POLITYKA INSIGHT | RESEARCH

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Nuclear Poland

How to bring reactors to Poland

Introduction

The development of nuclear power is the subject of public debate in Poland. It is one of the strategic directions and goals of Polish energy policy, and potentially a vehicle for the country's civilisational development. Implementing nuclear energy today seems essential for Poland to avoid an electricity supply gap and meet European climate goals.

Preparations for the construction of nuclear reactors have been ongoing for decades. The delays so far have been mainly due to the scale and cost of the investments, which were too difficult for the Polish economy to bear, and the inadequacy of the economic, legal and social environment for such activities. Today, the dynamic development of nuclear power in Poland is now possible, but due to the international as well as the economic situation, it must be accelerated. The question is how to carry out this process optimally.

The aim of this report is to analyse the current possibilities and directions of nuclear power development in Poland up to 2040. It presents a set of actions that need to be taken, depending on the planned scale of Poland's nuclear investment, as well as an analysis of their nature and importance.

The report consists of three sections. The first examines the current status of Poland's preparations for the construction of nuclear reactors. We also present the activities undertaken to date in this direction, and those planned for the future. The second section discusses the determinants of nuclear power development in Poland: technological, economic, legal, environmental and social. Understanding these makes it possible to identify bottlenecks in the development of nuclear power, and to look for solutions for the future. The authors of this part of the report are recognised authorities in their fields, who have additionally provided practical recommendations for Poland for the future. In the third section, we present three likely scenarios for the development of nuclear power in Poland, depending on its scale and pace: minimum, balanced, and nuclearisation of Poland. The implementation of each of these is analysed in terms of the prospects arising from the conditions discussed in the second section, and the actions to be taken in the financial, human resources, legal, social and technological-environmental aspects. Regardless of the scenario, one conclusion is consistent: whatever challenges the development of nuclear power poses, it requires the initiative and commitment of the government, public entities, but also private businesses, who, alongside citizens, will be the biggest beneficiaries of the reactors.

The report is based on an analysis of resources and source documents, academic and industry publications, investor data, as well as the authors' own research. The conclusions are based on publicly available information, including details of planned investments and declarations by public authorities and institutions. We wish you an interesting read.

Polityka Insight
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List of selected thematic abbreviations

ARE	Energy Market Agency
BWR	boiling water reactor
CfD	Contract for Difference
CPK	Central Airport
CSC	compensation for nuclear damage
DEJ	Department of Nuclear Energy
GDOŚ	General Director for Environmental Protection
IAEA	International Atomic Energy Agency
IBNI	International Bank for Nuclear Infrastructure
KPEiK	National Energy and Climate Plan
KSE	National Electricity System
KSOP	National Radioactive Waste Repository
MKiŚ	Ministry of Climate and Environment
NCBJ	National Centre for Nuclear Research
NEA	Nuclear Energy Agency
NFOŚiGW	National Fund for Environmental Protection and Water Management
NIMBY	opposition to development in the immediate vicinity of the respondent (Not In My Backyard)
OECD	Organisation for Economic Cooperation and Development
OWT	Technical Support Organisations
OZE	Odnawialne Źródła Energii (renewable energy sources)
PAA	Polish Atomic Energy Agency
PCA	Polish Centre for Accreditation
PCBC	Polish Centre for Testing and Certification S.A.
PEJ	Polish Nuclear Power Plants
PEP	Poland's Energy Policy
PFR	Polish Development Fund
PPEJ	Polish Nuclear Power Programme
PRSP	Transmission Network Development Plan
PSE	Polskie Sieci Elektroenergetyczne
PWR	pressurised water reactor
RAB	tariff model (Regulatory Asset Base)
SGOP	Deep Repository for Radioactive Waste
SMR	Small Modular Reactor
SP	State Treasury (pol. Skarb Państwa)
UDT	Technical Supervisory Authority
UNSCEAR	Scientific Committee on the Effects of Atomic Radiation
URE	Energy Regulatory Office

Key conclusions

The construction of two nuclear power plants with a capacity of 6-9 GW is enough for Poland to avoid a power deficit by 2040. Full energy security can be achieved, but only by increasing investment in nuclear reactors – both conventional and SMRs. For this to happen, action is needed in the economic, legal, social, educational and environmental spheres – these challenges are discussed in this report.

State financial support is essential for the construction of nuclear power plants. The implementation of planned and announced nuclear projects in Poland requires a systemic change in the approach to state aid and structural support from government agencies. Without this, the market will not provide an adequate amount of capital, especially in view of the limited business credibility of some of the analysed projects. In the short term, the construction of the first conventional reactors may be secured by a contract for difference or based on the SaHo Model, which do not involve end-users but minimise investor risk by involving multiple sources of capital. In the longer term, the construction of reactors may already require a significant participation of electricity consumers in the costs.

