Fessenheim 2	France	880	07 October 1977	30 June 2020
Duane Arnold	USA	601	19 May 1974	12 October 2020
Leningrad 2	Russia	925	11 July 1975	10 November 2020
Ringhals 1	Sweden	881	14 October 1974	31 December 2020

Source: World Nuclear Association, IAEA PRIS

1.3 New construction

Construction started on the second unit at Akkuyu in Turkey. In addition, construction on three HPR1000 (Hualong One) units started in China.

Table 3. Reactor construction starts in 2020

	Location	Model	Design net capacity	Construction start date
Akkuyu 2	Turkey	VVER - 1200	1114	8 April 2020
Zhangzhou 2	China	Hualong One	1126	4 September 2020
Taipingling 2	China	Hualong One	1116	15 October 2020
San'ao 1	China	Hualong One	1117	31 December 2020

Source: World Nuclear Association, IAEA PRIS

With four construction starts and five reactors connected to the grid, the total number of units under construction at the end of 2020 was one less than the end of 2019.

Table 4. Units under construction by region year-end 2020

	BWR	FNR	HTGR	PHWR	PWR	Total
Asia	2	2	1	4	27	36
East Europe & Russia					6	6
North America					2	2
South America					2	2
West & Central Europe					6	6

Source: World Nuclear Association, IAEA PRIS

Five reactors were connected to the grid for the first time in 2020. Two countries, Belarus and United Arab Emirates, were hosting their first nuclear reactors. Both countries have further units under construction.

Table 5. Reactor grid connections in 2020

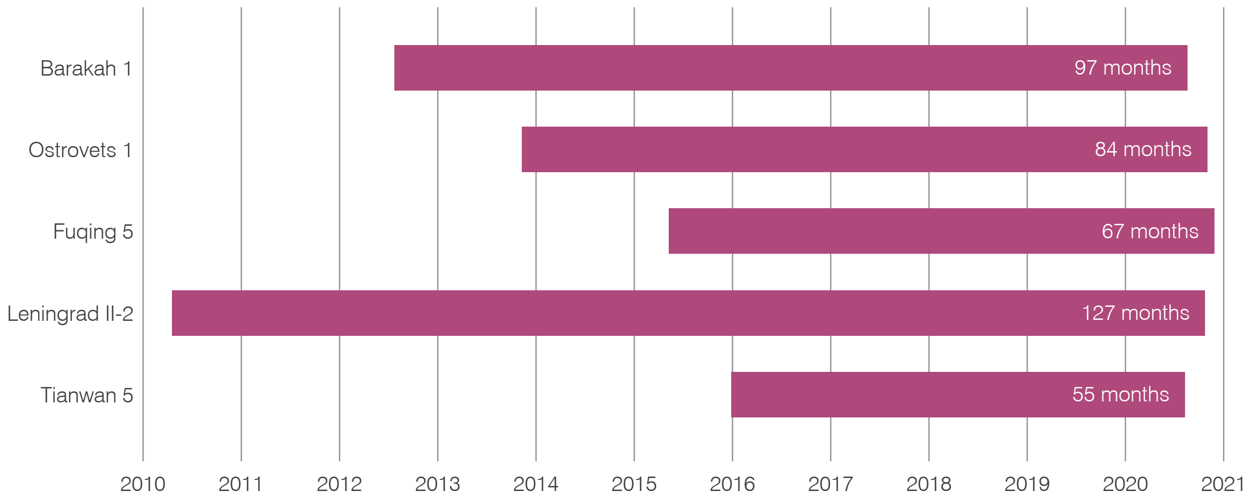
	Location	Capacity (MWe net)	Construction start	First grid connection
Barakah 1	United Arab Emirates	1345	19 July 2012	19 August 2020
Ostrovets 1	Belarus	1110	8 November 2013	3 November 2020
Fuqing 5	China	1000	7 May 2015	27 November 2020
Leningrad II-2	Russia	1066	15 April 2010	22 October 2020
Tianwan 5	China	1000	27 December 2015	8 August 2020

Source: World Nuclear Association, IAEA PRIS

Leningrad II-2 is the second VVER-1200/V-491 unit to enter service, following on from the first unit at Leningrad II, which entered service in 2018. Belarus's first nuclear reactor is also a VVER-1200/V491, which although starting construction more than three years after the Leningrad unit, was grid connected less than one month after.

The two shortest construction times were achieved by the two Chinese reactors, where series build and the retention of skills through the ongoing new build programme have help contribute to more rapid construction times.

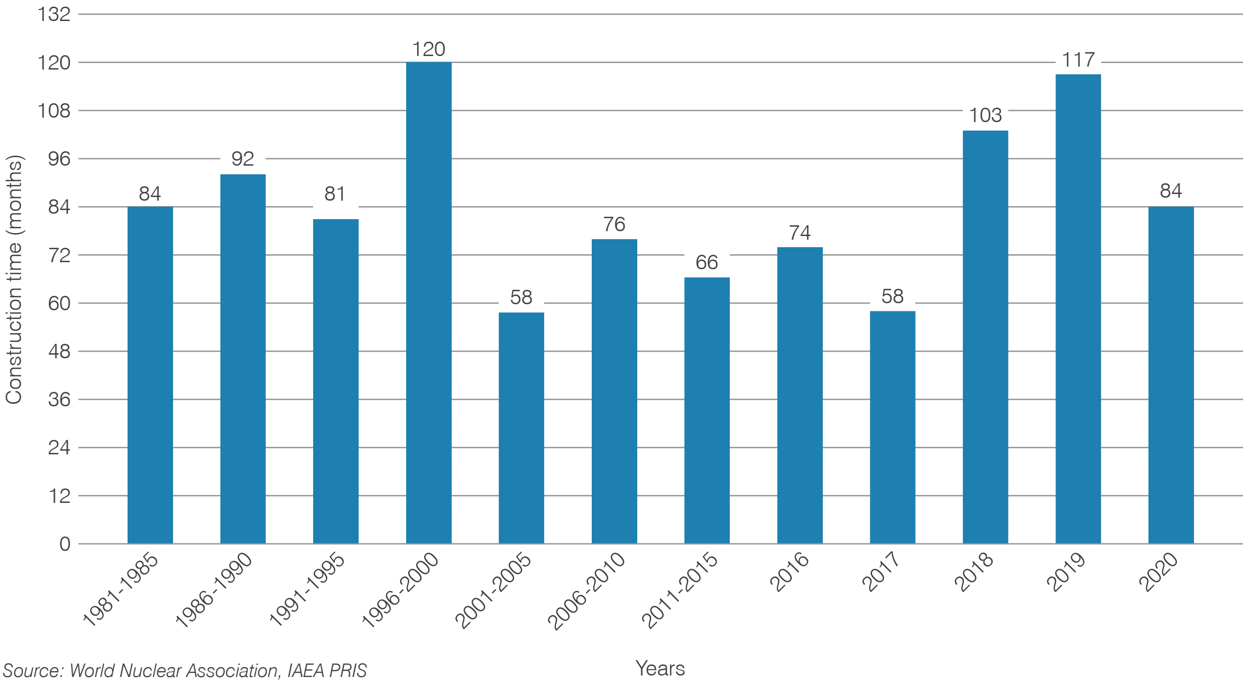
Figure 10. Construction times of new units grid connected in 2019



Source: World Nuclear Association, IAEA PRIS

The median construction time for reactors grid connected in 2020 was 84 months, a substantial reduction on the median construction times in 2019 and 2018.

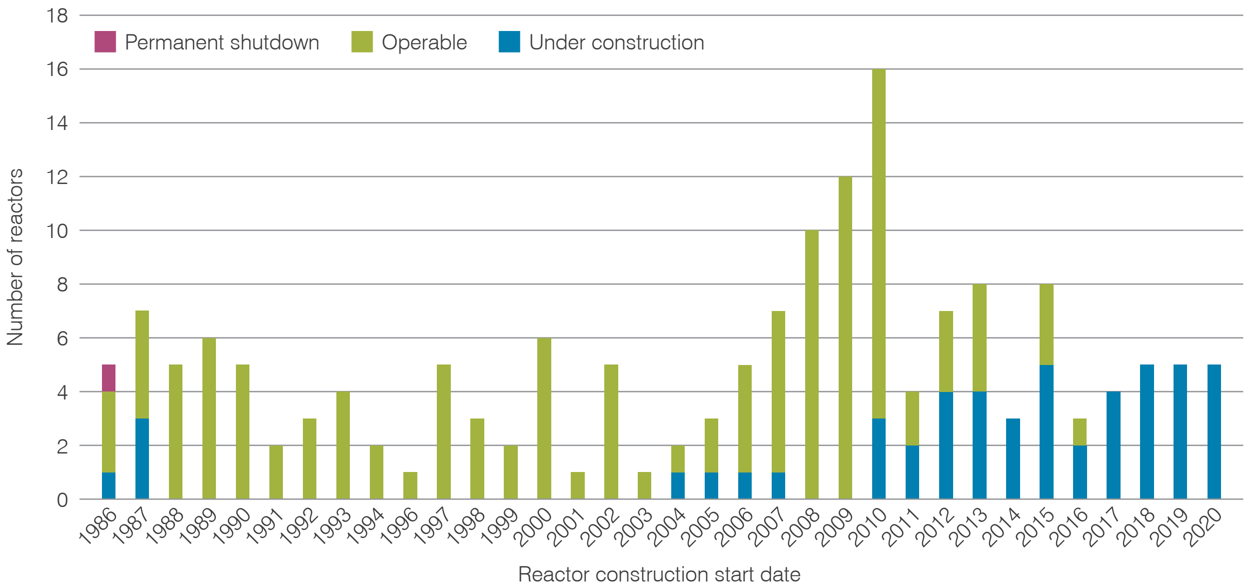
Figure 11. Median construction times for reactors since 1981



Source: World Nuclear Association, IAEA PRIS

Most reactors under construction today started construction in the last ten 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. In the case of Khmelnitski 3&4, two reactors that started construction in 1986 and 1987, there have been attempts to restart construction, but no active progress since 1990.

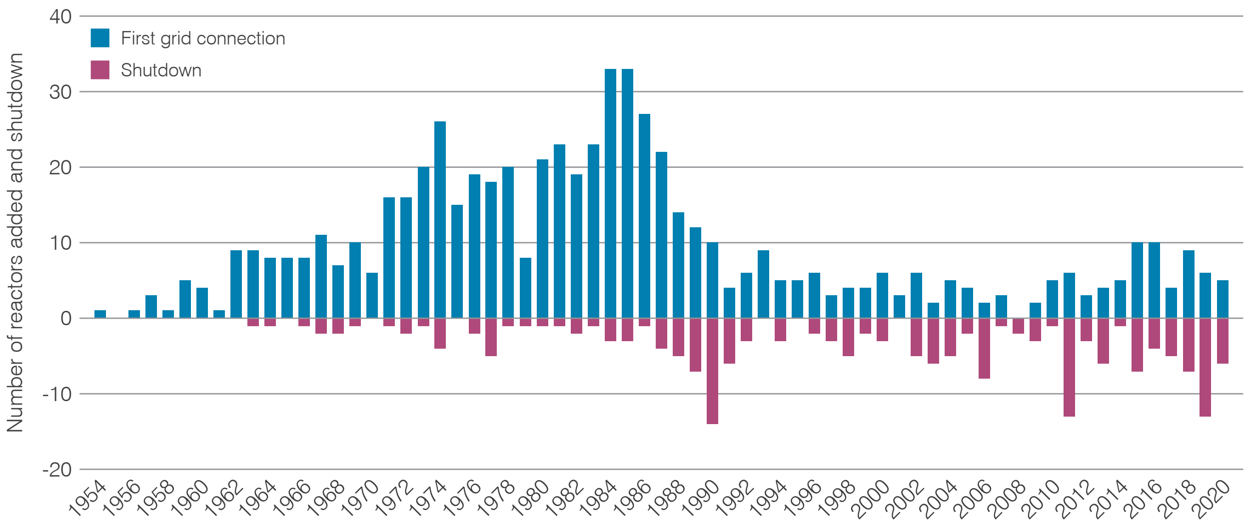
Figure 12. Operational status of reactors with construction starts since 1985



Source: World Nuclear Association, IAEA PRIS

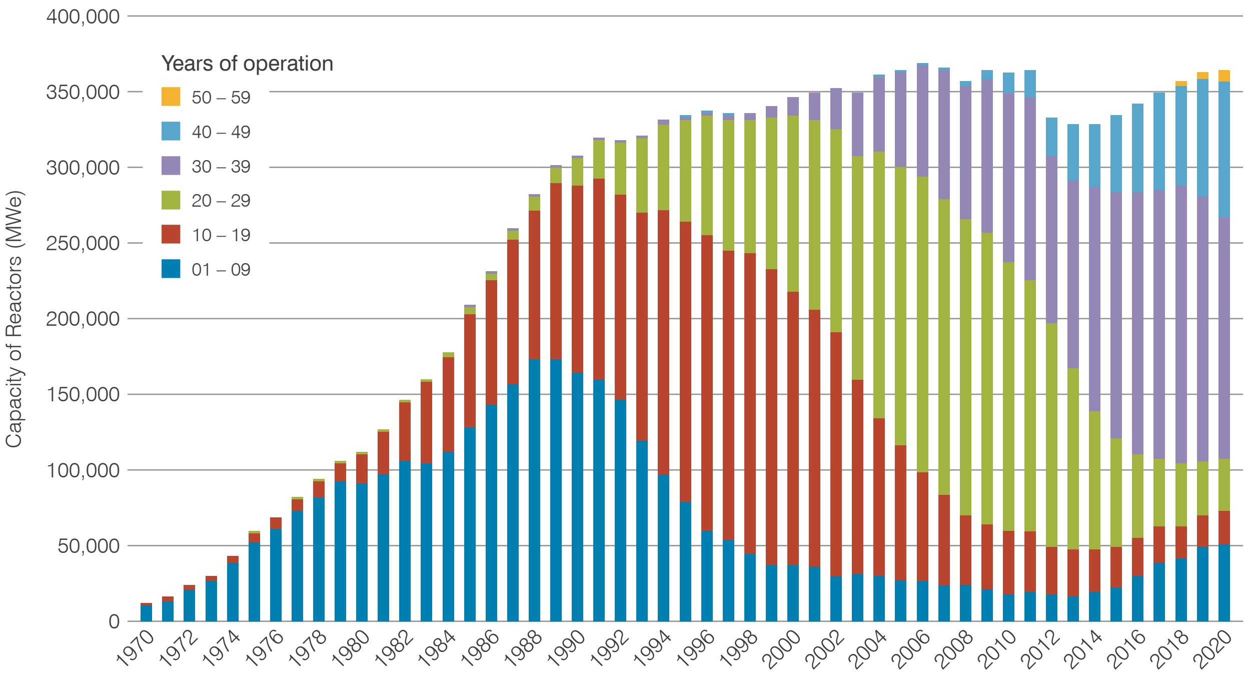
In 2020 five reactors were grid connected and six were permanently shut down. In terms of capacity 5521 MWe was grid connected and 5165 MWe was shut down. In the case of Fessenheim 1&2, the closure of these reactors was driven by French national policy to reduce the share of nuclear generation in its electricity mix. Both US units, Indian Point 2 and Duane Arnold, were closed ahead of their operating licences, which ran to 2024 and 2034 respectively.

Figure 13. Reactor first grid connection and shutdown 1954-2020



Source: World Nuclear Association, IAEA PRIS

Figure 14. Evolution of reactor ages



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

Figure 14 shows the total capacity of reactors of different ages operating in any one year since 1970. As time passes those reactors that remain in operation move into the next category every ten years.

The total capacity of reactors that have been in operation for less than 10 years declined from around 1990, as the pace of new reactor start-ups slowed. With increased construction and subsequent commissioning of reactors in recent years the total capacity of reactors that have been in operation less than 10 years old has started to increase again.

2 | Case Studies

Grohnde: Producing a record amount of low-carbon electricity

Grohnde nuclear power plant was first synchronized with the power distribution grid at 14:11 on 5 September 1984. Since it was first commissioned, Grohnde has been the reactor with the world's highest annual electricity output on eight separate occasions.

Another record was made on 7 February 2021 when Grohnde became the first reactor to produce its 400 billionth kilowatt hour of electricity. To date, no other nuclear unit in the world has produced more electricity.

This electricity generation has helped to reduce emissions of climate-damaging greenhouse gases, especially carbon dioxide (CO_2). Grohnde has saved approximately 400 million tonnes of CO_2 during its 36 years of operation.

Operational flexibility

During the first years of operation, Grohnde mainly provided stable base-load power. However, more recently, the plant has increasingly provided system services (standby work). Due to the increasing proportion of fluctuating solar and wind energy being fed into the electricity network, it has become more and more important to safeguard its stability. Grohnde has responded by raising its reactor output, improving efficiency, increasing load gradients and also by installing adaptive power distribution control technology in April 2016.

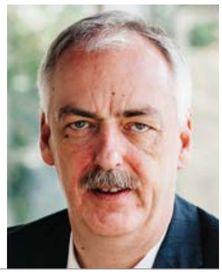
Grohnde nuclear power plant

First grid connection	5 September 1984
Capacity (thermal)	3900 MWt
Net capacity (electrical)	1360 MWe
Operator	PreussenElektra GmbH

Decommissioning dialogue with the public

In line with the phase-out of nuclear energy in Germany, Grohnde will cease commercial operation at the end of this year. Majority owner PreussenElektra is already planning the decommissioning of the power plant. PreussenElektra's transparent information policy, which it still practices today, is based on regular conversations with political, industrial and media representatives as well as on various communication materials for different occasions and target groups. This communication strategy has enabled PreussenElektra to maintain trust and, at the same time, strengthen the reputation of its nuclear power plants. PreussenElektra will continue to employ this tried and tested strategy during the dismantling of all its sites.

Grohnde NPP (Image: PreussenElektra)



Interview

Michael Bongartz, Plant Manager, Grohnde

The Grohnde plant will close down at the end of 2021. What plans are in place for the decommissioning of the reactor?

We already submitted our application in 2017 because we know from experience that permitting procedures in Germany can take several years. We hope to have the permit in our hands about a year after the shutdown, so that we can then start dismantling the reactor. The decommissioning plan has been roughly drawn up and there are already preparatory projects, *e.g.* on the future heat supply for the plant. There is also a personnel plan for the dismantling operations – we are currently in talks with the employee representatives about the framework for a socially acceptable adjustment of the personnel structure over the next few years.

What has been the relationship between the plant and the local community during the construction and operation of the reactor, and what will the transition to the decommissioning phase mean for that relationship?

Good and trusting contacts, regular exchange, generally a good deal of understanding for our approach at the site. We are working to ensure that this remains the case. There has always been criticism from a few opponents of nuclear power. Critics are now divided into those who constructively support dismantling and those who also condemn dismantling and the associated disposal – as we go about it. Criticism there, however, is directed less at us as operators than at the legal regulations in Germany.

What has been the effect of the growing share of renewable generation in Germany? Has Grohnde had to change the way it operates?

That is definitely the case. While we used to run at full load continuously in the past, we have to reduce output almost daily now. This is a situation to which we first had to adjust our plant. Due to the increasing feed-in of fluctuating renewables such as solar and wind energy, the demands on the stability of the grid have increased continuously. Grohnde reacted to this development by increasing load gradients and introducing adaptive power distribution. Thus, in 2020, Grohnde not only provided 379,652 MWh (11 full-load days) of so-called standby work, but also stabilized the grid for 4,700 hours by participating in redispatch or via primary and secondary control at the request of the grid operator.

The Grohnde reactor has produced more electricity than any other nuclear reactor to date. What does that mean to you and your colleagues at the plant?

It makes us very proud. It also means a lot to us since we have been able to show the numerous critics in Germany that nuclear power plants can be operated safely. Additionally, it demonstrates that our operational management has proven itself: via constant inspection of the plant, preventive maintenance of the components and our critical and scrutinizing basic attitude.

Employees at a preheater (Image: PreussenElektra; Photographer: Regine Rabanus)

Haiyang nuclear plant district heating project

Haiyang units 1&2

Haiyang nuclear power plant currently consists of two AP1000 PWRs, which started operating in 2018. Four more 1000 MWe reactors are planned for the site, with space reserved for an additional two.

In a PWR, the heat generated by the nuclear reactor is transferred to the secondary circuit through the steam generator to produce steam which then drives the steam turbine unit to generate electricity. The turbine extracts much of the energy of the steam, which is then cooled and condensed and returned to the feedwater circuit.

However, the steam leaving the turbine can also be used for heat supply. The main principle of nuclear heat supply is to extract steam from the secondary circuit of the nuclear power unit as a heat source.

In the Haiyan reactors, steam is subject to multi-stage heat exchange through the first exchange station inside the plant and the exchange station of the heat supply companies outside the plant. The heat is transferred to the final users via a municipal heating pipe network.

Using the heat supply capability of large-scale nuclear power plants, such as Haiyan, while maintaining annual power generation capacity provides cities with affordable low-carbon heat and electricity, a win-win situation for social and environmental benefits.

Putting it into practice

Shandong Nuclear Power has carried out research and practice of nuclear power steam extraction for heating, taking account of the needs of the region while ensuring the continued operation of the two units.

The 700,000 m^2 phase I heating project was officially put into operation on 15 November 2019. Residents and the heating companies have generally reported that nuclear heating is reliable, stable and effective. The 4,500,000 m^2 phase II heating project started construction in November 2020 and is expected to put be into operation in the colder months, later in 2021. At that time, the nuclear heating could provide full coverage of the the urban area of Haiyang city.

Interview

Wu Fang, Chairman of Shandong Nuclear Power Company

What is the process that converts heat from the plant to heat for the customers? Does it require specific human and technical resources?

In the whole process, there are actually two major steps: steam heats water and then water heats water. There is no direct contact between the nuclear power plant and heating users. Multiple isolation barriers have been set up. Only heat is transferred, without water exchange. What the users do come into contact with is the safe hot water that has been isolated layer by layer.

What effect does the supply of heat have on the overall operations of the plant and is there any impact on the supply of electricity or the performance of the reactor?

At present, the 700,000 m^2 phase I Haiyang Nuclear Power Steam Extraction for Heating project has been safely operated for two heating seasons. The National Energy Administration and the Shandong Provincial Energy Administration organized an independent third-party evaluation of the operation. The conclusion is that "it's clean, safe, stable, and efficient. It improves the nuclear energy utilization efficiency technically, possesses compatible competitiveness with coal-fired heating economically and has great value for large-scale promotion and application."

During the operation of the phase I heating project, the two units of the Haiyang nuclear plant continued to operate safely and stably. A comprehensive and in-depth safety analysis, showed that after nuclear power steam extraction heating, the turbine generator set and other systems and equipment can still operate normally within the allowed scope of the original design.

After the 4,500,000 m^2 phase II heating project is put into operation, the power generating capacity of the units will decrease, but the cycle thermal efficiency of the nuclear power plant will be increased by 3.25%. Therefore, the heating has no effect on the performance of the reactor.

How is the supply of heat for customers maintained through refuelling, or other outages?

Haiyang nuclear power project has already put two units into operation, which can back up each other in terms of providing nuclear power steam extraction as the heating source. At the same time, an emergency heating source is installed outside the nuclear power plant, which can guarantee the heating for residents during a short-term outage of the nuclear power plant.

Are there any particular characteristics of the AP1000 that make it more suitable to supply electricity and district heating, or would this be an option for other reactors?

The nuclear heat supply realized by Haiyang nuclear power plant can be applied to various large-scale PWR nuclear power plants in terms of business model and technology.

Akkuyu: Building first nuclear power plant in Turkey

Rosatom State Corporation is constructing the Akkuyu nuclear power plant based on the intergovernmental agreement (IGA) signed between the governments of Russia and Turkey on 12 May 2010.

Akkuyu will have four power units equipped with Generation III+ VVER-1200 reactors with a capacity of 1200 MW each. The design service life of the reactors is 60 years with the possibility of extension.

The plant is expected to generate about 35 TWh per year when all four units are commissioned. This amount is enough to meet about 90% of the electricity needs of a large metropolis such as Istanbul. Akkuyu will be able to meet up to 10% of Turkey's power demand.

Rosatom is the majority shareholder of Akkuyu NPP. The project is implemented as per the build-own-operate (BOO) model. This is the world's first BOO business case for a nuclear power plant.

Akkuyu Nuclear JSC, a company of Rosatom, is responsible for the design, construction, maintenance, operation and decommissioning of the nuclear power plant.

Akkuyu nuclear power plant

Reactor type	VVER-1200
Total installed capacity	4800 MWe
Design service life	60 years +
Start of construction:	
Unit 1	3 April 2018
Unit 2	8 April 2020
Unit 3	10 March 2021

The Russian party is funding 100% of the project. Rosatom may sell a stake of up to 49% to other parties who wish to invest into the project. It can be either one investor for all 49% or a smaller share, or several companies. Negotiations with potential investors are in progress.

According to the IGA, the construction period of the plant unit from the issuance of all construction permits by Turkey is 7 years. The licence for the construction of unit 1 was issued in April 2018. The project team is making every effort to have the first power unit completed by the centenary of the Republic of Turkey in 2023, with safety standards remaining the top priority.

September 2019, Unit 1 reactor cavity conductor installation (Image: Akkuyu image bank, ROSATOM)

Interview

Anastasia Zoteeva, CEO, Akkuyu Nuclear JSC

What is the current status of construction works?

Construction around the site is being carried out at the maximum rate possible. At unit 1, the foundation slabs of the reactor compartment and turbine hall have been formed, the corium catcher and three tiers of the inner containment of reactor building have been installed.

In May this year, we installed the Reactor Pressure Vessel. We are going to start welding the reactor coolant pipeline that interconnects the main equipment of the primary circuit before the end of the year.

As for unit 2, the corium catcher was manufactured and installed last year, the first tier of the inner containment was installed, this year the cantilever truss was installed in the reactor compartment.

On 10 March 2021, construction began at unit 3 as the Presidents of Russia and Turkey announced via video-broadcast the launch of the full-scale work. Progress is already visible: the concreting of the foundation slabs of the reactor and turbine buildings has been completed. By the end of this year, the Nuclear Regulatory Authority of Turkey is expected to issue a construction license for unit 4.

What effect will the Akkuyu project have on the socio-economic development of Turkey and the Mersin province in particular?

Joining the club of countries that use nuclear energy not only ensures stable generation of low-carbon electricity but also means technological leadership both in the energy sector and in many related industries.

Turkey is a fast-growing economy with a young population and a huge potential. The Akkuyu project offers new opportunities for the development of technology and science, creates thousands of new highly-qualified jobs, boosts effective demand, provides an impetus for the development of service industries including tourism in the region, development of transport infrastructure, and market expansion for local manufacturers.

To meet the high international standards of the nuclear industry, all Turkish manufacturers must have special licences, so together with the Turkish Standards Institute (TSE), we have developed a special localization programme to ensure that the products and services of local companies correspond to the declared level.

What will be the contribution of Akkuyu to climate change mitigation and sustainable development?

Nuclear power is a sustainable, low-carbon form of generation. The tariffs for nuclear electricity are quite predictable. This allows for strategic planning of the development of the economy while preserving the environment.

The implementation of nuclear projects contributes to the achievement of several UN Sustainable Development Goals (SDGs) at once. Taking Akkuyu as an example: apart from the most obvious goal, SDG 7 “Affordable and clean energy”, the project contributes to economic growth and employment, development of education, efforts to address climate change, and development of partnerships in the field of sustainable development.

June 2020, Unit 1 reactor building inner containment second tier installation (Image: Akkuyu image bank, ROSATOM)

Planning for 80 years of operation at Peach Bottom

Peach Bottom NPP (Image: Exelon)

Peach Bottom Atomic Power Station is located on the west bank of the Conowingo Pond (Susquehanna River) in Delta, Pennsylvania.

In June 2016 Exelon announced that the company was seeking a Subsequent (*i.e.*, Second) License Renewal for Peach Bottom Atomic Power Station.

Peach Bottom is co-owned by Exelon Generation and Public Service and Gas of New Jersey. Exelon Nuclear operates the two of three units at Peach Bottom that are currently in operation.

The first unit at the site was Peach Bottom 1, an experimental helium-cooled, graphite-moderated high-temperature reactor that operated from 1966 to 1974. Units 2&3 are boiling water reactors that began commecial operation the same year that unit 1 closed, and are currently licensed to operate through 2033 and 2034.

The two operating units generate a combined total of 2,770 megawatts of electricity, providing carbon-free power to more than 2.7 million homes and businesses.

Together, the two units are staffed by 860 full-time employees. Annual refuelling outages bring thousands of additional workers to the station each year.

Peach Bottom units 2&3

Reactor type	2 x BWR-4 (Mark 1)
Reactor thermal capacity	2 x 3951 MWt
Combined net capacity (electrical)	2,770 MWe
First grid connection	1974

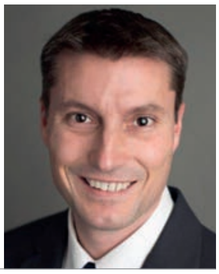
The Nuclear Regulatory Commission's (NRC) licence renewal process takes several years and requires a comprehensive review of the plant's ageing management programmes and activities that ensures the continuing health and readiness of the plant's safety systems, structures, and components to perform their protective design functions throughout the second period of extended operation

A second licence renewal enables Peach Bottom units 2&3 to operate for an additional 20 years; until 2053 and 2054.

Many of Peach Bottom's major components have been replaced or upgraded as part of a seven-year Extended Power Uprate (EPU) project, including the station's high- and low-pressure turbines, steam dryers, main generators and main power transformers.

As part of the project, Exelon has invested in new equipment and new technologies to increase Peach Bottom's generation capacity by approximately 12%. Peach Bottom is now generating an additional 270 megawatts of electricity, enough power for more than 250,000 regional homes and businesses, while saving more than two million tonnes of carbon dioxide each year.

In January 2018, Peach Bottom completed a Measurement Uncertainty Recapture (MUR) uprate on each of its two operating units. During the uprate, previously installed meters were recalibrated to provide a more precise measurement of the reactor's thermal power level. Because only minor modifications to the plant were necessary, the uprates were an effective way to generate additional electricity without the need for new construction. Completion of the uprate has enabled Peach Bottom to generate approximately 22 MWe additional power per unit.



Interview

Matthew Herr, Vice President, Peach Bottom Atomic Power Station Site

What made Peach Bottom a good candidate for a second licence renewal?

Since 2010, Exelon has invested in new equipment and new technologies to increase Peach Bottom's generation capacity by approximately 12%. Peach Bottom now generates an additional 314 megawatts of carbon-free electricity, enough power for approximately 310,000 more regional homes and businesses, while saving more than two million tonnes of CO_2 each year.

Many of Peach Bottom's major components, including the station's high and low-pressure turbines, steam dryers, main generators and main power transformers have been replaced or upgraded. With these state-of-the art technology upgrades and new equipment installations in place, Peach Bottom is positioned to continue running safely, more reliably and more efficiently for many years. We do not foresee any changes in the plant operations in the licence extension period.

Why did Peach Bottom request a licence renewal so far in advance?

Peach Bottom's current operating licences were due to expire in 2033 and 2034. The second operating licence allows the plant to operate until 2053 and 2054, as long as it continues to meet the NRC's stringent requirements for safety and operational performance. We applied for the second licence renewal in July 2018 because the NRC's licence renewal application process is a rigorous, multi-year procedure that includes comprehensive design reviews and inspections. Most applications are more than 2,000 pages and require a detailed review of historical equipment and component performance as well as a rigorous review of the existing maintenance and engineering programmes to ensure that the station can maintain plant systems over the extended licence period.

What will the licence extension mean to people working at the plant and to the local communities around Peach Bottom?

This licence renewal is extremely important for our employees and the local community. The opportunity for long-term employment helps build a more stable community. Our employees also give their time, talent and funds to charitable organizations surrounding the plant, which benefits everyone.

Additionally, if Peach Bottom continues to run through 2054, it is estimated that its clean energy production would avoid more than 486 million tonnes of carbon from entering the atmosphere. That amount of carbon avoidance is equivalent to removing 3.3 million cars from the roadway every year for 34 years.

There have been reactor closures in the USA recently, and the majority of these have been because of market conditions. What needs to be done to ensure that those reactors that are granted licence extensions can operate for the full period of that extension?

Operating Peach Bottom for another 20 years would be good news for the environment, our employees and the community. However, nuclear plants must remain financially viable to continue to operate. It's critical that we continue to pursue policy reforms that value the environmental, economic and reliability benefits that zero-carbon nuclear energy provides.

3 | Country Pages

Argentina

Argentina has two nuclear power plants: Atucha (two units), 100 km northwest of Buenos Aires; and Embalse (one unit), about 100km south of the city of Cordoba. All three reactors are pressurized heavy water reactors (PHWRs).

Atucha 1 was connected to the grid in 1974, followed by unit 2 in 2014. The two-unit plant has a capacity of 1033 MWe.

Embalse began operation in 1983. The unit returned to service in May 2020 following a three-year upgrade and reconditioning programme, preparing it for a further 30 years of operation. The programme involved reactor retubing and steam generator replacement, and increased the reactor's net capacity by 35 MWe to 608 MWe. The Embalse reactor is used to produce cobalt-60 for the domestic market and export, as well as electricity.

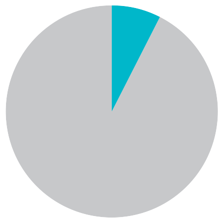
Construction work is ongoing on Argentina's first domestically-designed and developed power unit, CAREM, located at the Atucha site.

Argentinian authorities are in discussions with Chinese counterparts about the potential construction of Chinese-designed reactors at the Atucha site.

Operable Reactors

1641 MWe

Nuclear Share of Generation

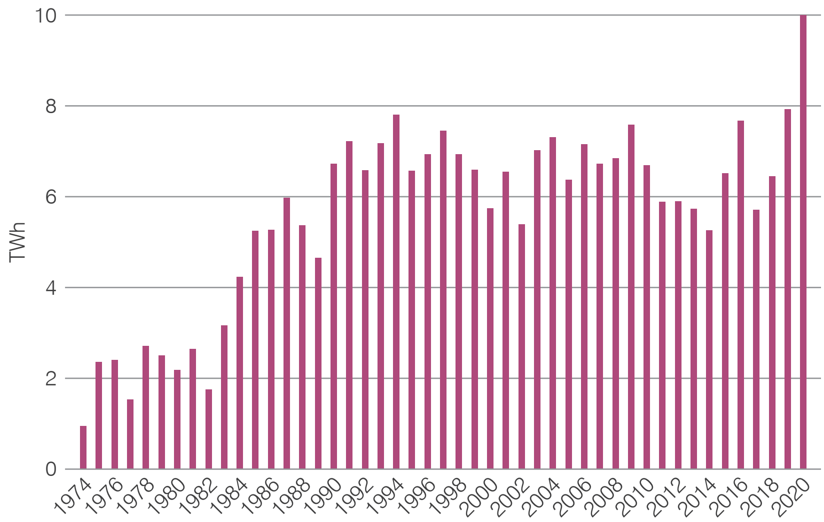


7.5 %

Reactors Under Construction

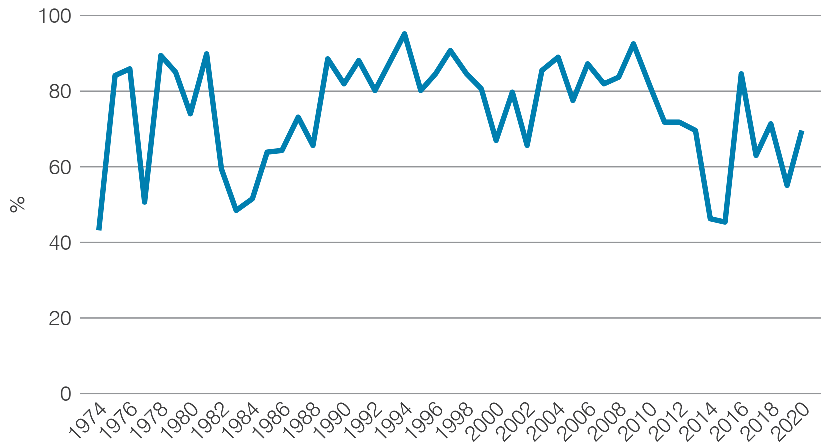
25 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

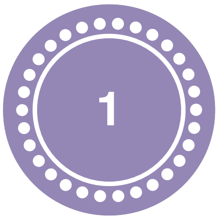
Armenia

Armenia has one nuclear power plant, Metsamor. It is located 30km west of the Armenian capital of Yerevan and is also known as the Armenian Nuclear Power Plant (or ANPP).

The plant comprises two Russian-built VVER reactors which started operating in 1976 and 1980. Both units were taken offline in 1988 due to safety concerns regarding seismic vulnerability, although they had not sustained any damage in a major earthquake in the region earlier that year and had both continued to operate. Unit 1 was shut down in 1989, but unit 2 was restarted in 1995 in the face of severe energy shortages. Both units originally had a reference unit capacity of 408 MWe, which was reduced to 376 MWe in 1988.

In January 2021 the Armenian government's strategic programme for the development of the energy sector until 2040 was approved by the cabinet. The plan outlines the extension of the operating life of Metsamor to beyond 2026, and the subsequent construction of a new unit. It states: "Having a nuclear power plant in the energy system will allow Armenia to diversify its energy resources, avoid increasing the country's dependence on imported natural gas, as well as cut the volume of emissions." The Metsamor plant will be offline for a scheduled 114 days in 2021 as work continues on upgrades to allow for its continued operation. Armenia is in discussions with Russia about its plans to construct a new nuclear power plant.

Operable Reactors



375 MWe

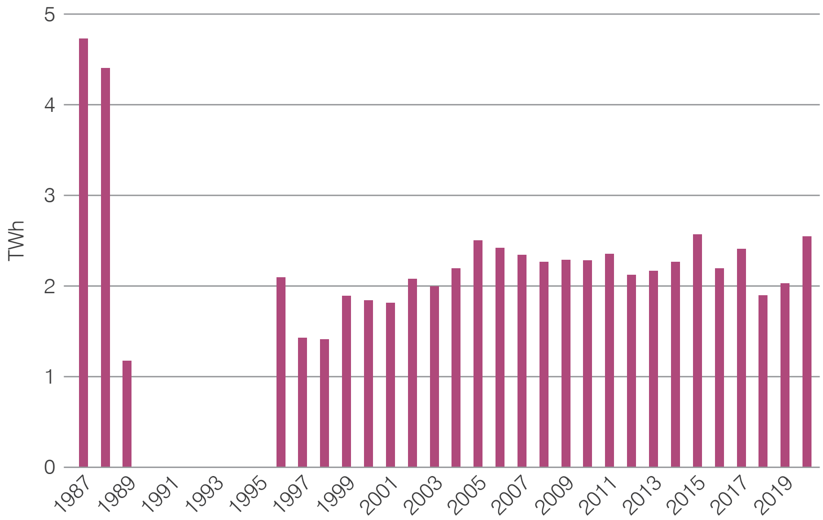
Nuclear Share of Generation

34.5 %

Reactors Under Construction

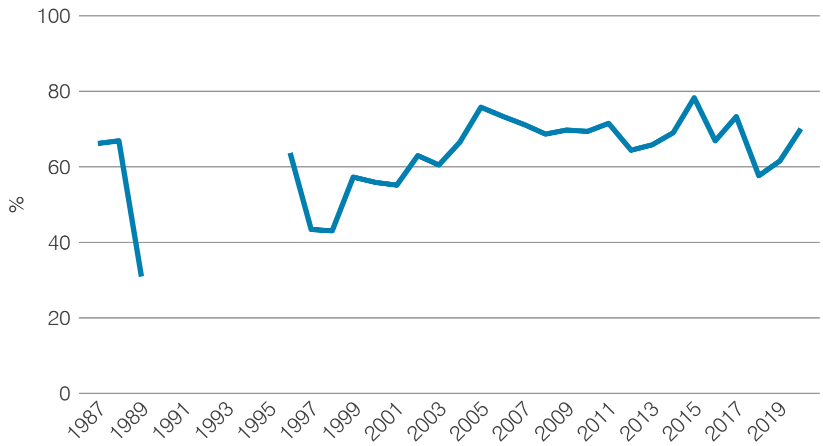
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Bangladesh

Two 1080 MWe reactors are under construction at Rooppur, approximately 160 km northwest of Dhaka.

Construction of unit 1 began in November 2017, followed by unit 2 in July 2018. The reactors are VVER-1200s, based on the V-392M reactors at Novovoronezh II. The two units are due to be connected to the grid in 2023 and 2024.

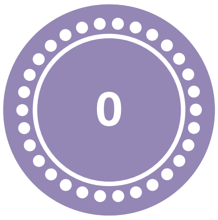
Bangladesh, which has a population of 160 million, plans to produce 9% of its electricity from nuclear power and reduce its dependence on fossil fuels by the middle of the 2020s.

The pouring of concrete for the foundation on the turbine building at unit 2 at Rooppur was completed in August 2019, following the same milestone for unit 1 a year earlier.

In July 2020 Atommash, part of the engineering division of Russian nuclear corporation Rosatom, completed hydraulic tests on the reactor pressure vessel of unit 1.

In November 2020 the reactor pressure vessel for unit 1 arrived at Rooppur. The total journey between Russia and Bangladesh covered 14,000 km and took almost 10 weeks.

Operable Reactors



0 MWe

Nuclear Share of Generation

0 %

Reactors Under Construction

2160 MWe

Rooppur under construction (Image: Trest RosSEM)

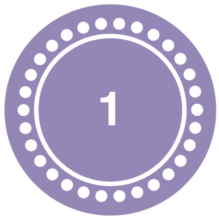
Belarus

Belarus connected its first nuclear power reactor to the grid in November 2020, and it entered commercial operation in June 2021. It is the first of two VVER-1200 units at Ostrovets, about 120 km northwest of Minsk.

The two units started construction in 2013 and 2017 and are the first VVER-1200 units to be built outside Russia. Unit 2 is expected to be connected to the grid later this year.

In September 2020 Estonia, Latvia and Lithuania reached an agreement to cease electricity trading with Belarus. Lithuanian Energy Minister said "Ostrovets is a geopolitical project, but the ban is meant to reduce motivation for it, to keep it from becoming profitable." Lithuania has long-opposed the project, citing safety concerns.

Operable Reactors



1110 MWe

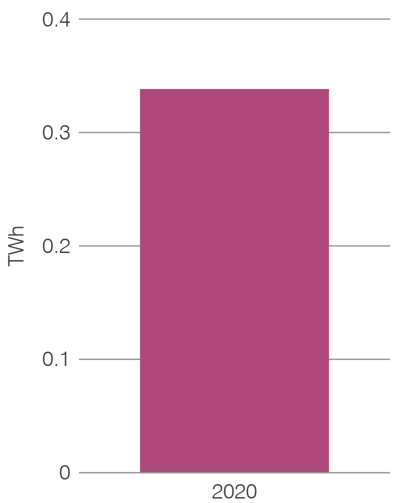
Nuclear Share of Generation

1 %

Reactors Under Construction

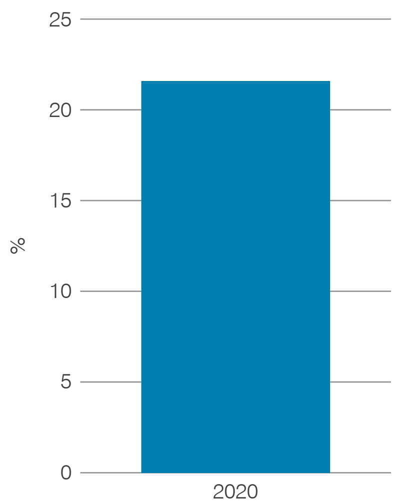
1110 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Ostrovets nuclear power plant (Image: ROSATOM)

Belgium

Belgium has four reactors at the Doel nuclear power plant, 15km northwest of Antwerp, with a total capacity of 2934 MWe, and three at Tihange, 24 km west-southwest of Liege, with a total capacity of 3008 MWe.

Belgium elected a new coalition federal government in 2020, led by Alexander De Croo. The new government has signed an agreement reaffirming the policy to phase out nuclear power in the country by 2025. Under the plan, Doel 3 and Tihange 2 will be shut down in 2022 and 2023, respectively. The newer units at each plant, Doel 4 and Tihange 3, will be shut down by 2025.

However, the agreement also calls for a report on Belgium's security of electricity supply and the impact on electricity prices of the nuclear phaseout. If the report, which is due to be published in November 2021, shows potential supply problems, the government may be prompted to review plans to allow the retention of 2 GWe of nuclear capacity.

In November 2020 Electrabel said it will not make further investments at Doel 4 and Tihange 3 unless it is given clarity about whether the reactors will be allowed to operate beyond 2025.

Earlier in July 2019 Belgium grid operator Elia concluded that the country would need more capacity than previously forecast to cope with its planned nuclear exit and is not yet ready for any scenario, including one where the phaseout of nuclear reactors is more gradual than envisaged.

Operable Reactors

5942 MWe

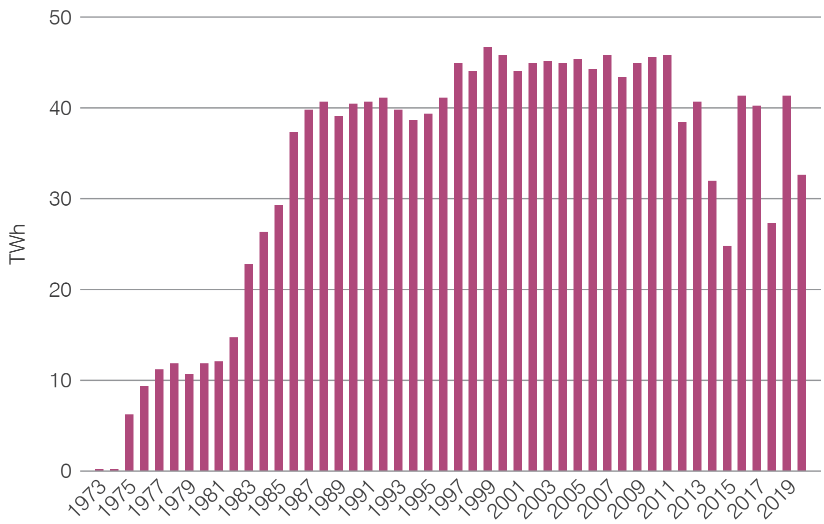
Nuclear Share of Generation

39.1 %

Reactors Under Construction

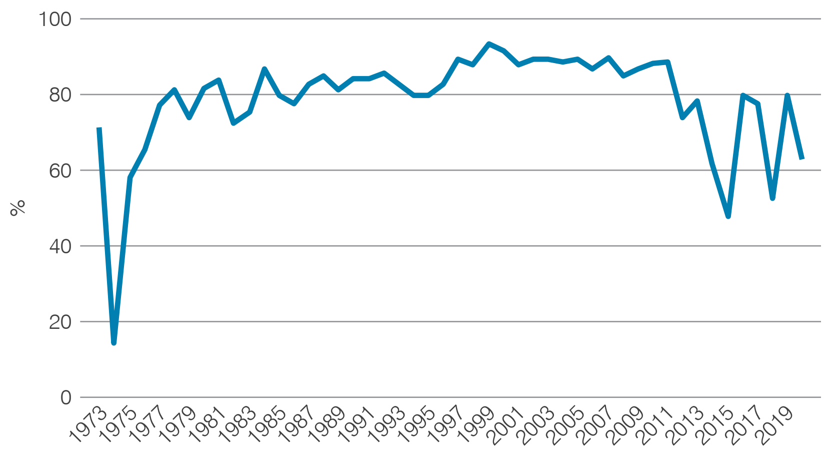
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Brazil

Brazil has two reactors at Angra, 200 km west of Rio de Janeiro. One is a PWR with a capacity of 609 MWe which began operating in 1982. The other is a 1275 MWe PWR which began operating in 2000.

Work on a third unit at Angra began in 1984 but was halted in 1986 before full construction began. The project was restarted in 2010, before being halted again in 2015.

In June 2020 Brazil's Investment Partnership Programme (PPI) council approved a business model to complete Angra 3, devised by state development bank BNDES. In July 2021 BNDES hired a consortium – Tractabel Engineering Ltd, Tractebel Engineering SA and Grouped Entrepreneurs International SA. The consortium is tasked with defining the investment needed for the project, the detailed schedule of work and specification of how one or more construction companies will be hired to carry out the work. According to BNDES, a financing agreement to finish the unit should be ready by the end of 2022.

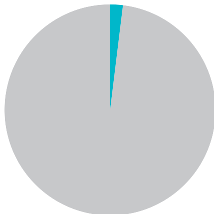
Earlier, in March 2021 Eletronuclear invited bids for a contract to conduct civil work on Angra 3 "to advance some construction activities" before hiring a contractor to complete the construction of the unit.

As Brazil looks to restart construction activities at Angra, it is progressing other aspects of its fuel cycle. In December 2020 the country started uranium mining from the new open-pit Engenho mine at Caetite in Brazil's Bahia state.

Operable Reactors

1884 MWe

Nuclear Share of Generation

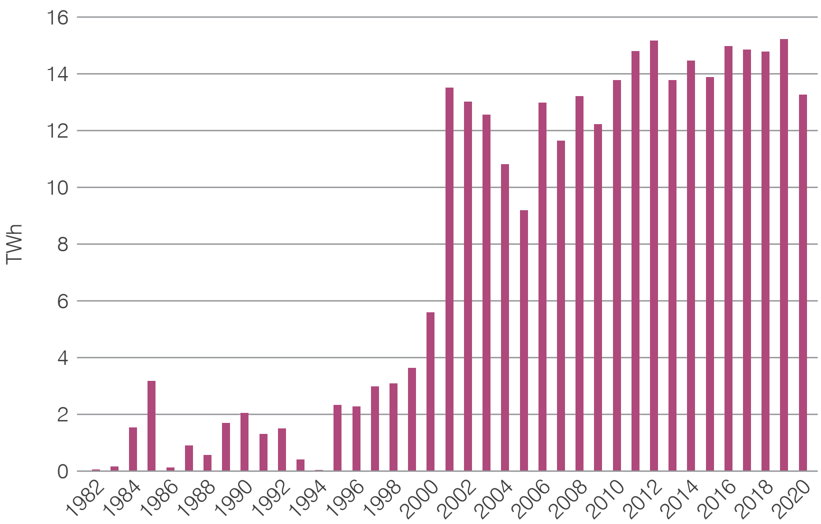


2.1 %

Reactors Under Construction

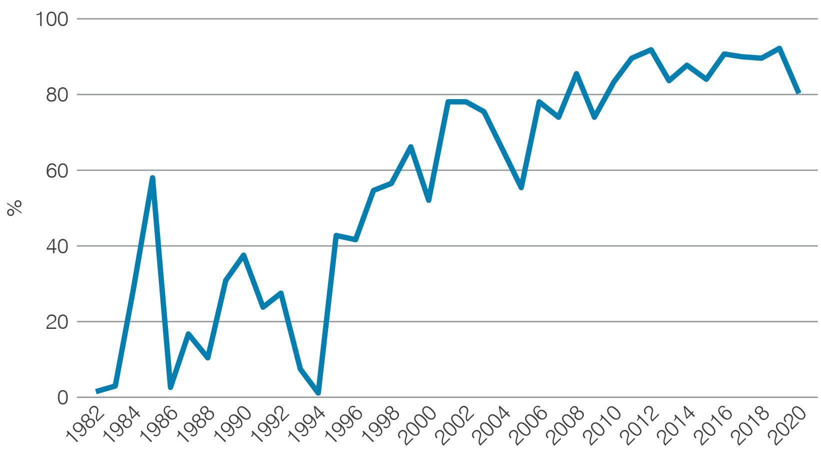
1340 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Bulgaria

The Kozloduy nuclear power plant, 120 km north of Sofia, has two operable VVER-1000 reactors which supply around one-third of the country's electricity. Four shutdown VVER-440 units are also at the same site.

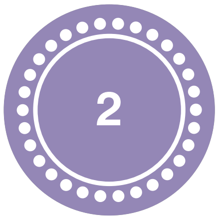
Since 1980 Bulgaria has planned to construct a second nuclear power plant at Belene, also in the north of the country, 100 km east of Kozloduy. In August 2019, 13 applications for participation in various roles in the project were received following the government's advertisement for a strategic investor. Later in the year the government shortlisted five companies: CNNC, Rosatom, Korea Hydro & Nuclear Power, Framatome and General Electric for equipment contracts.

In June 2020 Rosatom announced that it had signed a memorandum of understanding with Framatome and GE Steam Power to participate in a tender to construct Belene. In September 2020 the USA and Bulgaria signed an MoU on civil nuclear cooperation.

Separately, in January 2021, the Bulgarian cabinet approved plans for a seventh unit at the Kozloduy site. Russian-supplied equipment purchased for the Belene project will be used, and discussions have been held with Westinghouse to construct the unit. It is unclear what the implications of the plan for a seventh unit at Kozloduy are for the Belene project.

In February 2021 NuScale Power and Kozloduy Nuclear Power Plant – New Build Plc agreed to evaluate the suitability of the company's SMR design for deployment at the site.

Operable Reactors



2006 MWe

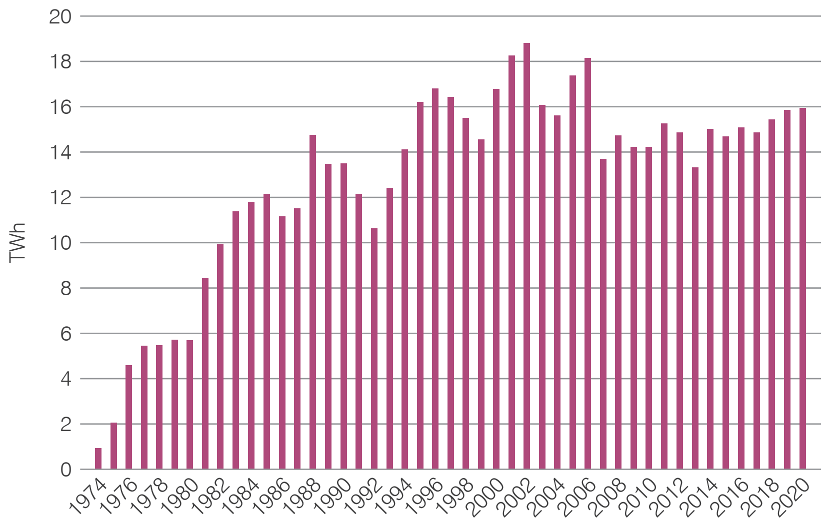
Nuclear Share of Generation

40.8 %

Reactors Under Construction

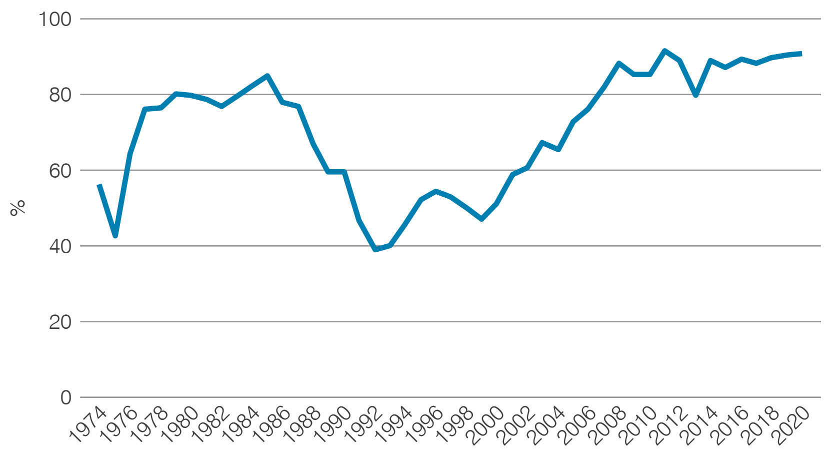
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Canada

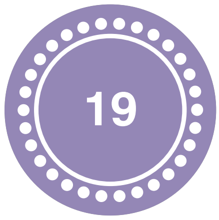
Nineteen reactors operate in southeast Canada, 18 of which are in Ontario and one in New Brunswick. All reactors are Candu PHWR models with capacities ranging from 515 to 881 MWe.

Units 3-8 at the Bruce site are being refurbished, extending their operation to 2064. Units 1&2 have already been refurbished and Bruce 6 was taken offline in January 2020.

In June 2020 Darlington 2 was reconnected to the grid after a three-year refurbishment. Work began on unit 3 in September 2020. The two other units will also be refurbished, with the entire project scheduled for completion by 2026. The work will allow the plant to continue operation until 2055. Darlington 1 in February 2021 set a new world record with 1106 consecutive days of unbroken operation.

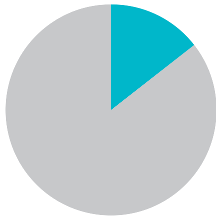
In October 2020 OPG announced it is working with three developers – GE Hitachi, Terrestrial Energy and X-energy – to advance engineering and design work of grid-scale small modular reactors. Also in October, the Canadian government announced investment of US$ 15 million to accelerate deployment of Terrestrial Energy's 400 MWe Integral Molten Salt Reactor. As of November 2020 Advanced Reactor Concepts, New Brunswick Power and Moltex Energy are working to set up an SMR 'vendor cluster' in New Brunswick. In December 2020 the Canadian government released its SMR Action Plan, responding to the 53 recommendations identified in the country's November 2018 SMR Roadmap. The plan lays out the next steps to be taken to secure the deployment of SMRs both domestically and abroad.

Operable Reactors



13,624 MWe

Nuclear Share of Generation

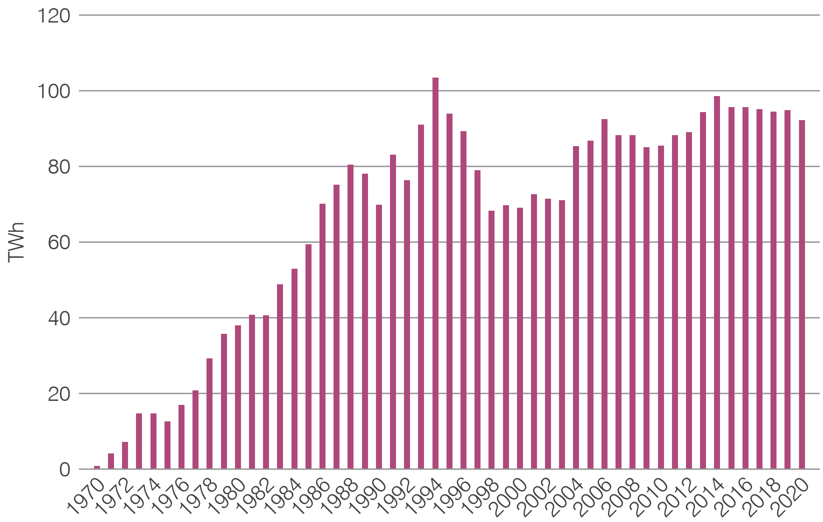


14.6 %

Reactors Under Construction

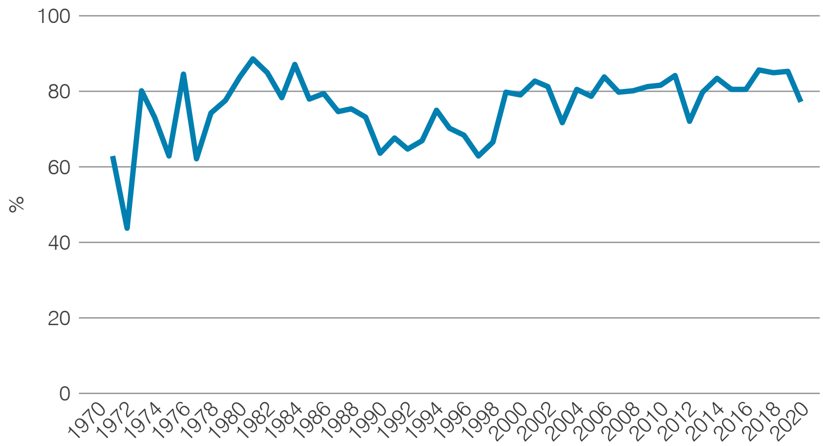
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

China, mainland

Mainland China has 51 operable reactors primarily at sites along its southeast coastline. Nuclear generation has grown substantially over the last 20 years, from 16 TWh in 2000 to 345 TWh in 2020.

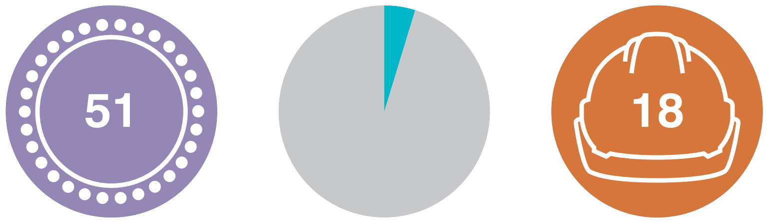
According to the National Development and Reform Commission, China aims to have 200 GWe of nuclear generating capacity in place by 2035, out of a total generating capacity of 2600 GWe. In December 2020 China's State Council published a white paper, Energy in China's New Era, affirming the country's commitment to nuclear power generation to help fight climate change.

In the past 12 months China has added four domestically-designed reactors to the grid. In 2020 Tianwan 5, an ACPR1000, was connected in August and Fuqing 5 became the first Hualong One reactor to be connected to the grid in November. So far in 2021 two reactors have been connected to the grid: Tianwan 6 in May, and Hongyanhe 5 in June.

Over the same period, eight reactors have commenced construction: Zhanghou 2 (September 2020), Taipingling 2 (October 2020), Xiapu 2 and San'ao 1 (December 2020), Changjiang 3 (March 2021), Xudabao 3 and Tianwan 7 (May 2021), and the SMR at Changjiang (July 2021). Site works for the CFR600 fast reactor began in December 2020.

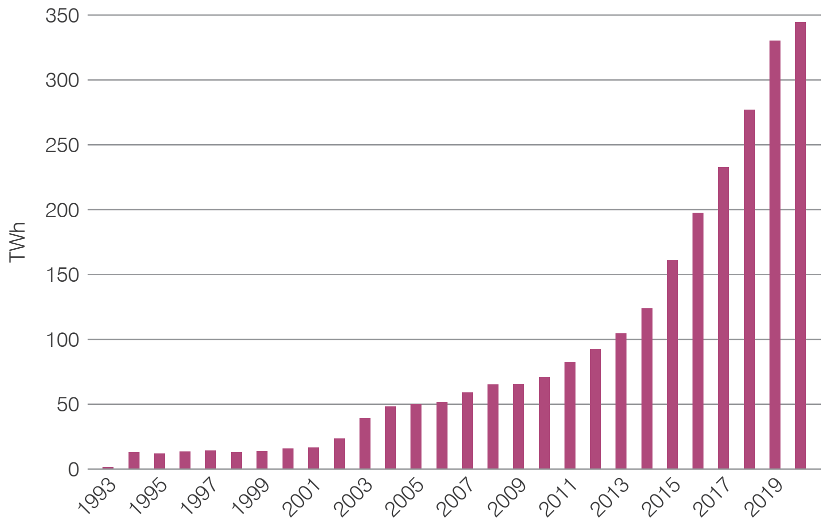
The Changjiang SMR, an ACP100, or Linglong One, unit, was identified as a 'key project' in China's 12th Five-Year Plan, and is designed for electricity production, heating, steam production or seawater desalination.

Operable Reactors	Nuclear Share of Generation	Reactors Under Construction



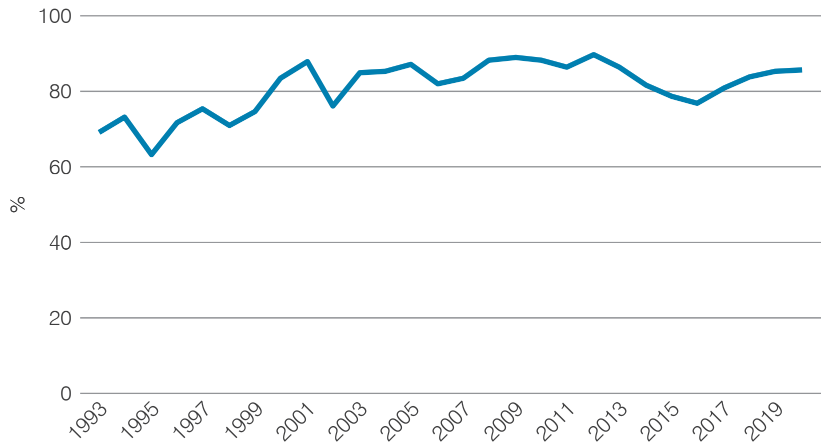
45,569 MWe	4.9 %	17,270 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Taiwan, China

Taiwan has three operable reactors: two at Maanshan, at the southern end of the island, 9km south of Hengchun airport, and one at Kuosheng, 25km northeast of Taipei. Kuosheng 1 was shut down early in July 2021 due to a lack of capacity for used fuel storage. Together the four reactors provided 13% of the island's electricity in 2020.

In February 2019 it was announced that Taiwan would proceed with its plan to phaseout the use of nuclear energy, despite citizens voting against the policy in a referendum.

The Democratic Progressive Party (DPP) was elected in 2016 with a manifesto that included a nuclear phase-out policy. Shortly after taking office, the government passed an amendment to the Electricity Act, passing the policy into law.

However, in a referendum held in 2018, voters chose to abolish the amendment. The Ministry of Economic Affairs said the amendment was officially removed from the Electricity Industry Act on 2 December. However, the decommissioning of the Chinshan units would continue as planned and, the operating licences of the Kuosheng and Maanshan units would not be extended.

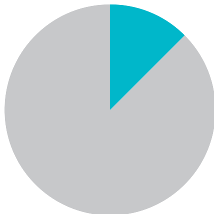
The plan to decommission the Chinshan plant includes the construction of a dry storage facility for used fuel. Construction of this facility was completed in 2013. However, the New Taipei City municipal government has yet to issue a permit for its use.

State-owned Taiwan Power Company (Taipower) has ruled out the possibility of completing the Lungmen project, which consists of two partially-constructed ABWRs.

Operable Reactors

2859 MWe

Nuclear Share of Generation

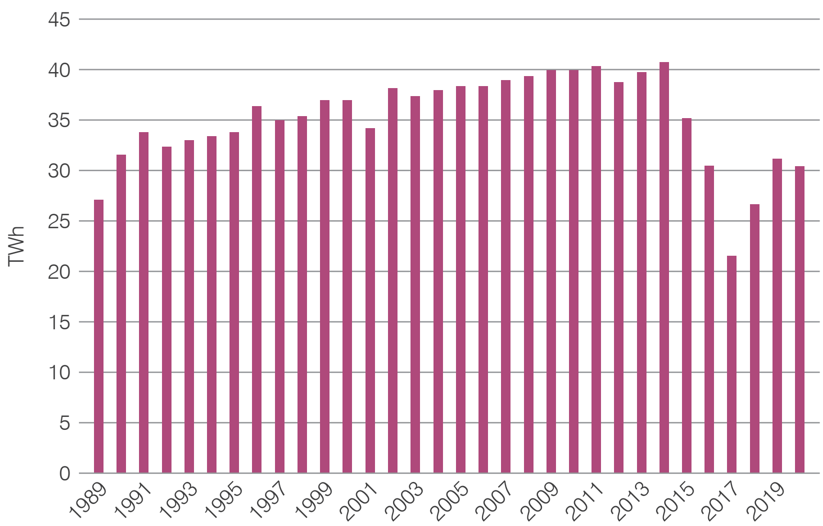


12.7 %

Reactors Under Construction

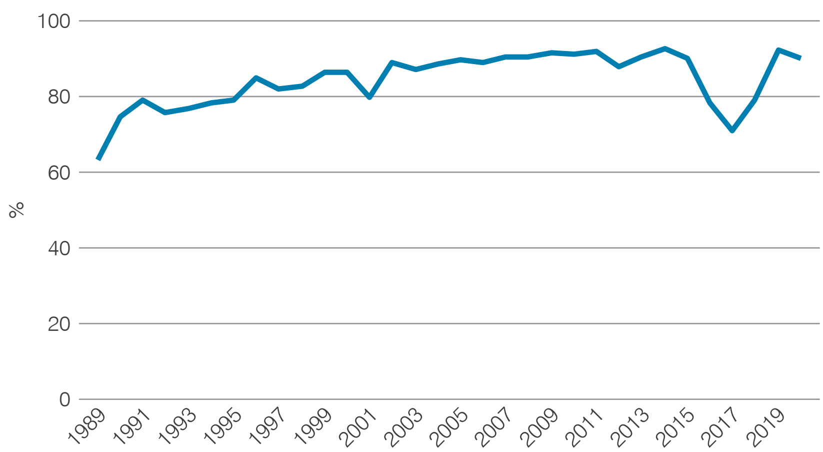
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Czech Republic

The Czech Republic has six operable reactors: two units are at Temelin, 100 km south of Prague; and four units at Dukovany, 34 km west of Brno.

The government's long-term energy strategy, adopted in 2015, forecasts the need to increase the share of nuclear power in the country's energy mix to 50-55% by 2050. Czech utility CEZ has said it expects to operate the four Dukovany units until 2045 and 2047, and the two Temelin units until 2060 and 2062.

CEZ was awarded a site licence for two new 1200 MWe PWR reactors at its Dukovany plant in March 2021. The Czech Ministry of Industry and Trade selected EDF, Korea Hydro & Nuclear Power and Westinghouse for pre-qualification for the tender for the new units in the same month, notably excluding CGN and Rosatom. In June 2021 CEZ began its security assessment of the three vendors.

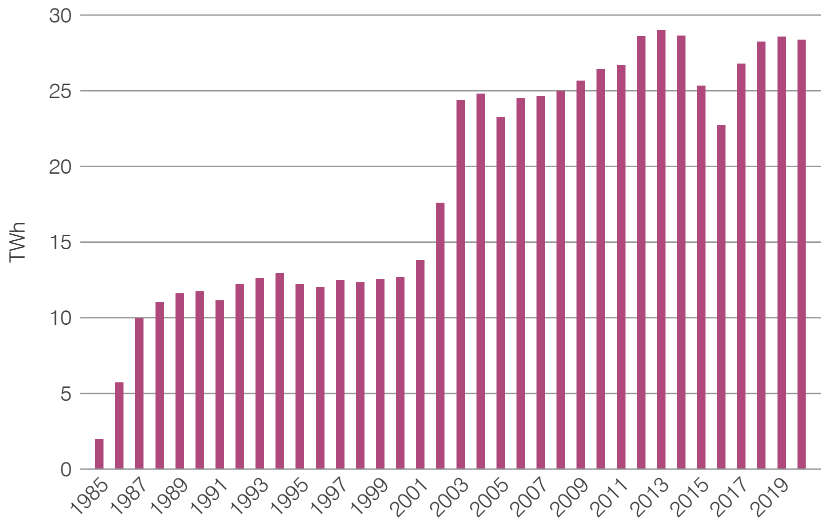
Under the current schedule, a reactor vendor is expected to be selected by the end of 2022, with a construction licence to be issued in 2029.

Earlier in May 2020 the Czech prime minister announced that the government would loan 70% of the cost of building a single 1200 MWe unit, with CEZ funding the remaining 30%. In October 2019 Deputy Prime Minister and Minister of Industry and Trade Karel Havlicek had said that the Czech Republic would need to build not only one new unit at Dukovany, but also more reactors at Temelin if it were to avoid becoming dependent on electricity imports from 2030.

Operable Reactors | Nuclear Share of Generation | Reactors Under Construction

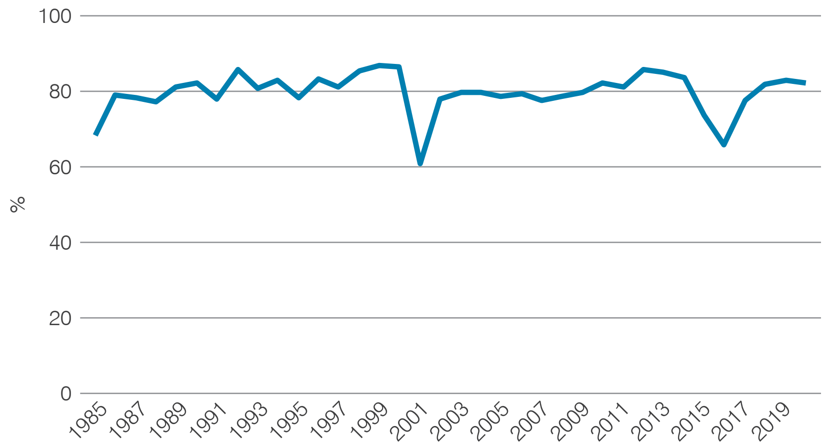
3934 MWe | 37.3 % | 0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Finland

Finland has two nuclear power plants, Loviisa, 80km east of Helsinki, with two VVER reactors, and Olkiluoto, 225 km northwest of the capital, with two BWR reactors. A fifth reactor, the Olkiluoto 3 EPR, is long-delayed but nearing completion, and a sixth unit (a VVER) is planned for Hanhikivi.

After delays owing to measures put in place to prevent the spread of COVID-19, fuel loading at Olkiluoto 3 commenced in March 2021. In June 2021 it was announced that Hitachi ABB Power Grids will build a 90 MWe battery storage system, Europe's largest, to ensure the stability of Finland's electricity network in the event of an unplanned shutdown of Olkiluoto 3.

In December 2020 Fennovoima provisionally accepted the 'Basic Design Stage 1' documentation for the Hanhikivi 1 project. The documentation prepared by RAOS Project, a subsidiary of Rosatom, provides the basis for the Finnish regulator's assessment of the project ahead of issuance of a construction licence. In April 2021 Fennovoima announced that it still expected to receive a construction licence by the end of 2021, but that the schedule was now "challenging". In the same month, the utility announced that the project was now expected to enter commercial operation a year later than originally planned and cost up to US$ 1.2 billion more.

In May 2021 excavation of the first final disposal tunnel started at the Onkalo underground fuel repository near Olkiluoto. The repository is planned to begin operations in the mid-2020s.

Operable Reactors

2794 MWe

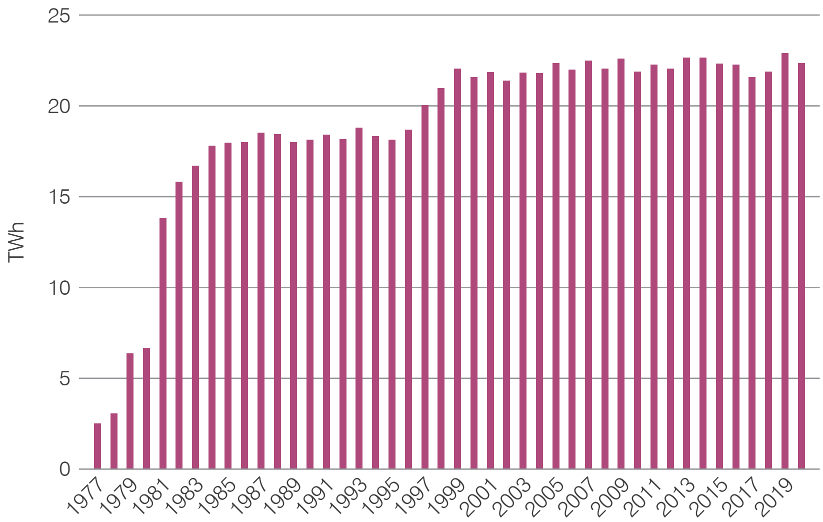
Nuclear Share of Generation

33.9 %

Reactors Under Construction

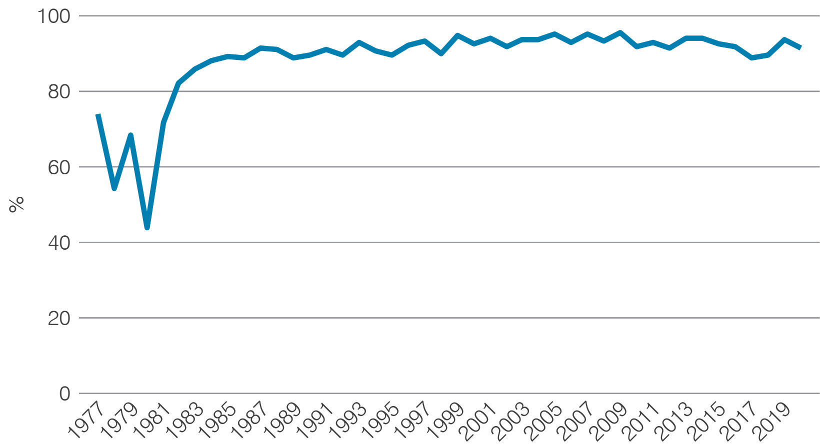
1600 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

France

France has 56 operable reactors at a variety of coastal and inland sites throughout the country.

Nuclear generation has supplied about 75% of the country's electricity for 30 years, following a major expansion of capacity in the 1970s and 1980s.

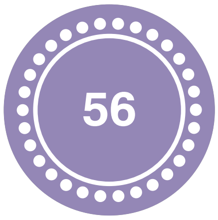
In February 2020, unit 1 at Fessenheim was closed, after 42 years of operation. The closure of unit 2 followed in June.

The closure of Fessenheim was imposed as part of France's current energy policy, which aims to reduce the nuclear share in the electricity mix to 50% by 2035. The policy will require 14 of the country's nuclear reactors to close by 2035. The plan does, however, state that the option to build new reactors remains.

Despite this, in December 2020 President Emmanuel Macron said that France's energy and ecological future depends on nuclear power, adding; "Few sectors offer as much, particularly to our young people and all across the country."

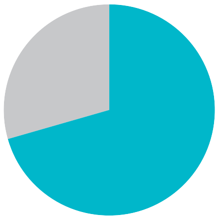
An EPR has been under construction at Flamanville since 2007. In October 2019 it was concluded that repairs to the reactor's main secondary system penetration welds would further delay loading of fuel until the end of 2022. In March 2021 design anomalies were found on three nozzles of the main primary system.

Operable Reactors



61,370 MWe

Nuclear Share of Generation

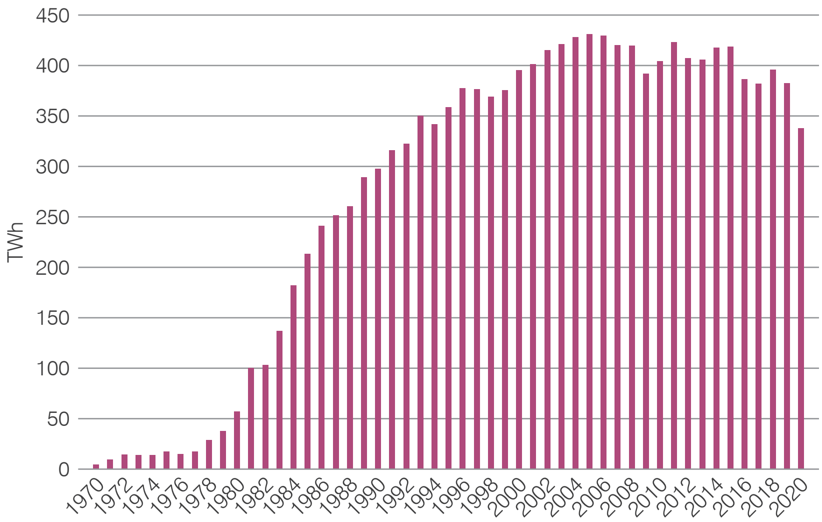


70.6 %

Reactors Under Construction

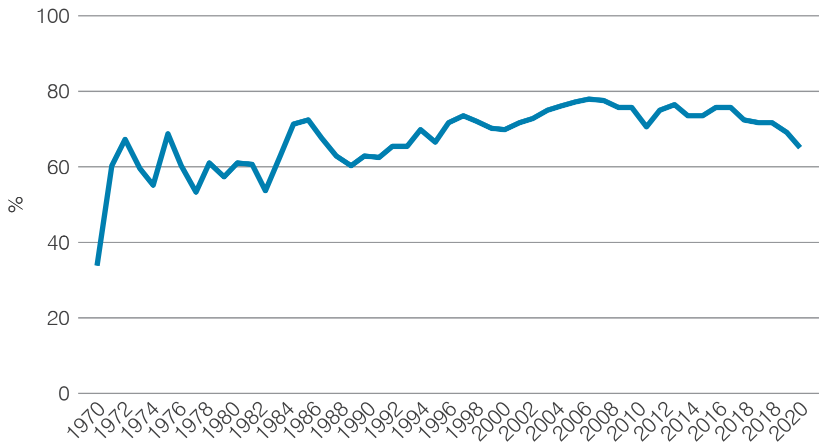
1630 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Germany

Nuclear capacity has been more than halved in Germany since 2010 as part of the country's policy to close all reactors by the end of 2022.

The country now has six operable reactors, which together provided 60.9 TWh of electricity in 2020, about one-quarter of Germany's supply of low-carbon electricity. Half of Germany's remaining fleet will be shut down at the end of 2021.

In February 2021 Germany's Grohnde nuclear power plant became the first reactor in the world to produce more than 400 TWh of electricity.

In March 2021 the German government reached an agreement with E.ON, EnBW, RWE and Vattenfall on compensation for the forced premature closure of their reactors. The utilities will receive a total of € 2.5 billion between them. The agreement followed Vattenfall's successful legal challenge in November 2020 in its case against the government relating to proposed compensation for its plants in Brünsbuttel, Krümmel and Mülheim- Kärlich.

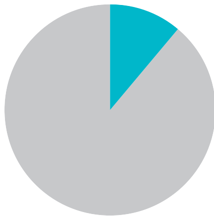
Despite nuclear providing over 50% of the EU's low-carbon power, Germany has been leading resistance from a small group of EU states to the proposed inclusion of nuclear energy in the EU's green finance taxonomy.

In December 2020, Polish climate and environmental activists submitted to the German embassy in Warsaw an open letter signed by Polish scientists, activists and citizens asking the country to reconsider its decision to phase out nuclear power.

Operable Reactors

8113 MWe

Nuclear Share of Generation

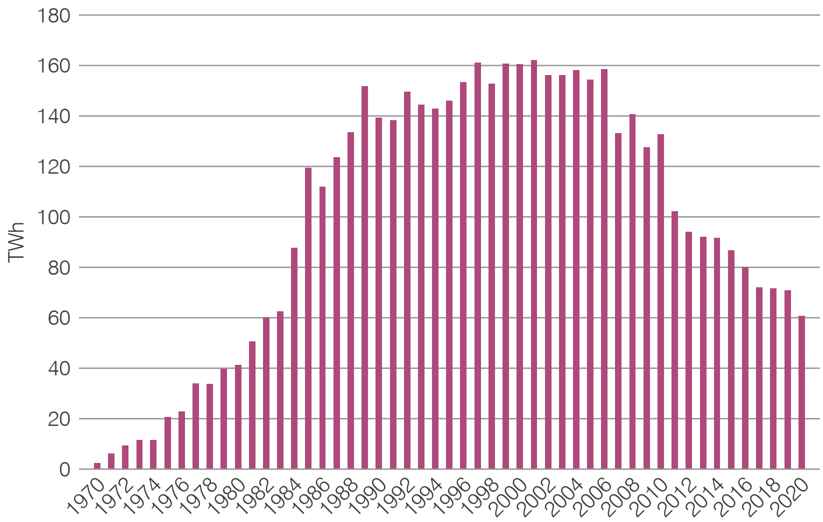


11.3 %

Reactors Under Construction

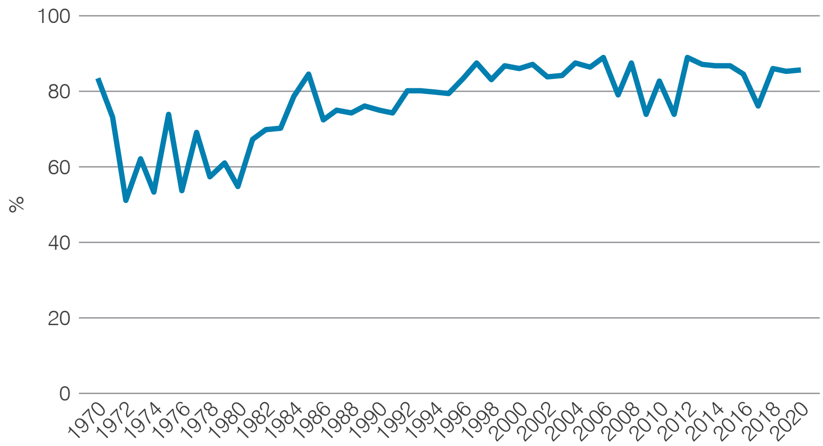
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Hungary

Four VVER-440 reactors operating at the Paks nuclear power plant, 100 km south of Budapest, provide about half of the electricity generated in Hungary.

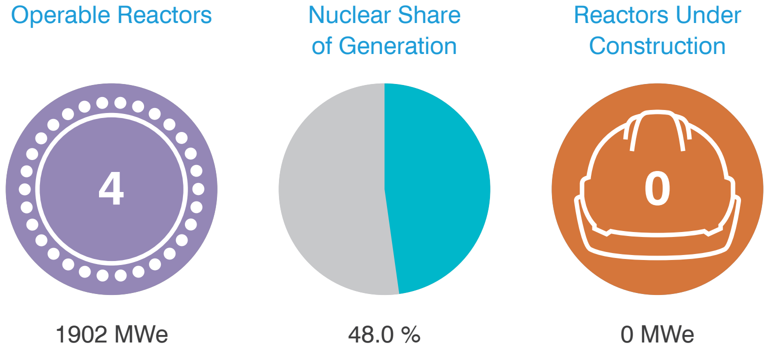
Plans are advanced for the construction of two new large units at the same site. In November 2020 the Hungarian Energy and Public Utilities Regulatory Authority approved Atomerőmű Zrt's plan to construct two VVER-1200 units at the site.

In April 2020, János Süli, Minister without Portfolio responsible for the planned two new reactors at Paks, emphasized the role of the Paks plant in ensuring Hungarian electricity supplies during the COVID-19 pandemic. The minister said that the plant was "of strategic importance in these difficult times."

Regarding the proposed new nuclear units at Paks, Süli said that they were a major investment that could be a lifeline for many Hungarian businesses recovering from the pandemic and a livelihood for many Hungarian people, with the project employing 8000-10,000 people at its peak.

In April 2021 Hungary's Finance Ministry reached an agreement to start the repayment of the Russian state loan for the project five years later than originally agreed. The change means that Hungary can use the income from the nuclear power plant to repay the loan.

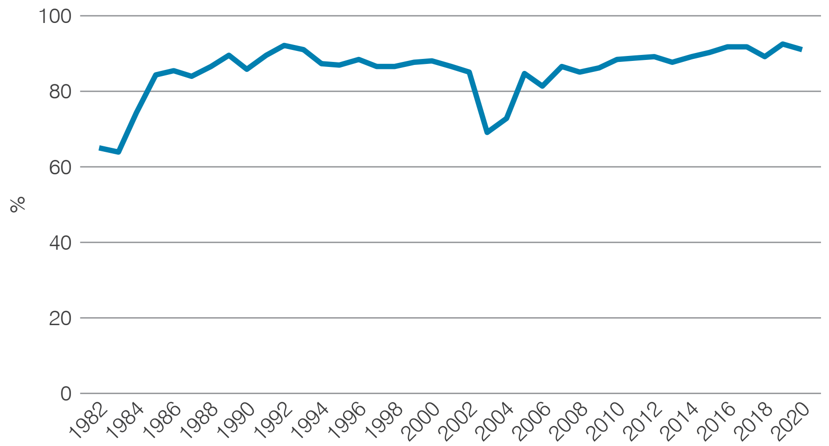
In December 2020 TVEL loaded a new design of fuel into Paks unit 3. The new VVER-440 fuel was developed under a contract between TVEL and MVM Paks NPP Ltd. It will enable an increase in efficiency of fuel usage and improve the plant's economic performance.



Nuclear electricity production

Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

India

India has 23 operable reactors in seven locations. Reactors are located both inland and along the coast, and a further seven are under construction. The majority of reactors are indigenously- designed pressurized heavy water reactors (PHWRs). Two Russian VVER-1200 reactors are in operation at Kudankulam.

India has plans to increase its nuclear generation capacity substantially. In January 2019 the Department of Atomic Energy (DAE) announced that India plans to build 21 reactors with a capacity of 15.7 GWe by 2031. In October 2019 the DAE chairman said that 17 nuclear power reactors are planned in addition to those already under construction.

In November 2020 India's regulator gave its consent for the pouring of first concrete at Gorkakhpur. The indigenously-designed 700 MWe PHWR units are to be built by NPCIL. In January 2021 Kakrapar 3 was connected to the grid in India's Gujarat state.

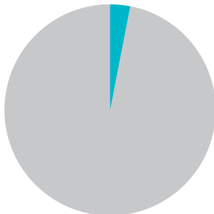
In June 2021 construction commenced on unit 5, a VVER-1000 reactor, at Kudankulam – the first reactor to begin construction in India for nearly four years. A further two VVER units are under construction at the site.

Earlier in April 2021 EDF submitted its binding techno-commercial offer to NPCIL to build six EPR reactors at Jaitapur in Maharashtra. Once built, the six units would make the Jaitapur plant the largest in the world with an installed capacity of 9.6 GWe. It would be capable of supplying some 70 million Indian households.

Operable Reactors

6885 MWe

Nuclear Share of Generation

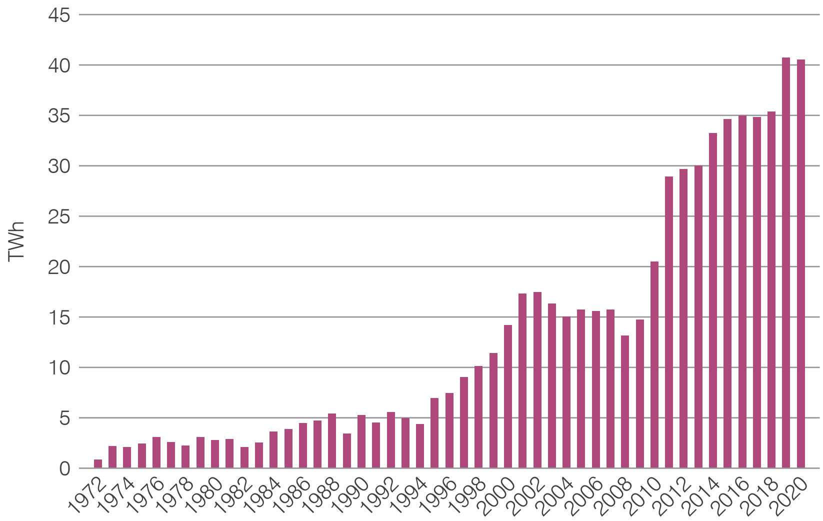


3.3 %

Reactors Under Construction

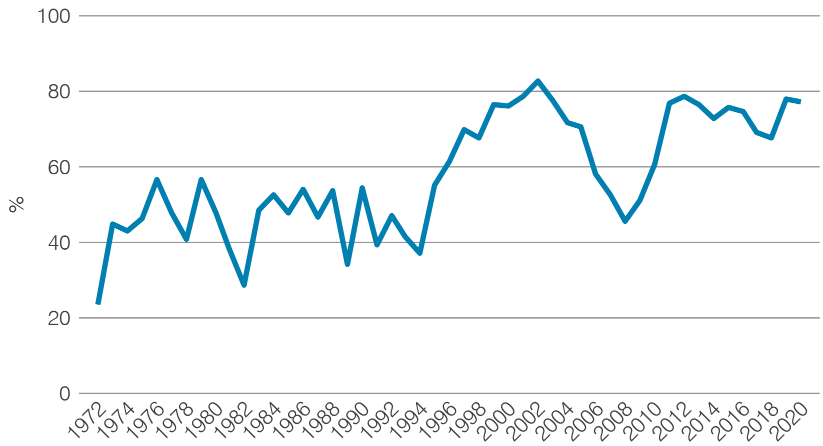
5194 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Iran

A single VVER/V-446 reactor operates at the Bushehr site, 185 km west of the city of Shiraz.

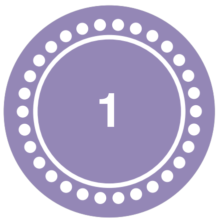
Construction on Bushehr's second reactor, an updated VVER-1000, commenced in November 2019. The reactor is expected to start up in 2024, with a third unit due two years later.

Since 2015, nuclear activities in Iran have been carried out under the Joint Comprehensive Plan of Action (JCPOA) agreed by Iran, China, France, Germany, Russia, the UK and the USA.

Under the terms of the JCPOA, Iran agreed to limit its uranium enrichment activities, eliminate its stockpile of medium-enriched uranium and limit its stockpile of low-enriched uranium over the subsequent 15 years. In 2018 the USA withdrew from the agreement and imposed sanctions on Iran.

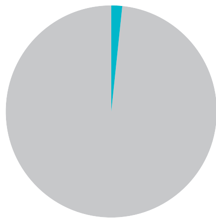
In July 2021 IAEA Director General Rafael Grossi stated that Iran had informed the agency that it intends to use indigenously-produced uranium enriched up to 20% U-235 in the manufacture of fuel for the Tehran Research Reactor (TRR). The Foreign Ministers of France, Germany and the UK said in a statement that this action represented "a serious violation" or Iran's commitments under the JCPOA.

Operable Reactors



915 MWe

Nuclear Share of Generation



1.7 %

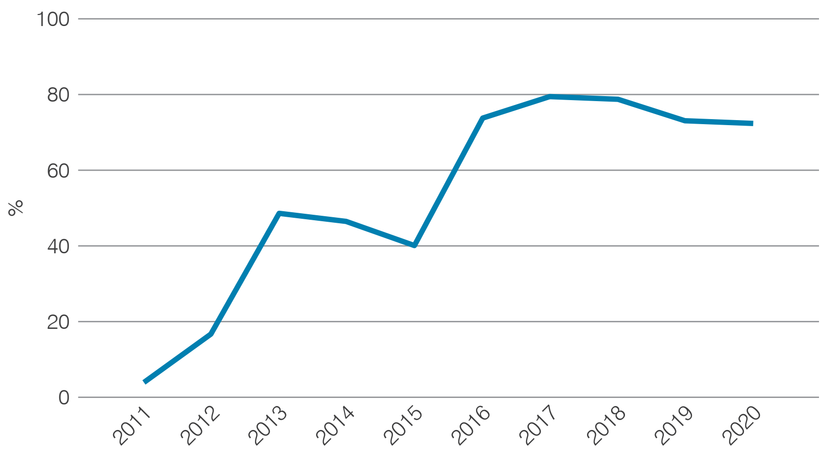
Reactors Under Construction

974 MWe

Nuclear electricity production

Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Japan

Until 2011 Japan generated some 30% of its electricity from its nuclear reactors. This proportion had been expected to increase to at least 40% by 2017, but the plan now is for 20-22% by 2030.

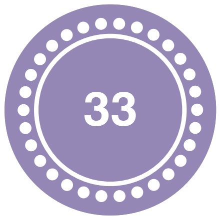
In January 2021 the head of the Japanese Atomic Industry Forum (JAIF) implored the government to restart idled reactors as soon as possible, stressing the importance of nuclear for realizing the government's carbon neutrality goal. In a separate New Year statement, the chairman of the Japan Iron and Steel Federation called on the government to find an "urgent solution" to high Japanese industrial electricity prices, citing the restart of nuclear power plants as essential for securing the cost-competitiveness of Japan's industry.

In February 2021 Japan's energy minister described nuclear energy as "indispensable" if the country is to meet its net zero emissions target of 2050.

Since the March 2011 accident at the Fukushima Daiichi plant, all reactors have had to obtain regulatory clearance to restart. So far, ten reactors have restarted. A further 16 are in the process of obtaining regulatory approval for restart.

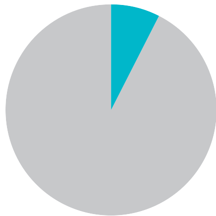
Reactors that have restarted are required to construct bunkered backup control centres within five years of regulatory approval to restart. Because these facilities were not completed at Sendai within the five-year time limit, the plant's two reactors were taken offline in March and May 2020. Unit 1 returned to operation in November 2020 following completion of the bunkered control room.

Operable Reactors



31,679 MWe

Nuclear Share of Generation

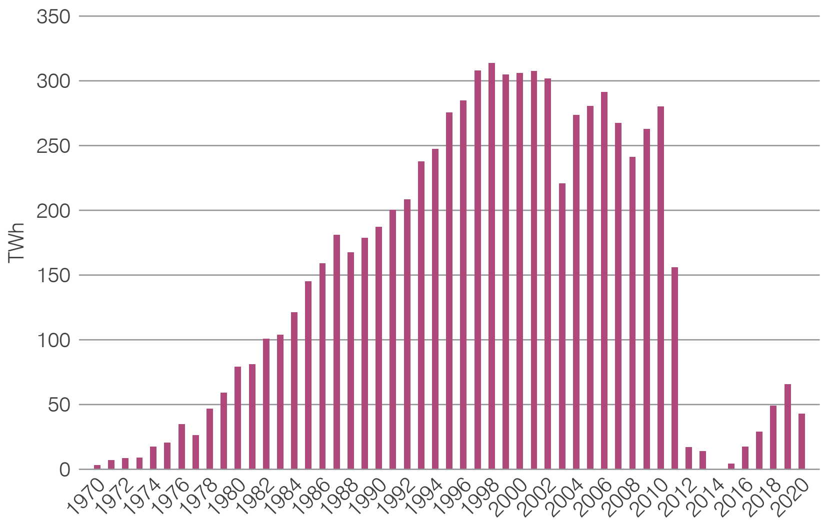


7.5 %

Reactors Under Construction

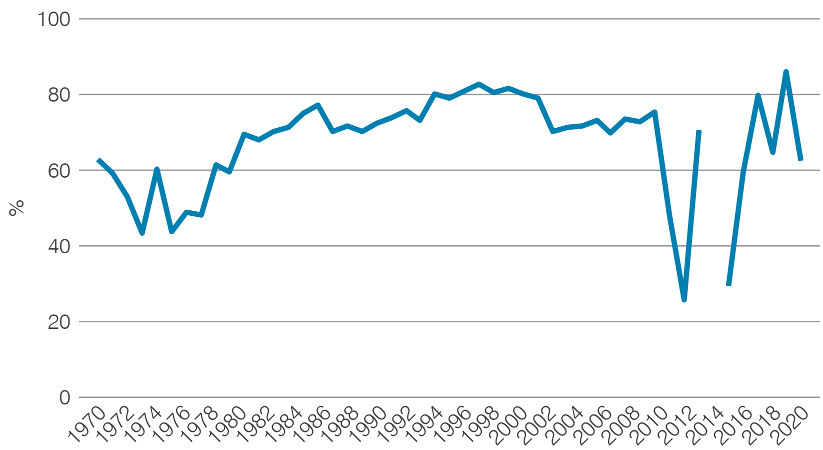
2653 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

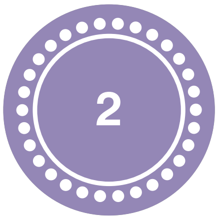
Mexico

Mexico has two operable reactors located on the east coast of the country, 285km east of the capital, Mexico City. Unit 1 of Laguna Verde began commercial operation in 1990, and unit 2 in 1995.

In July 2020 the Mexico energy ministry gave final approval for a 30-year extension of the operating licence for the first unit of Laguna Verde. This would allow the reactor to operate until 2050. An application for a similar extension for unit 2 has been filed and is under review.

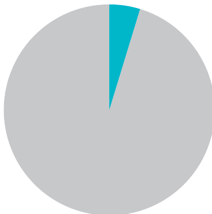
Ahead of the licence extensions, Laguna Verde underwent a 10-day SALTO (Safety Aspects of Long Term Operation) peer review mission. To obtain the licence extension, a series of upgrades, inspections and tests were required at unit 1.

Operable Reactors



1552 MWe

Nuclear Share of Generation

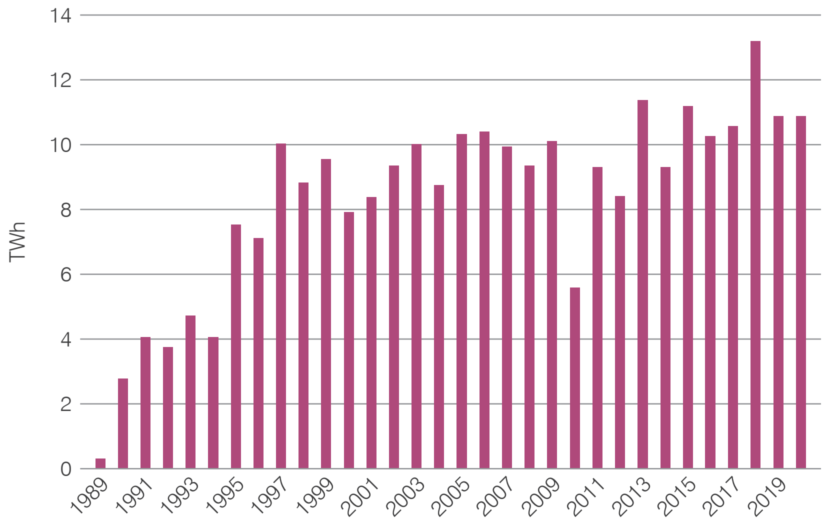


4.9 %

Reactors Under Construction

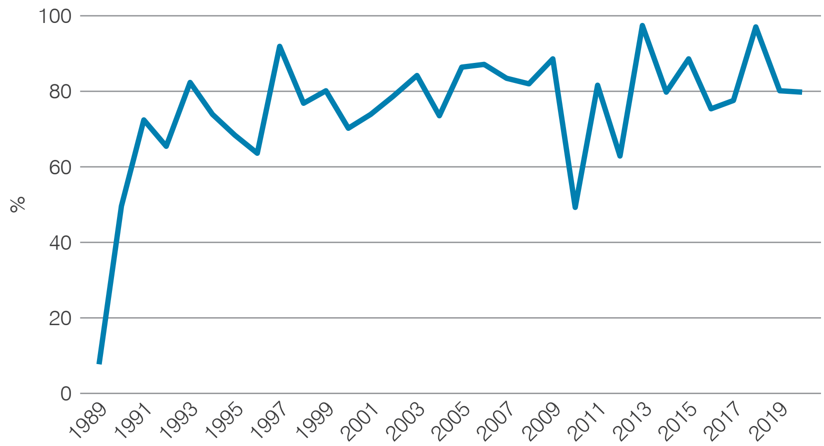
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Netherlands

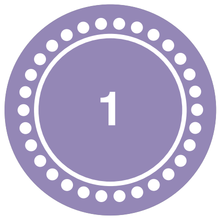
A single 485 MWe PWR at Borssele is located 70km southwest of Rotterdam.

In September 2020 a letter sent to the Dutch Parliament by Eric Wiebes, the then Minister for Economic Affairs and Climate Policy, suggested that the Netherlands is considering the expansion of nuclear power in its energy mix. In the letter, citing research by consultants Enco, Wiebes stated that nuclear "is no more expensive than wind and solar if the system costs are included" and that it is "the safest way of producing energy per terawatt hour." In December 2020 EPZ, operator of the Borssele nuclear power plant, called for an extension in its operation beyond 2033 and for the construction of two new large rectors at the site.

Interest in nuclear has been rekindled following the government's announcement in May 2018 of a draft law for phasing out coal-fired generation by 2030. In April 2021 Dutch NGO, e-Lise Foundation, released a white paper with 13 recommendations for the Dutch government to help realize the construction of new nuclear power plants in the Netherlands.

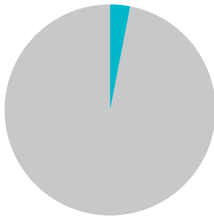
In July 2021 a KPMG study requested by The Ministry of Economic Affairs and Climate Policy concluded that market participants in the Netherlands – contractors, operators and suppliers – would invest in the construction of new nuclear generating capacity. In response to the study, the State Secretary for Economic Affairs and Climate Policy, Dilan Yesilgöz-Zegerius, requested a study into the possibility of including nuclear power in the country's plans for meeting energy and climate goals.

Operable Reactors



482 MWe

Nuclear Share of Generation

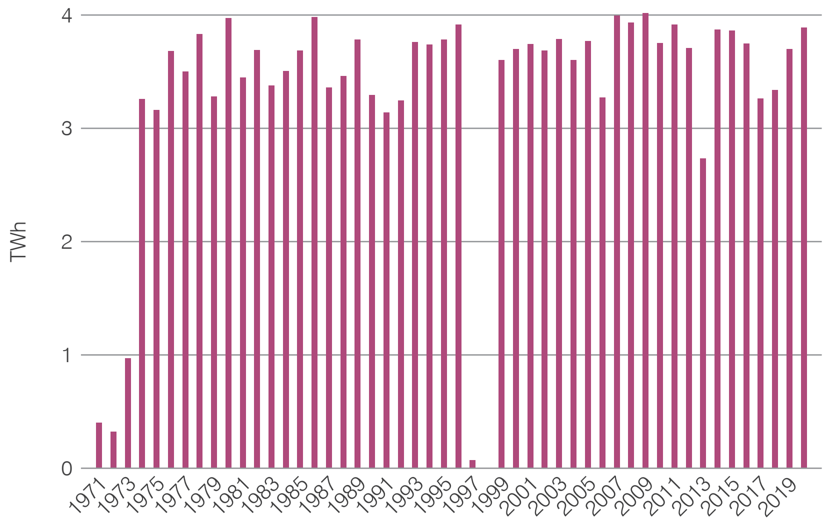


3.2 %

Reactors Under Construction

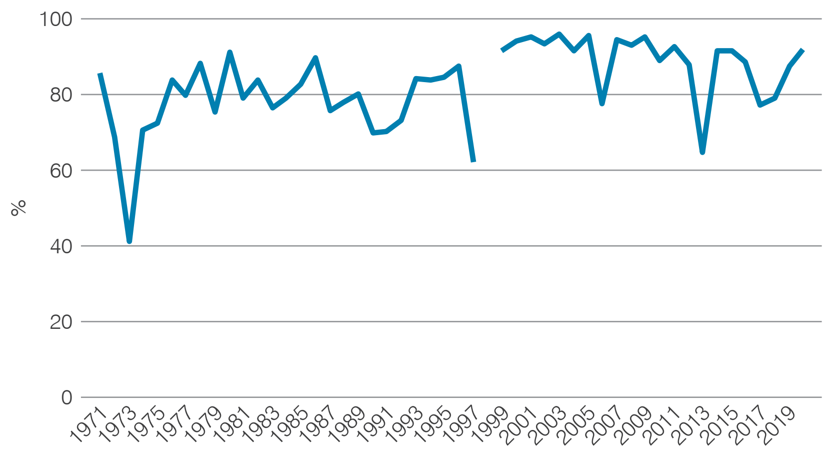
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Pakistan

There are two nuclear power plant sites in Pakistan. Chashma, 200 km southwest of Islamabad, and Karachi, 22 km west of Karachi.

Chashma hosts four 300 MWe units. All are CNP-300 models, based on Qinshan 1 in China. The first reactor was connected to the grid in 2000 and the fourth in 2017.

Karachi hosts a small 90 MWe Canadian PHWR which started up in 1971. It is operated at reduced power due to its age. In March 2021 unit 2 at the power plant, a Chinese-design HPR1000 (the export model of Hualong One), was connected to the grid. Upon grid connection, the 1000 MWe unit almost doubled Pakistan's nuclear generating capacity.

At the inauguration of Karachi 2 in May 2021 Pakistan's Prime Minister, Imran Khan, said that the environmental and economic benefits will be "huge" in a country that is particularly vulnerable to climate change.

Karachi 2 is the first of two HPR1000 units to be constructed at the site, with the second scheduled be connected to the grid in 2022. Cold testing at Karachi 3 began in April 2021.

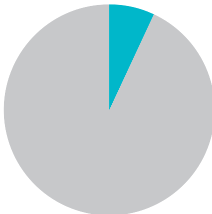
In light of its inability to buy uranium on the open market, Pakistan has agreed that CNNC is to provide lifetime fuel supply for the two reactors, specified as 60 years.

Pakistan aims for a significant expansion of nuclear power over the coming decades in order to meet its growing demand for energy.

Operable Reactors

2332 MWe

Nuclear Share of Generation

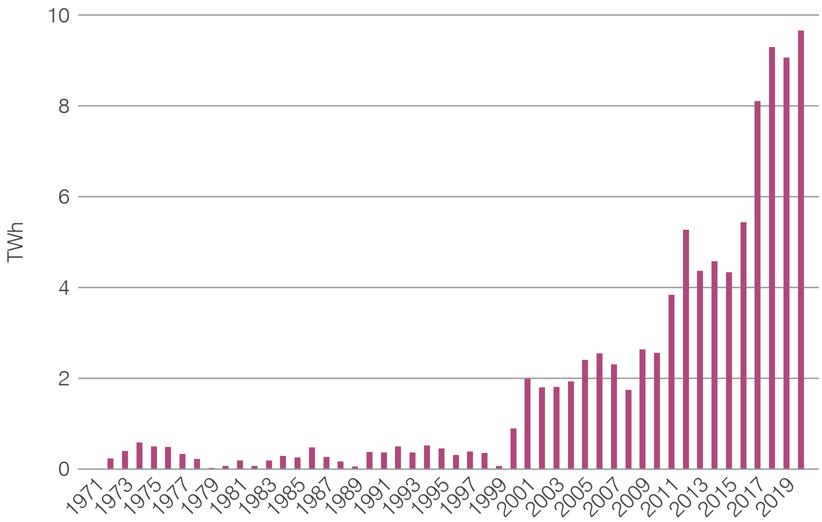


7.1 %

Reactors Under Construction

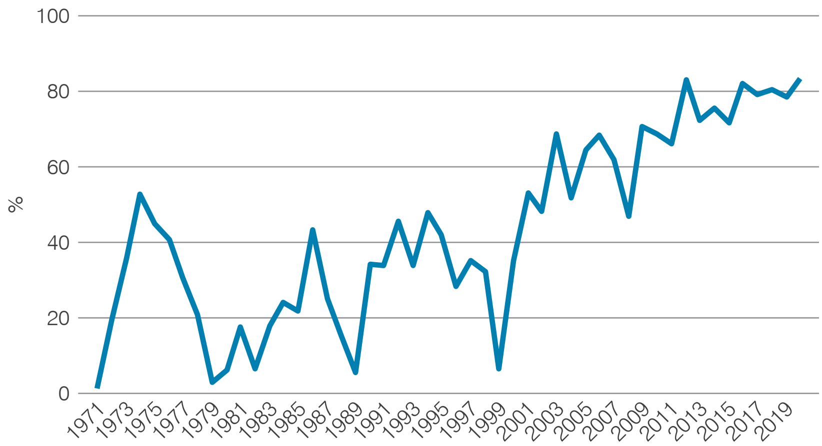
1014 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Romania

Two CANDU-6 PHWRs operate at the Cernavoda nuclear power plant, which is directly adjacent to the town of Cernavoda and 50 km west of the city of Constanta. In addition to electricity, the plant also provides district heating to Cernavoda town.

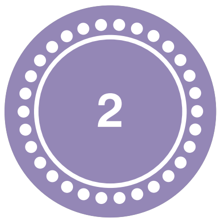
Originally planned as a five-unit plant, work on the later units was suspended to focus on completion of unit 1, and later unit 2.

In July 2020 the government announced it would create a committee headed by the energy minister tasked with completing units 3&4, cancelling a May 2019 agreement between Romania and China. A tender for a new feasibility study on completing the units was launched a few days later.

In October 2020 Romania signed intergovernmental agreements with both the USA and France. Among other things, both agreements aim to work to complete units 3&4 of the Cernovada plant. In February 2021 the CEO of Nuclearelectrica stated that a final investment decision on the expansion project is expected in 2024, with commissioning of unit 3 planned within 10 years.

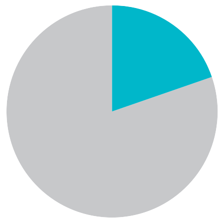
Romania is also interested in the use of SMRs. In January 2021 Nuclearelectrica was awarded a grant of USD 1.28 million by the US Trade and Development Agency (USTDA) for identification of potential sites in Romania to host SMRs. The USTDA is a federal government agency focused on connecting US companies with export opportunities.

Operable Reactors



1300 MWe

Nuclear Share of Generation

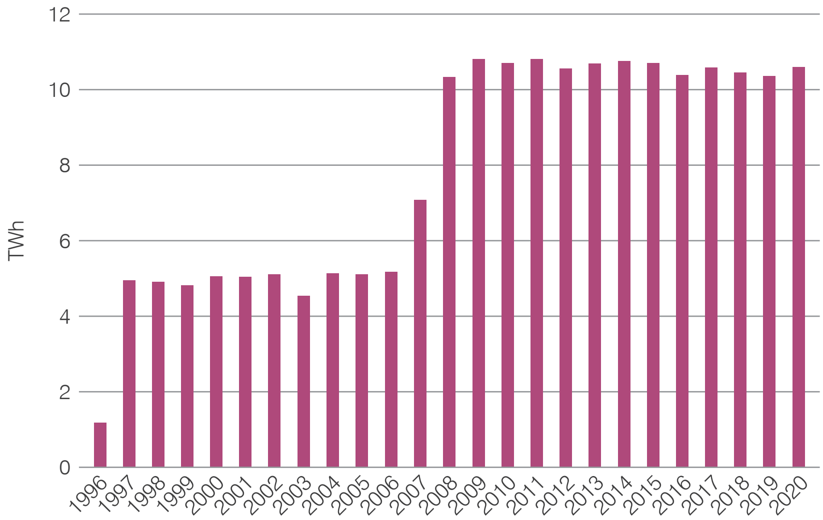


19.9 %

Reactors Under Construction

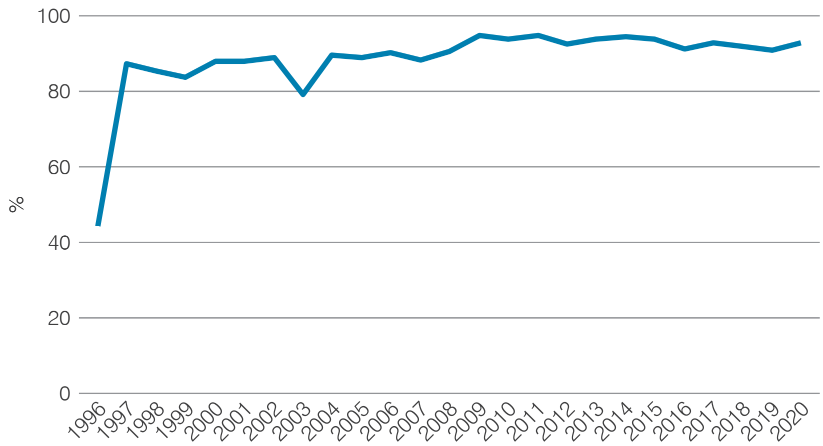
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Russia

There are 38 operable reactors in Russia, with the majority in the west of the country. Three small reactors are in operation at Bilibino, on the northeast Arctic coast, which are being replaced by a floating power plant moored at the nearby town of Pevek.

Russia has connected 10 reactors to the grid in the last decade, increasing its overall nuclear capacity by about 25%. There are two reactors currently under construction at its Kursk nuclear power plant.

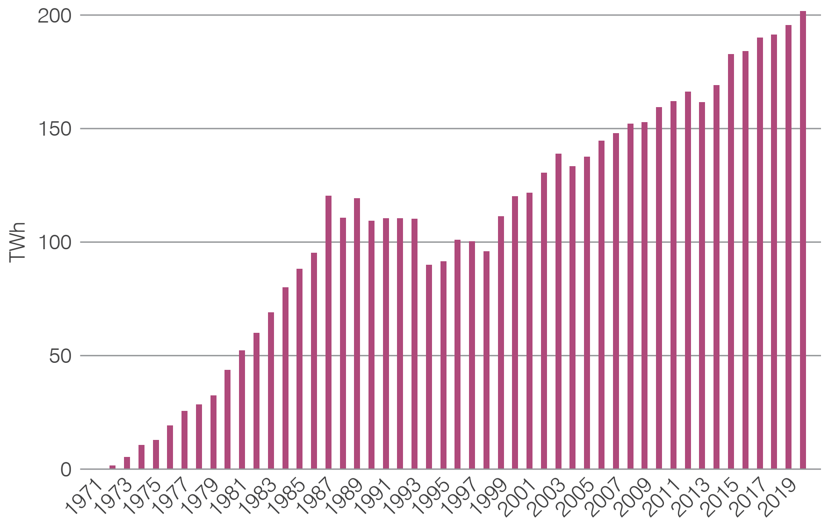
In March 2021 Rosatom announced that President Vladimir Putin's decision to increase the share of nuclear power in the country's mix to 25% by 2045 will require the construction of 24 new units.

In October 2020 Leningrad II-2 was connected to the grid, replacing an RBMK reactor at the same site, Leningrad 2, which was shut down a month later. Leningrad II-2 entered commercial operation in March 2021.

In December 2019 Siberian Chemical Combine (SCC) contracted Titan-2 to construct the BREST-OD-300 lead- cooled fast neutron reactor facility at its site in Seversk. The project is part of Rosatom's *Proryv* or Breakthrough project, which aims to enable a closed nuclear fuel cycle. Construction started in June 2021.

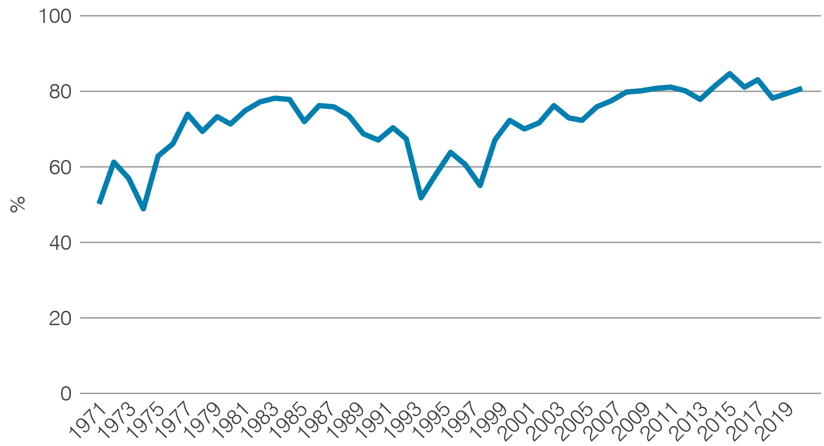
Operable Reactors	Nuclear Share of Generation	Reactors Under Construction
28,578 MWe	20.6 %	2350 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Slovakia

Two VVER-440 reactors are in operation at Mochovce, 100 km east of Bratislava, and a further two are in operation at Bohunice, 140 km northeast of Bratislava.

Construction on two more reactors at Mochovce originally started in 1987, before being halted in 1992. Construction restarted in 2009, and startup of unit 3 is now expected this year, with unit 4 a year later. In May 2021 Slovakia's regulator issued an operating licence for unit 3, as well as related permits for the management of radioactive waste and used nuclear fuel. As of March 2021 unit 3 was 99.95% complete and unit 4 88%.

SE expects the two new reactors, with a combined capacity of 942 MWe, to produce about 7 TWh per year, which would cover about 10-15% of Slovakia's electricity demand. TVEL has signed a contract with SE for the supply of nuclear fuel for 2022-2026 with the possibility of extension to 2030.

In August 2020 work to modernize the turbines of units 1&2 of the Mochovce plant began. The upgrade will increase the capacity of each unit from 471 MWe to 500 MWe.

Operable Reactors

1837 MWe

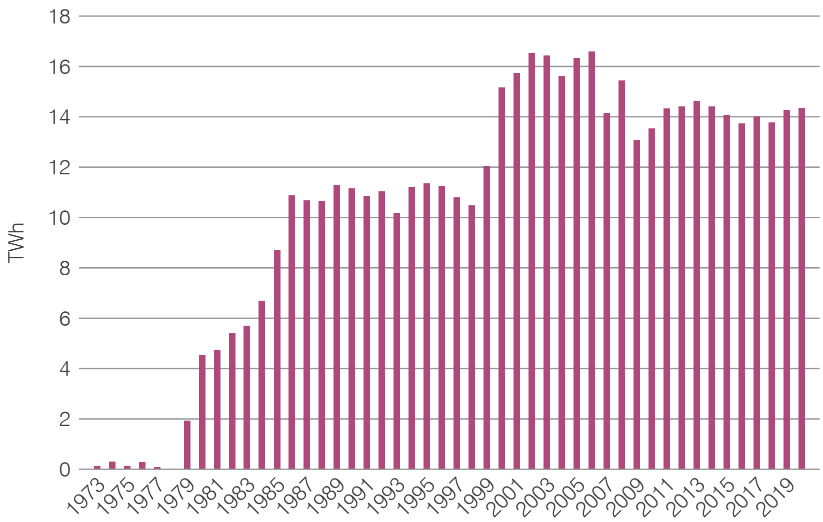
Nuclear Share of Generation

53.1 %

Reactors Under Construction

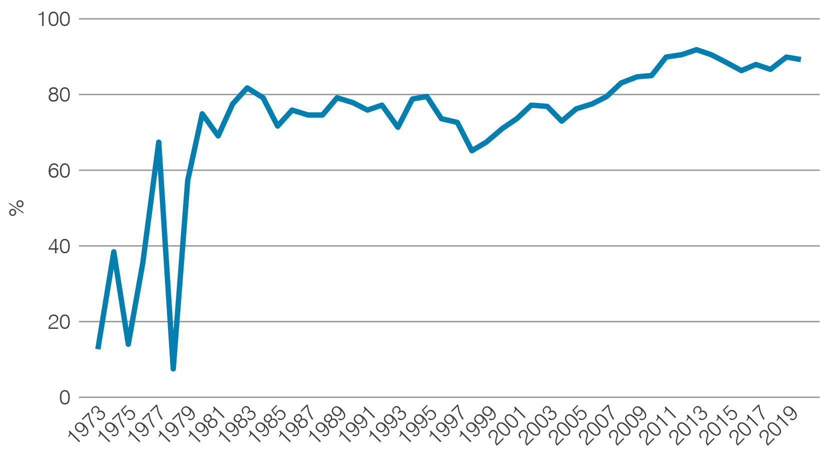
880 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Slovenia

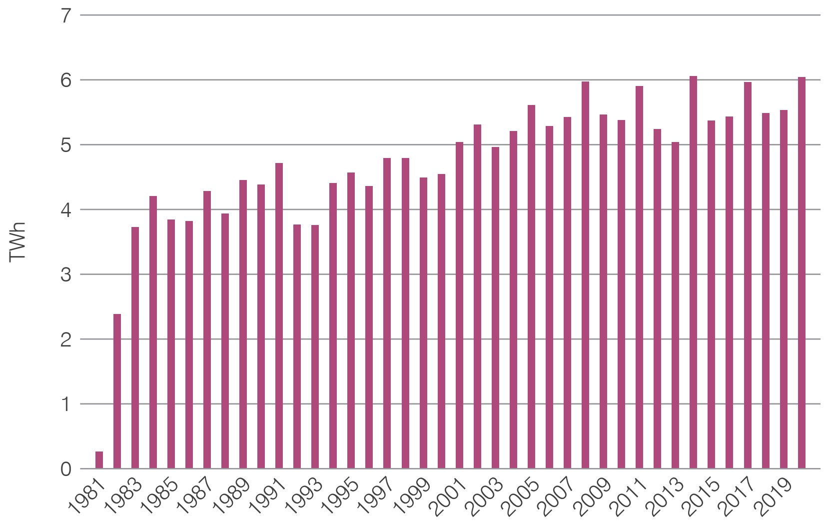
Slovenia's only nuclear power plant at Krško, 80 km east of Ljubljana, is a two-loop Westinghouse pressurized water reactor with a net capacity of 688 MWe.

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). The plant generates about 35-40% of the electricity produced in Slovenia and supplies more than one-quarter of Slovenia's and 15%'s of Croatia's electricity demand.

At the end of December 2020 a 6.4 magnitude earthquake struck the town of Petrinja. The Krško plant, which is located about 80 km from Petrinja, shut down as a precaution, but was reconnected to the grid two days later.

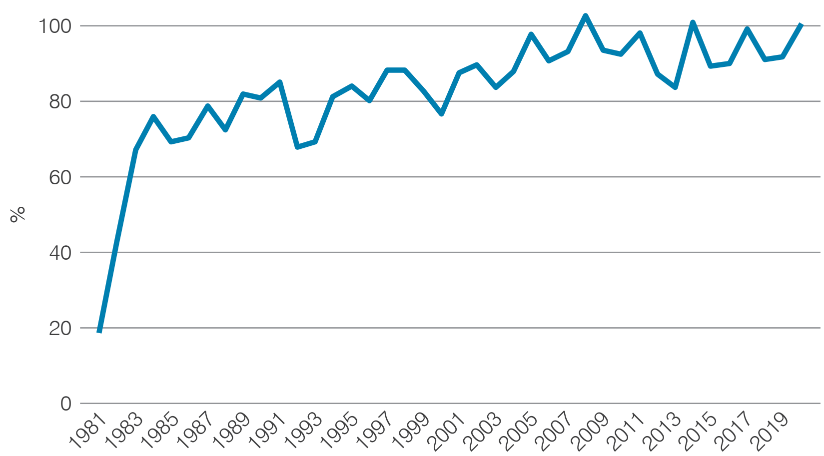
In May 2020 Infrastructure Minister Jernej Vrtovec said that the country will make a decision by 2026 at the latest on whether to build a second plant at the Krško site.

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

South Africa

Koeberg nuclear power plant's two reactors lie about 30 km north of Cape Town. The reactors have been in operation since the mid-1980s.

In October 2019 it was announced in the update to the country's Integrated Resource Plan (IRP) that the operation of Koeberg would be extended by 20 years to 2044.

In September 2020 the first of six replacement steam generators arrived at Koeberg. The generators are being replaced as part of the US$ 1.2 billion programme needed to extend the operating life of the plant.

The government also committed in October 2019 to immediately starting a nuclear new build programme to add 2500 MWe of generating capacity.

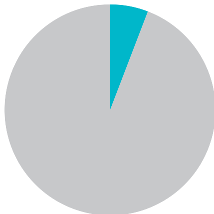
In May 2020 the Department of Mineral Resources and Energy (DMRE) announced it would begin work on a roadmap for the procurement of 2500 MWe of new nuclear capacity. It said it will consider "all options" including SMR projects led by private companies and consortia. In November 2020 South Africa's regulator invited public comment on the government's plans to procure the new capacity.

In February 2021 Eskom refuted media claims that the reinforced concrete containment buildings at Koeberg had suffered extensive corrosion. Eskom says that tests have confirmed the performance of the structures, to which repairs have already been made.

Operable Reactors

1860 MWe

Nuclear Share of Generation

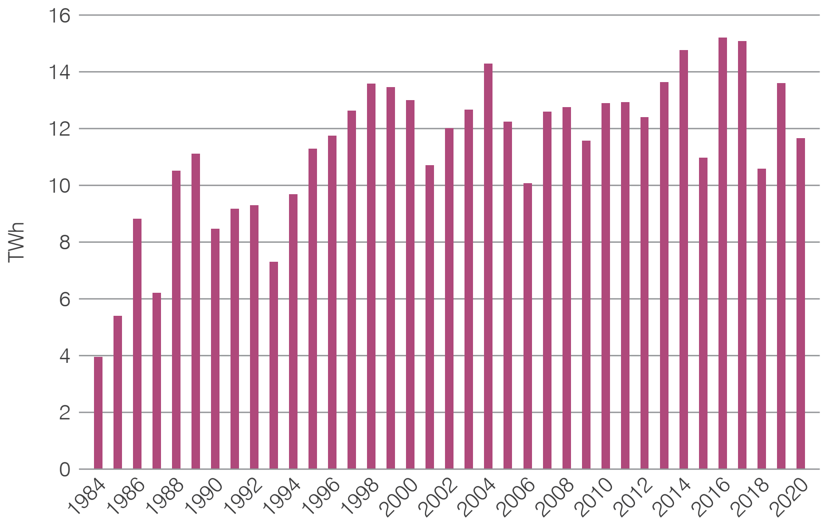


5.9 %

Reactors Under Construction

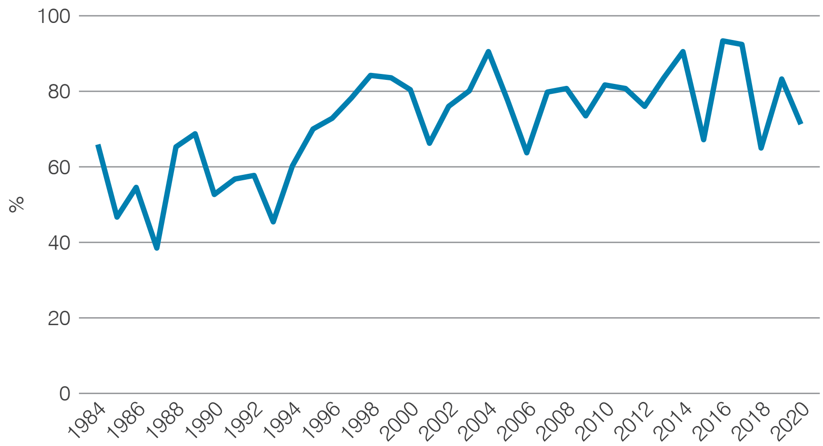
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

South Korea

There are 24 reactors operating in South Korea, with six on the west coast of the country at Hanbit, and 18 across three sites on the east coast, at Hanul, Wolsong/Shin Wolsong, and Kori/Shin Kori.

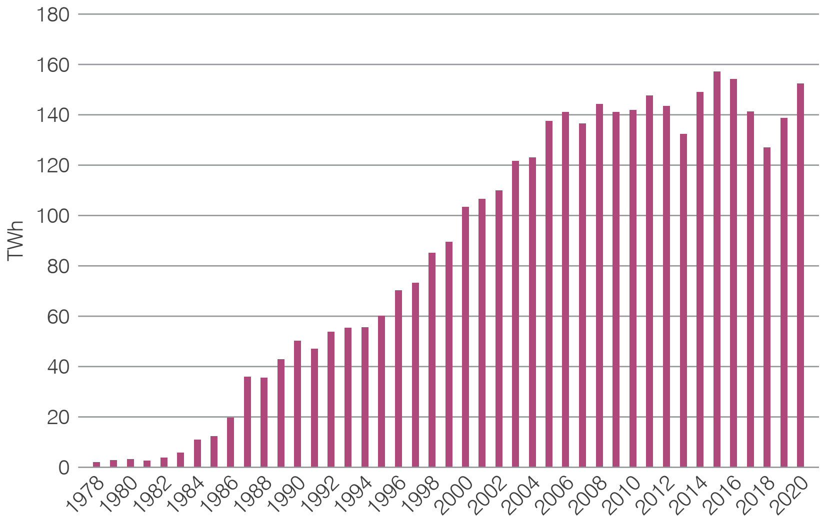
Two units are also being constructed at Shin Hanul, with the first unit expected to begin commercial operation in March 2022. Shin Kori 5&6 are under construction and are expected to start operation by 2024.

These units are expected to come online despite a government policy that came into force in 2018 to phase out nuclear power over a period of 40 years. The plan assumes that power demand will grow at an average of 1% a year to 2034 and that there would be 17 operable reactors by then. Construction on Shin Kori 5&6 was paused for three months pending a decision on the units' completion and in October 2017 a government-appointed committee voted 59.5% in favour of continuing construction.

The South Korean industry continues to pursue cooperation opportunities and business outside of South Korea. In October 2020 Kepco E&C and Daewoo Shipbuilding & Marine Engineering signed a memorandum of understanding to cooperate on developing floating nuclear power plants. Similarly, in June 2021 The Korea Atomic Energy Research Institute and shipbuilder Samsung Heavy Industries announced plans to work together on the development of a molten salt reactor for marine propulsion and floating power plants. Also in July, Doosan Heavy Industries and Construction increased its investment to support deployment of NuScale's SMR and Samsung C&T Corporation also committed to making an equity investment in NuScale.

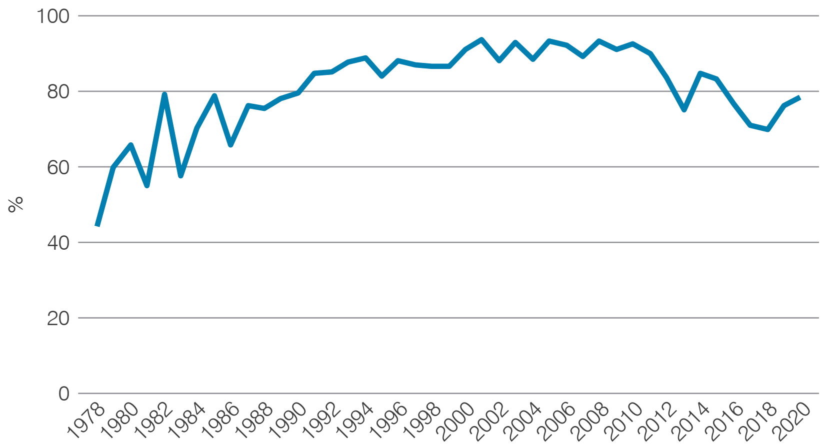
Operable Reactors	Nuclear Share of Generation	Reactors Under Construction
		
23,150 MWe	29.6 %	5360 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Spain

Seven nuclear reactors generate around 20% of Spain's electricity. These reactors all started operation in the 1980s.

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 and the reactors currently in operation are now expected to close over the next 15 years. In May 2020, Almaraz 1&2 were granted permission to operate until 2027 and 2028, respectively, and in February 2021 Confrentes' operating licence was extended until November 2030.

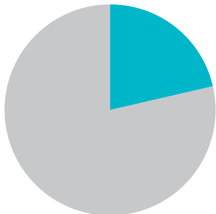
Spain aims to generate all its electricity from renewable sources by 2050. In a review of the country's energy policy in May 2021, the IEA said that it should consider the usefulness of nuclear energy, including for non-electricity applications, for diversifying technical options to achieve long-term carbon neutrality.

In May 2020, an application was submitted to the Ministry for Ecological Transition and Demographic Challenge (MITECO) for the transfer of ownership of the Garoña nuclear power plant and the first phase of its dismantling. The first phase is expected to last three years, the main activities will be loading of used fuel into containers and its transfer to the on-site interim storage facility.

Operable Reactors

7121 MWe

Nuclear Share of Generation

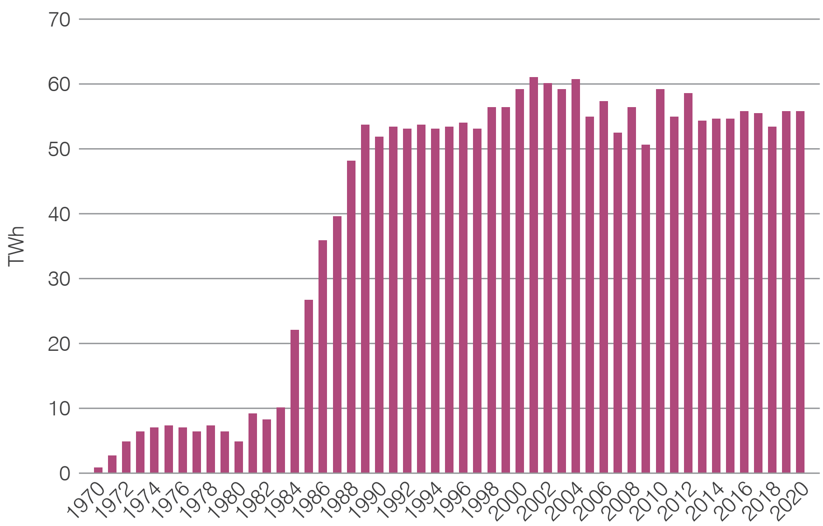


21.4 %

Reactors Under Construction

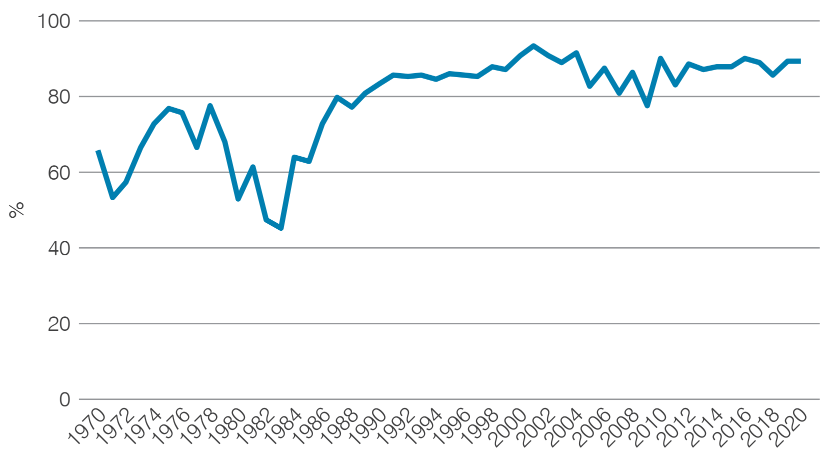
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Sweden

There are six reactors operating in three locations in Sweden. Ringhals, 50 km south of Gothenburg, Oskarshamm, 22 km northeast of the city of the same name; and Forsmark, 120 km north of Stockholm.

In January 2020 the Swedish Parliament narrowly rejected by a one vote majority a proposal from the Swedish Democrats party to reverse the planned closure of Ringhals 1&2.

Ringhals 1 went offline from March 2020 for a maintenance outage and remained offline due to low electricity demand but returned to service in June to provide grid stability. Despite providing this essential service, the reactor was shut down in December.

In October 2020 the municipal council of Östhammar voted in favour of SKB's planned repository for used fuel at Forsmark. The final decision to authorize the project now rests with the Swedish government.

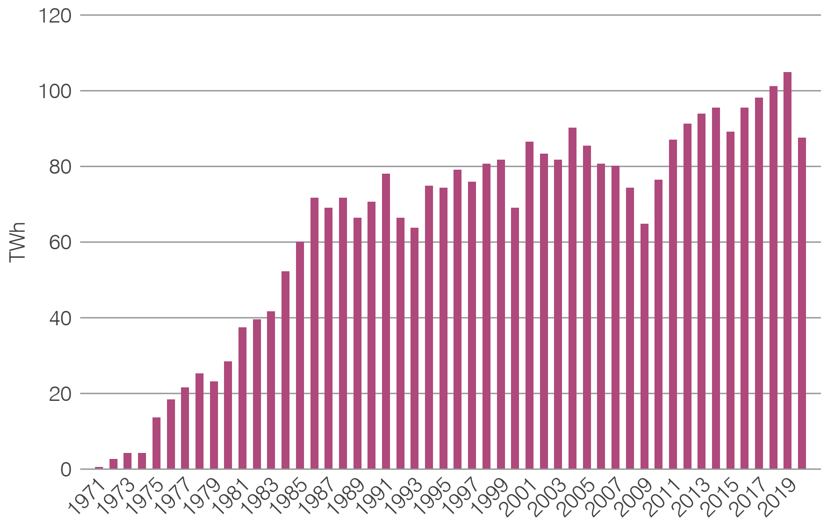
In November 2020 Vattenfall and Estonia's Fermi Energia signed a letter-of-intent to expand their cooperation on small modular reactors, having for the past year conducted a feasibility study together on the possibility of deploying such reactors in Estonia. In June 2021, Vattenfall agreed to take a minority stake in Fermi Energia with seed investment of €1 million.

Separately, in February 2021, Uniper Sweden, LeadCold and the Royal Institute of Technology (KTH) formed a joint venture to explore the possibility of construction a demonstration LeadCold SEALER SMR at Sweden's Oskarshamn plant by 2030.

Operable Reactors	Nuclear Share of Generation	Reactors Under Construction

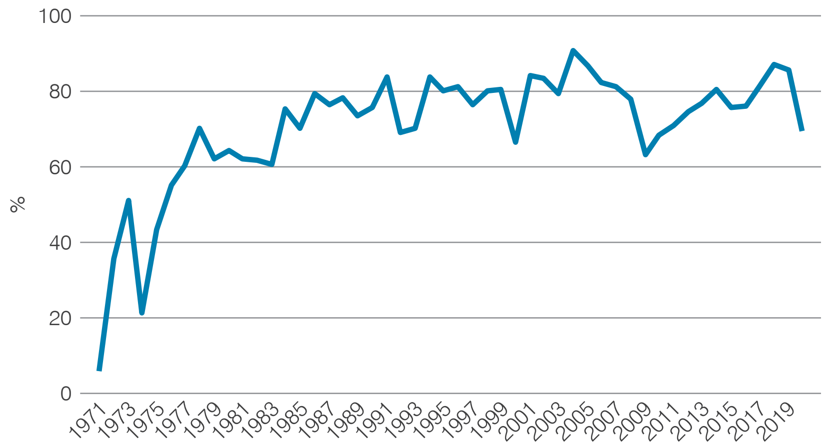
6882 MWe	29.8 %	0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Switzerland

Switzerland has two reactors at Beznau, 30 km southwest of Zurich, one reactor at Gosgen, 40 km southwest of Zurich and one at Leibstadt, 35 km northwest of Zurich. A fifth reactor at Muhleberg ended generation in December 2019 after 47 years in operation.

Switzerland voted to approve a revision to the country's energy policy that promotes the use of renewable energy sources and energy conservation in a referendum in May 2017. The revised Federal Energy Act also prohibits the construction of new nuclear power plants.

In October 2018, the IEA warned that Switzerland's phased withdrawal from nuclear power presented challenges for maintaining electricity security. In July 2021, media reports suggested that Switzerland's government was discussing extending the scheduled closure of the country's nuclear units.

During the winter months Switzerland is reliant on imports of electricity from the EU. Concerns were raised after, in May 2021, Switzerland's Federal Council rejected the institutional framework agreement, a deal negotiated with EU over seven years, that would have replaced Switzerland's existing electricity sharing agreements with the bloc.

Operable Reactors

2960 MWe

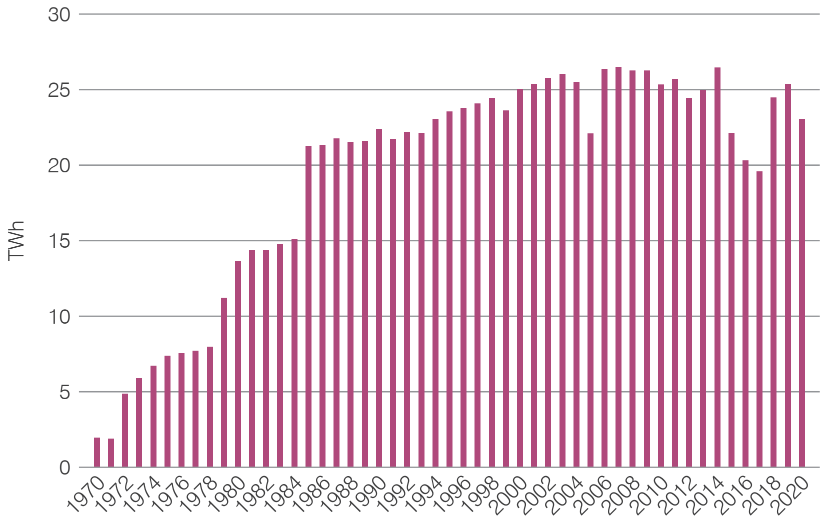
Nuclear Share of Generation

32.9 %

Reactors Under Construction

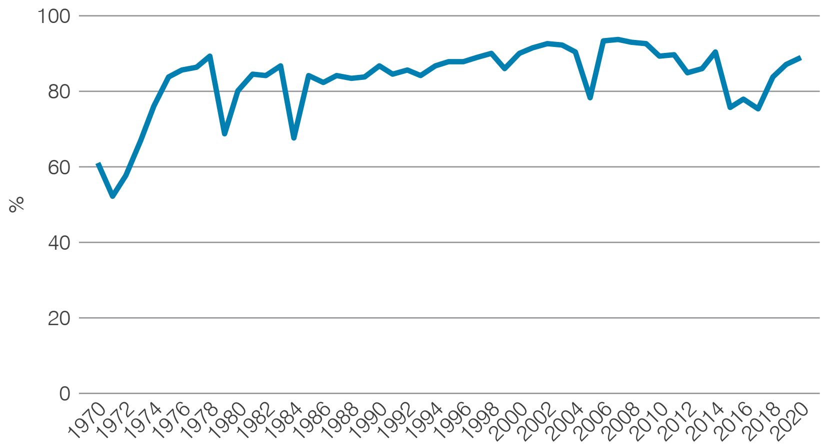
0 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Turkey

Construction is continuing on the Akkuyu nuclear plant on Turkey's southern coast, 120 km southwest of Mersin.

The plant will comprise four 1114 MWe VVER-1200/V-509 reactors, based on the V-392M reactors at Novovoronezh II.

In March 2021 first concrete was poured for unit 3. Construction commenced on units 1 and unit 2 in April 2018 and 2019, respectively. In November 2020 Russia delivered the reactor pressure vessel for unit 1, which was installed in June 2021. Earlier in January 2021 GE Steam Power delivered the first of the four turbines to the plant.

The four units are expected to be connected to the grid over four years from 2023. When fully operational the plant will supply about 10% of Turkey's electricity needs.

In March 2021 the Akkuyu project secured two loans of up to US$ 200 million and US$ 100 million for a period of seven years from Sovcombank to help finance the project. The loans are being provided on special terms, including a reduced interest rate to recognize the project's sustainability credentials.

Operable Reactors	Nuclear Share of Generation	Reactors Under Construction
0		3
0 MWe	0 %	0 MWe

Reactors under construction at Akkuyu, Turkey. (Image: Akkuyu image bank, ROSATOM)

Ukraine

Ukraine has 15 reactors operating from four sites, at Rovno and Khmelnitski in the west and South Ukraine and Zaporozhye in the south. Together they supply about half of the country's electricity needs.

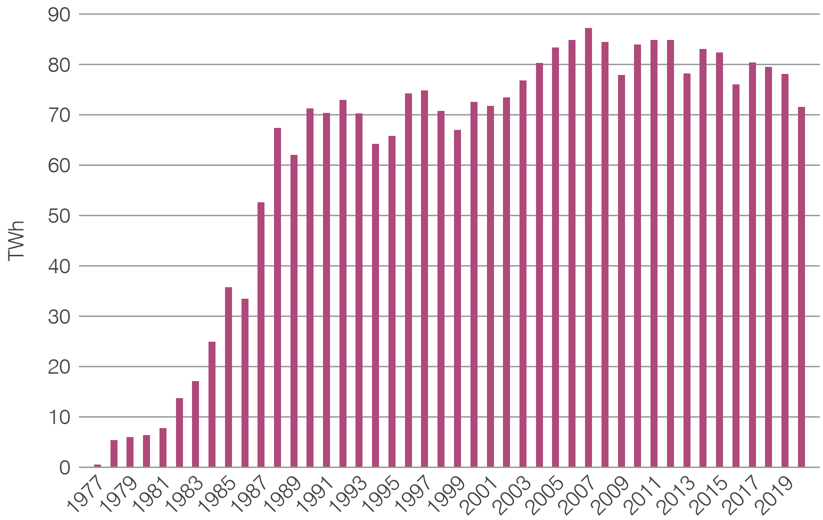
In October 2020 President Volodymyr Zelensky expressed his support for nuclear energy and confirmed the country's plans to complete the building of new reactors at Khmelnitsky and Rovno.

In November 2020 construction work resumed at Khmelnitsky 3&4. Construction of the two units originally started in 1985 and 1886, respectively, but work stopped in 1990 following a moratorium on the construction of new nuclear power plants. The project to complete the two units is part of the so-called 'Energy Bridge' with the EU. In January 2021 the president of Energoatom, Petro Kotin stated that the completion of the two units will put Ukraine alongside other countries in Europe that are experiencing a "nuclear renaissance".

In January 2021 the Ukrainian regulator approved a 10-year extension to the operating licence of Zaporozhe 5. The US Department of Energy (DOE) has been working with Argonne National Laboratory and Ukraine's NT-Engineering to help Energoatom enhance its approach to maintenance. The team assessed system configurations and maintenance routines to identify which services could be safely performed during operation. In July 2021 the DOE said that if the same work were carried out throughout the Ukrainian fleet, the country could boost its annual nuclear power production by 10% — the equivalent of an additional VVER-1000.

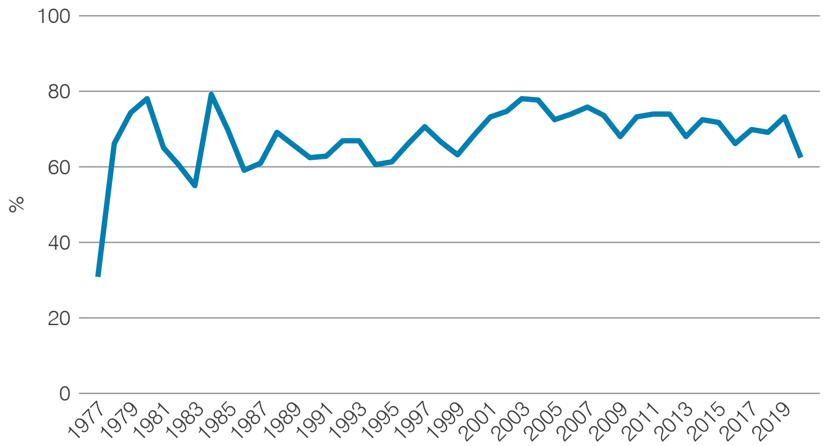
Operable Reactors	Nuclear Share of Generation	Reactors Under Construction
13,107 MWe	51.2 %	2070 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

United Arab Emirates

The United Arab Emirates has one operable reactor, Barakah 1. Having achieved grid connection in August 2020, the unit entered full commercial operation in April 2021.

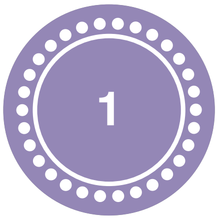
It is the first of four APR1400 units being built at the site, located 50 km east of Al Sila, in the Al Dhafrah region. Construction of unit 2 is complete and, following the issuance of an operating licence, in March 2021 fuel loading commenced. It is expected to be connected to the grid later in 2021.

Once all four units are operational, the plant will supply 25% of the UAE's electricity.

In June 2021, Emirates Nuclear Energy Corporation (ENEC) reported that it had achieved four years and more than 100 million safe man-hours without a Lost Time Injury at Barakah.

In November 2020 UAE and Saudi nuclear regulators agreed to cooperate in nuclear and radiation regulatory matters. The agreement followed the signing of a bilateral accord in 2019 on cooperation in nuclear energy between the two countries.

Operable Reactors



1345 MWe

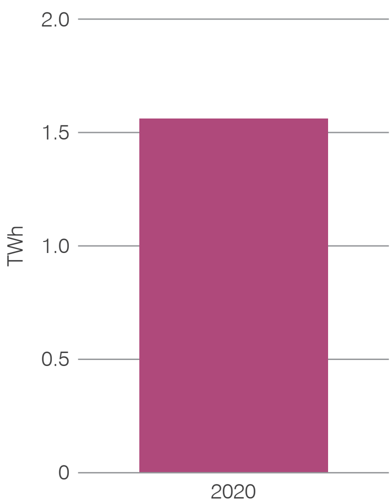
Nuclear Share of Generation

1.1 %

Reactors Under Construction

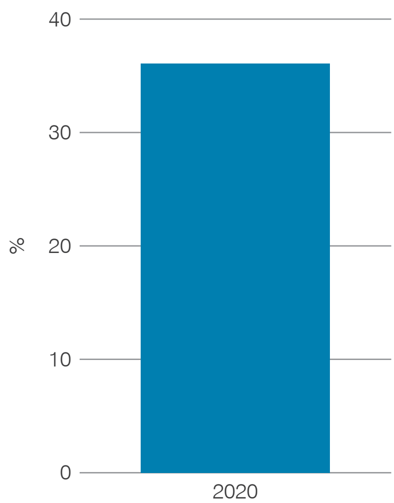
4035 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

Barakah 2 (Image: ENEC)

United Kingdom

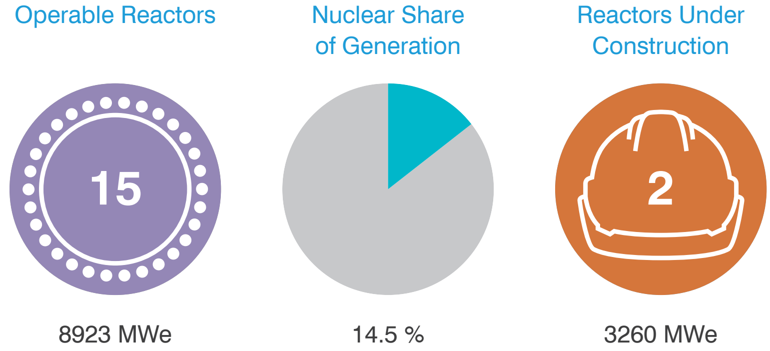
The UK has 15 reactors at seven sites, 14 of which are advanced gas-cooled reactors (AGRs), with one PWR at Sizewell. Around half of the AGRs are scheduled to shut down by 2025, with the remaining ones closing by 2030. Two EPRs are under construction at Hinkley Point.

In November 2020 UK Prime Minister Boris Johnson unveiled the country's 10-point plan for reducing emissions. Point 3 of the plan is the government's commitment to develop new nuclear power. In the same month the UK Treasury said that it is important to consider large-scale nuclear projects in addition to Hinkley Point C if the country is to meet its net-zero target.

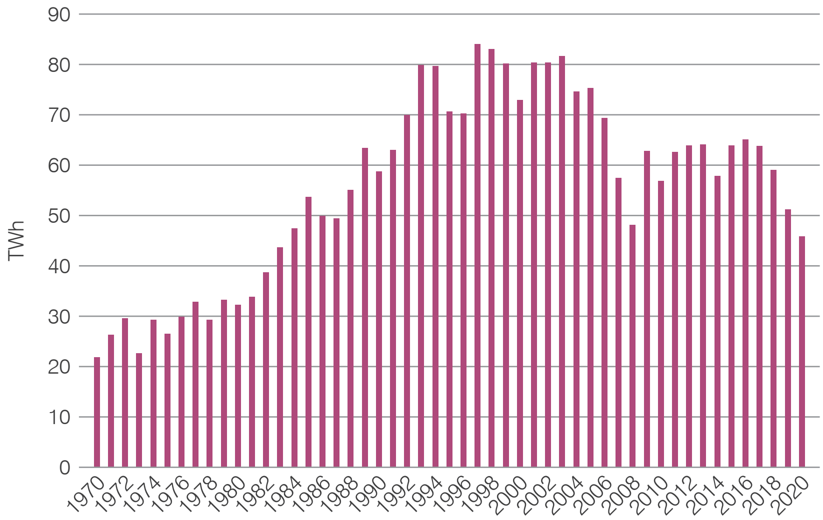
In September 2020 Hitachi withdrew from its planned project with Horizon at Wylfa Newydd. Horizon subsequently secured two delays to the decision on the Development Consent Order (DCO) for the project so that it could explore talks with third parties. However in January 2021 Horizon withdrew its planning application.

In June 2021 EDF Energy announced that Dungeness B would not restart, having been on an outage since 2018.

Construction continues on the two EPRs at Hinkley Point C, EDF Energy announced that construction of the 180-tonne liner cup for unit 2 was 30% quicker than it had been for unit 1, demonstrating the benefits of fleet build. In January 2021 EDF announced a revision to the schedule and budget for Hinkley Point C, with the start of electricity generation from unit 1 now expected in June 2026 (rather than the end of 2025).

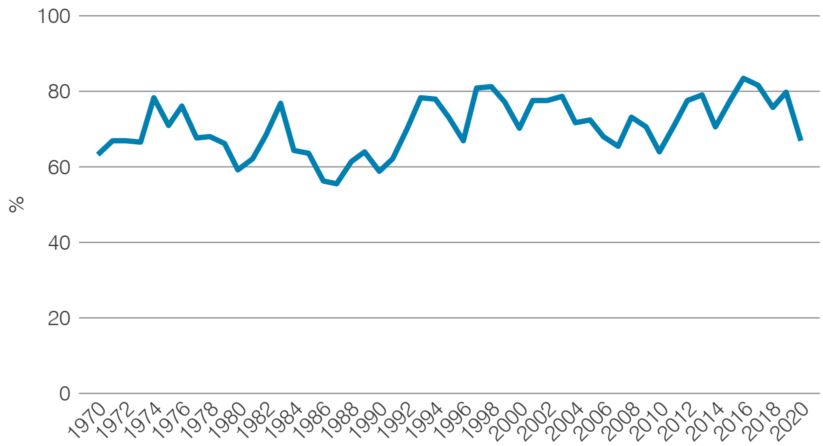


Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

United States of America

The USA has 93 operable reactors, with a combined capacity of 95.5 GWe, the largest nuclear fleet of any single country.

Two AP1000 reactors are under construction at the Vogtle power plant in the state of Georgia. In December 2020 Georgia Power took delivery of nuclear fuel for Vogtle 3. The company expects to start up the first unit in 2022.

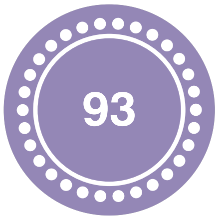
The Vogtle reactors will be the only ones to enter service following 17 licence applications made since mid-2007 to build 26 new nuclear reactors. Some states have liberalized wholesale electricity markets, which makes the financing of capital-intensive power projects difficult, and this, coupled with lower gas prices since 2009, has put the economic viability of some existing reactors and proposed projects in doubt.

Two reactors have shut down in the in the USA in the past 12 months: Duane Arnold in October 2020 and Indian Point 3 in May 2021. The closure of Indian Point 3 brought to an end a record breaking period of 751 days uninterrupted operation — the longest achieved by any commercial light water reactor.

In March 2020, Peach Bottom 2&3 became the third and fourth units in the US authorized for 80 years of operations. Surry 1&2 received similar authorization in May 2021.

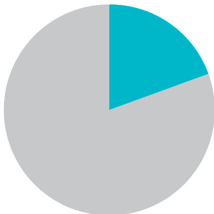
The USA is examining the potential for SMRs and advanced nuclear reactors. To support advanced reactors the DOE expects to invest US$ 600 million over the next seven years as part of its Advanced Reactor Concepts programme.

Operable Reactors



95,523 MWe

Nuclear Share of Generation

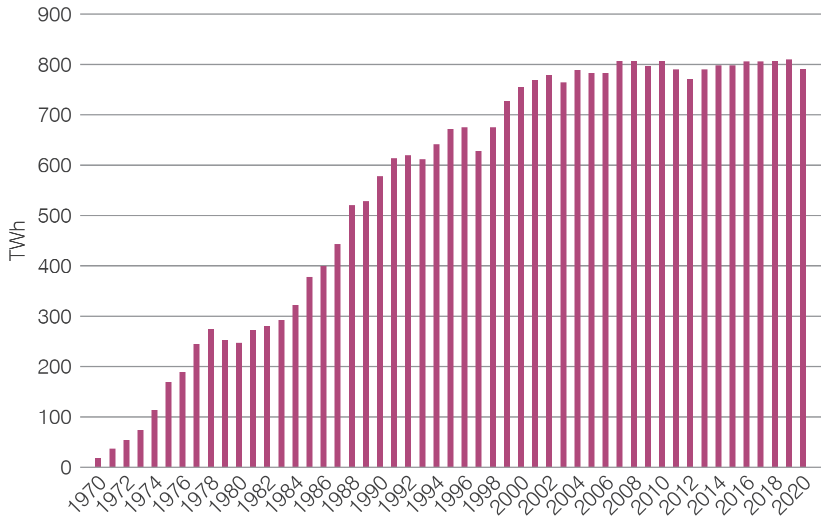


19.7 %

Reactors Under Construction

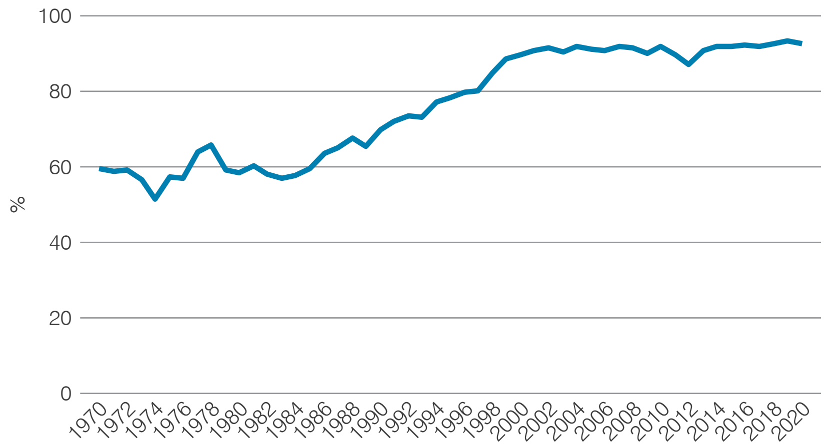
2234 MWe

Nuclear electricity production



Source: World Nuclear Association, IAEA PRIS

Average nuclear capacity factor



Source: World Nuclear Association, IAEA PRIS

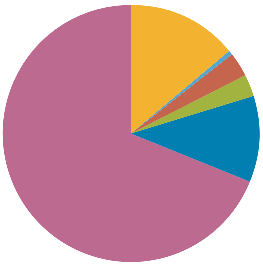
4 | Nuclear Reactor Global Status

1 September 2021

Operable reactors

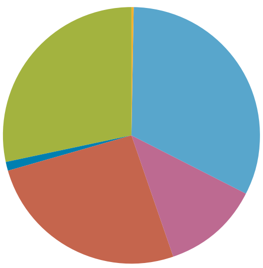
394,282 MWe

Operable reactors by type



BWR	62
FNR	2
GCR	14
LWGR	12
PHWR	49
PWR	304

Operable reactors by region



Africa	2
Asia	143
East Europe & Russia	54
North America	114
South America	5
West & Central Europe	125

Grid connections 2021

Reactor name	Model	Type	Net Capacity (MWe)	First grid connection	Location
Kakrapar 3	PHWR-700	PHWR	630	10 January 2021	India
Karachi 2	HPR1000	PWR	1014	18 March 2021	Pakistan
Tianwan 6	ACPR-1000	PWR	1000	11 May 2021	China
Hongyanhe 5	ACPR-1000	PWR	1061	25 June 2021	China

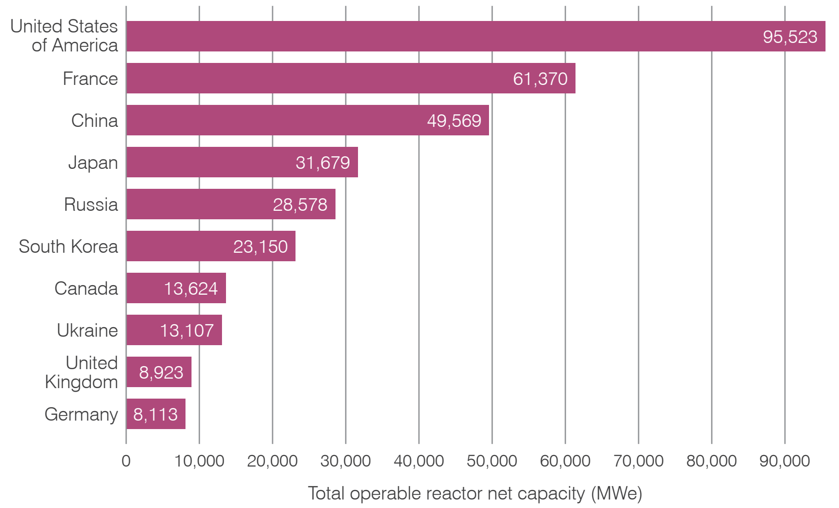
Construction starts 2021

Reactor name	Model	Type	Net Capacity (MWe)	Construction start	Location
Akkuyu 3	VVER V-509	PWR	1114	10 March 2021	Turkey
Changjiang-3	Hualong One	PWR	1100	31 March 2021	China
Tianwan 7	VVER V-491	PWR	1100	19 May 2021	China
Seversk BREST-OD-300	BREST-OD-300	FBR	300	8 June 2021	Russia
Kundankulam 5	VVER-1000	PWR	1000	29 June 2021	India
Changjiang SMR-1	ACP100	PWR	125	13 July 2021	China
Xudabao 3	VVER V-491	PWR	1100	28 July 2021	China

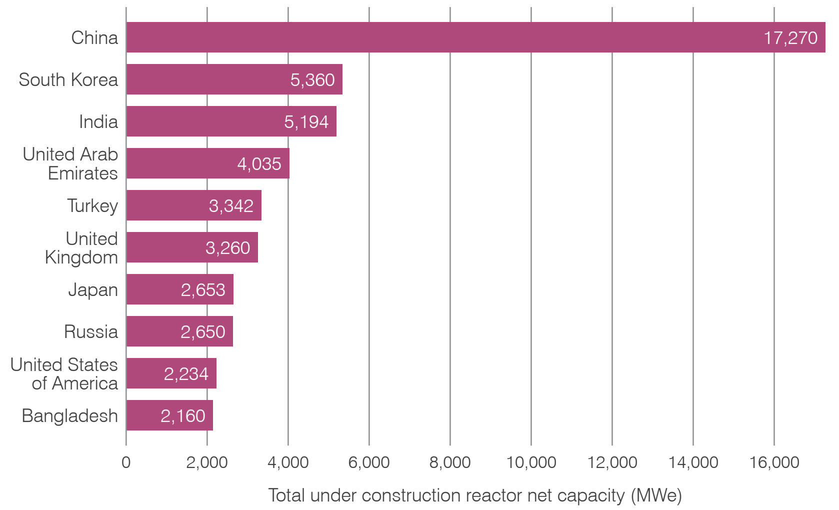
Permanent shutdowns 2021

Reactor name	Model	Type	Net Capacity (MWe)	Permanent shutdown	Location
Indian Point 3	W (4-loop) DRYAMB	PWR	1030	1 May 2021	United States of America
Kuosheng 1	BWR-6	BWR	985	1 July 2021	Taiwan

Top 10 countries installed capacity



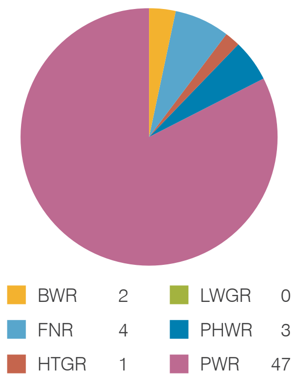
Top 10 countries capacity under construction



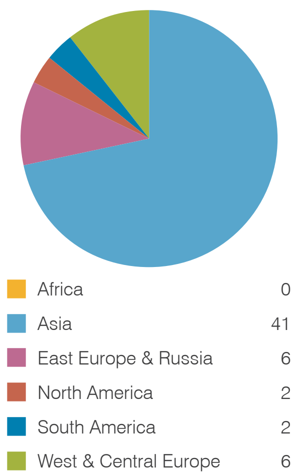
Under construction

58,801 MWe

Under construction by type



Under construction by region



5 Director General's Concluding Remarks

Throughout 2020 the world's nuclear reactors have shown their resilience in the face of the challenges posed by the ongoing global pandemic. Supported by the commitment and professionalism of operators everywhere, nuclear reactors have continued to supply electricity reliably. At the same time, reactors have shown they are able to operate more flexibility, adapting to the lower overall demand and consequential increased share of renewables.

Unfortunately, even with the tentative economic recovery seen so far has come a sharp rebound in fossil fuel emissions. The International Energy Agency has warned that coal-fired generation will meet much of the expected 5% rise in electricity demand expected in 2021, pushing carbon emissions to record highs.

Urgency, ambition, and time for action

The IPCC's 6th assessment report makes for stark reading. We are no longer in the situation in which taking action would avoid climate change, but have reached the point where urgent action is needed just to limit its effects. Only a massive reduction in greenhouse gas emissions can keep global temperatures from rising by more than two degrees. While 2050 net-zero pledges from countries and companies continue to capture headlines, few of these commitments are supported by realistic action plans. And given the conclusions of the report, 2050 maybe too late… we may need to actually focus on 2040.

The IPCC report highlights the importance of using all the tools currently at our disposal today to decarbonize all sectors of the economy, and to continue to invest in new technologies that will be able to contribute to combat climate change in the relatively short term.

As the single largest source of low-carbon electricity in advanced economies, nuclear energy is ready to continue to provide reliable 24/7 affordable clean electricity in the more than 30 countries that already use it, as well as in many new countries that are planning to include it in their energy portfolio. Additionally, nuclear energy is eager to join forces with other low-carbon technologies to accelerate the decarbonization of the global economy.

Maintaining the current fleet

At a time when all zero-carbon generation is precious, it is imperative to maintain the current fleet of nuclear reactors up and running, because experience shows that when reactors are shut down fossil fuel generation takes their place. Moreover, additional generation from existing nuclear reactors is the most cost-effective mitigation action that can be taken in electricity generation.

Decision makers must take urgent action to enact policies that support nuclear power plants threatened by early closure because of distorted markets that fail to value their climate and energy security benefits.

Governments that have implemented policies to reduce or phase out nuclear generation must reassess those policies now. All proposed alternatives result in a greater reliance on fossil fuels, less reliable electricity systems and higher electricity prices.

Building the next generation

While existing reactors can continue to provide electricity for decades to come, the growing worldwide demand for electricity and energy, combined with the need to decarbonize the entire economy, means that there must be a substantial acceleration in new nuclear build programmes.

The green light should be given to the many reactor new build projects that could start soon. They will provide jobs, stimulate investment, and deliver low carbon electricity from today and into the 22nd century. These new projects will take advantage of the capacity, know-how and supply chains rebuilt by recent FOAK nuclear projects, and will capitalize on the window of opportunity to lower nuclear construction costs created by the lessons learned from these recent projects.

There must also be a commitment to nuclear research, development and deployment, to bring forward the next generation of reactors, large and small, including SMRs and advanced nuclear technologies.

Access to affordable financing

More than 75% of the cost of nuclear electricity is due to financing costs. Thus, if nuclear plants are to be deployed on the scale required to achieve net-zero by 2050 (or 2040!) then they will need to have access to affordable financing. Government commitment to nuclear energy will be essential to instill investor confidence, incentivize long term planning and attract private and public financing.

Globally, the investment community is prioritizing climate finance and projects compliant with ESG (Environment, Social and Governance) principles. Nuclear energy and the nuclear industry perform strongly in meeting climate and ESG criteria. However, too often this performance is not recognized, with deliberate political pressure exerted to pre-emptively exclude nuclear projects, such as seen with the proposed EU Sustainable Financing Taxonomy.

These political efforts to impose non-inclusive energy policies on other countries by limiting access to affordable financing must be rejected. ESG and climate financing criteria must be technology neutral, science-based and should be applied consistently to all economic activities.

Streamlining the international licensing process

Current regulatory requirements can present significant challenges to the deployment of new nuclear projects. This is an issue that may particularly burden the deployment of new technologies, including small modular reactors.

Late last year the CORDEL working group produced a report on harmonization of reactor design evaluation and licensing. The report recommended that an international framework is established for the harmonization of reactor design evaluation and licensing. At the heart of the framework would be a multinational regulatory advisory panel, composed of experts from national regulatory bodies, empowered by an international agreement.

Governments, regulators, and industry must work together to accelerate the deployment of new nuclear projects, so that nuclear technologies can maximize their contribution to help decarbonize generation, and sectors beyond electricity supply.

Nuclear beyond electricity

This report details the performance of nuclear reactors in terms of electricity generation. But, as the case study on the use of steam from the Haiyang plant for district heating demonstrates, nuclear technologies have the potential to contribute to many other sectors currently reliant on fossil fuels.

With governments looking to phase out gas-fired central heating systems and replace them with hydrogen-fuelled boilers demand for hydrogen is expected to increase dramatically. Adding to that demand would be the use of hydrogen for fuels cells, used for example in transportation applications.

At present, much of the hydrogen produced today is made fossil fuels, with high resulting greenhouse gas emissions. Nuclear technologies can provide alternatives. Electrolysis of water can produce hydrogen using electricity from any generation source, including nuclear. Reactors currently under development could supply heat directly at temperatures high enough to thermochemically split water to produce hydrogen.

High temperature process heat from nuclear reactors could have applications far beyond hydrogen production, with essential products such as concrete, glass and steel all requiring process heat in their manufacture, and currently depending on burning fossil fuels to provide that heat.

Climate change will bring increasing fresh water supply stresses. Supplying potable water through desalination is already a well-established application of nuclear technology.

Given that nuclear energy is the only low-carbon energy source that can produce zero-carbon electricity and heat, the potential for nuclear energy to decarbonize many hard-to-abate sectors of the economy is an opportunity that cannot be dismissed. Furthermore, the possibility of expanding beyond electricity the product offering of nuclear energy, will also improve the business case for existing and new nuclear power plants.

Abbreviations and Terminology

AGR	Advanced gas-cooled reactor
BWR	Boiling water reactor
CO_2	Carbon dioxide
COVID-19	Disease caused by the SARS-CoV-2 coronavirus
CORDEL	Cooperation in Reactor Design Evaluation and Licensing
ESG	Environmental, Social, and Governance
EU	European Union
FNR	Fast neutron reactor
FOAK	First of a kind
g	gram
GCR	Gas-cooled reactor
GWe	Gigawatt (one billion watts of electric power)
HTGR	High temperature gas-cooled reactor
IAEA	International Atomic Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LWGR	Light water-cooled graphite-moderated reactor
MoU	Memorandum of understanding
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)

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 where they to operate at 100% output for the fraction of the year in which they were in an operable status.

Geographical Categories

Africa
South Africa, Egypt

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

East Europe & Russia
Belarus, Russia, Ukraine

North America
Canada, Mexico, USA

South America
Argentina, Brazil

West & Central Europe
Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Hungary, Italy, Lithuania, Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK

Further Reading

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

World Nuclear Association Reactor Database
https://world-nuclear.org/information-library/facts-and-figures/reactor-database.aspx

The Nuclear Fuel Report: Global Scenarios for Demand and Supply Availability 2019-2040 (published September 2019)
https://world-nuclear.org/shop.aspx

The World Nuclear Supply Chain: Outlook 2035
https://world-nuclear.org/shop.aspx

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

The Harmony programme
https://world-nuclear.org/harmony

International Atomic Energy Agency Power Reactor Information System
https://www.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.

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