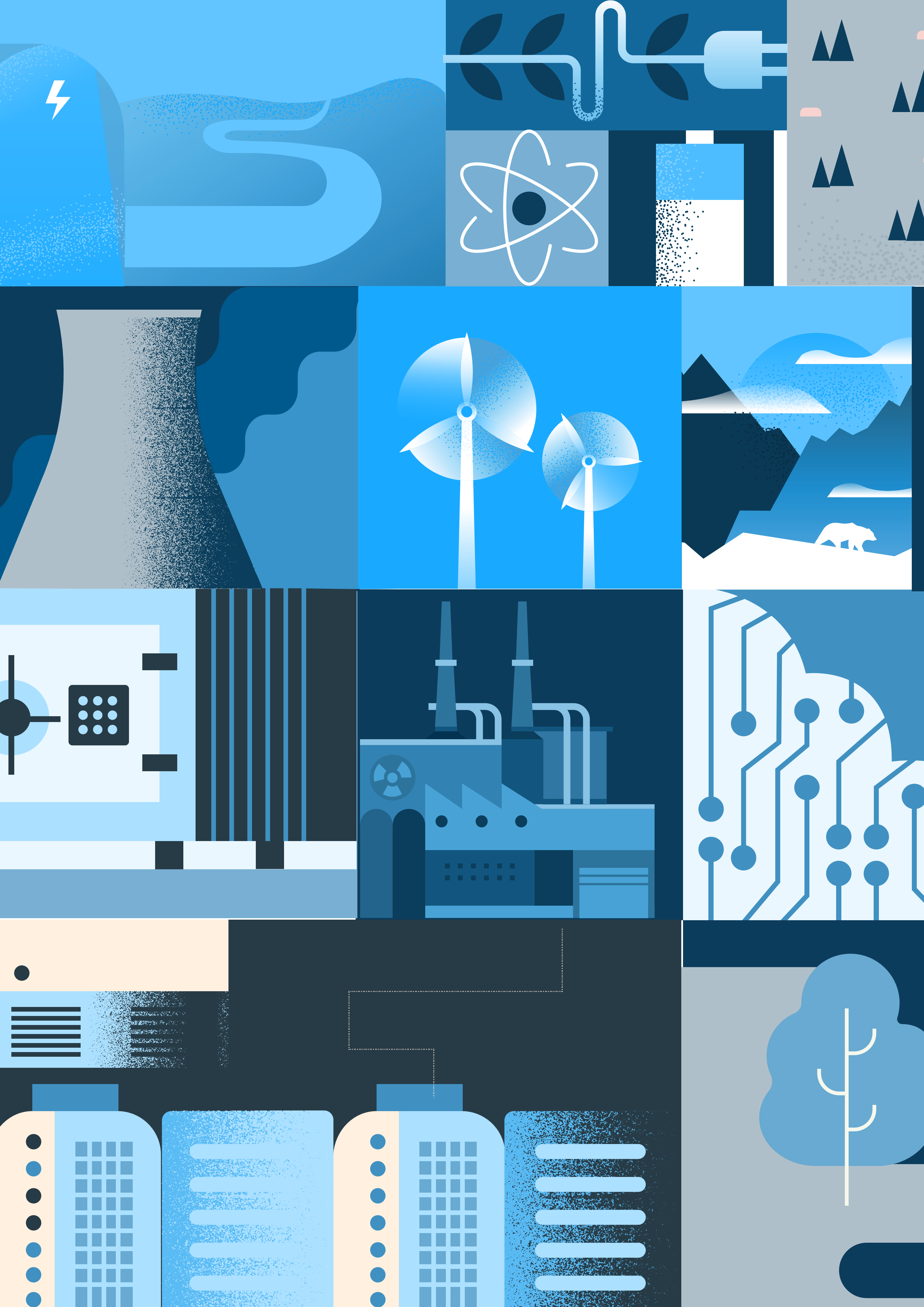
A major obstacle to the construction of nuclear power plants is the lack of a sufficiently abundant and qualified workforce. Within a few years, Poland, and especially the public administration, faces a shortage of staff trained to carry out and supervise the project to build reactors. This threatens delays in issuing approvals for the construction of reactors and, consequently, delays in the implementation of investments and increased risks for investors. An immediate increase in investment in nuclear training is therefore essential.

The legal regulations in place, taking into account the legislative amendments enacted in 2023, largely correspond to the needs arising from the investments envisaged in the Polish Nuclear Power Programme (PPEJ). However, the development of nuclear power in Poland requires the modification of individual areas of the law and the creation of new ones. For example, the announced development of small reactors (SMRs) may entail the need to differentiate in legislation the legal requirements for reactors according to their power or even to include SMRs in a separate special act. However, this will probably not happen until the specification of this technology and the possibilities for its implementation in Poland are better known, as is currently the case in the US and Canada.

The European Union's experience of several decades in operating reactors should be a valuable lesson for Poland. Based on this, areas in the law that usually need to be regulated at later stages of reactor construction or operation can be addressed well in advance. These may include, for example, regulations related to spent nuclear fuel and its disposal or reprocessing. To a large extent, however, further proposals for regulatory changes can only be expected during the implementation of individual projects. It is only then that it will become clear how effective the current measures regulating the development of nuclear power plants in Poland are, including those designed to prevent protraction of the investment process.

The high public support in Poland for the construction of nuclear power plants is rather unstable and depends on external conditions. Reactor failures or natural disasters related to nuclear waste management may increase the number of opponents to the construction of reactors in Poland. This also raises the risk of increasing the susceptibility of Poles to populist slogans calling for the abandonment of such an investment despite the merits.

Small reactors are an attractive and promising prospect in the transformation of Polish industry. If the technology becomes commercialised in the West, its implementation in Poland may be faster than in other European countries, helping the energy and heating sectors. At the moment, however, the costs of building and operating SMRs are uncertain, so their reliable and credible development is one of the tasks for the coming years and a prerequisite for their commercialisation.



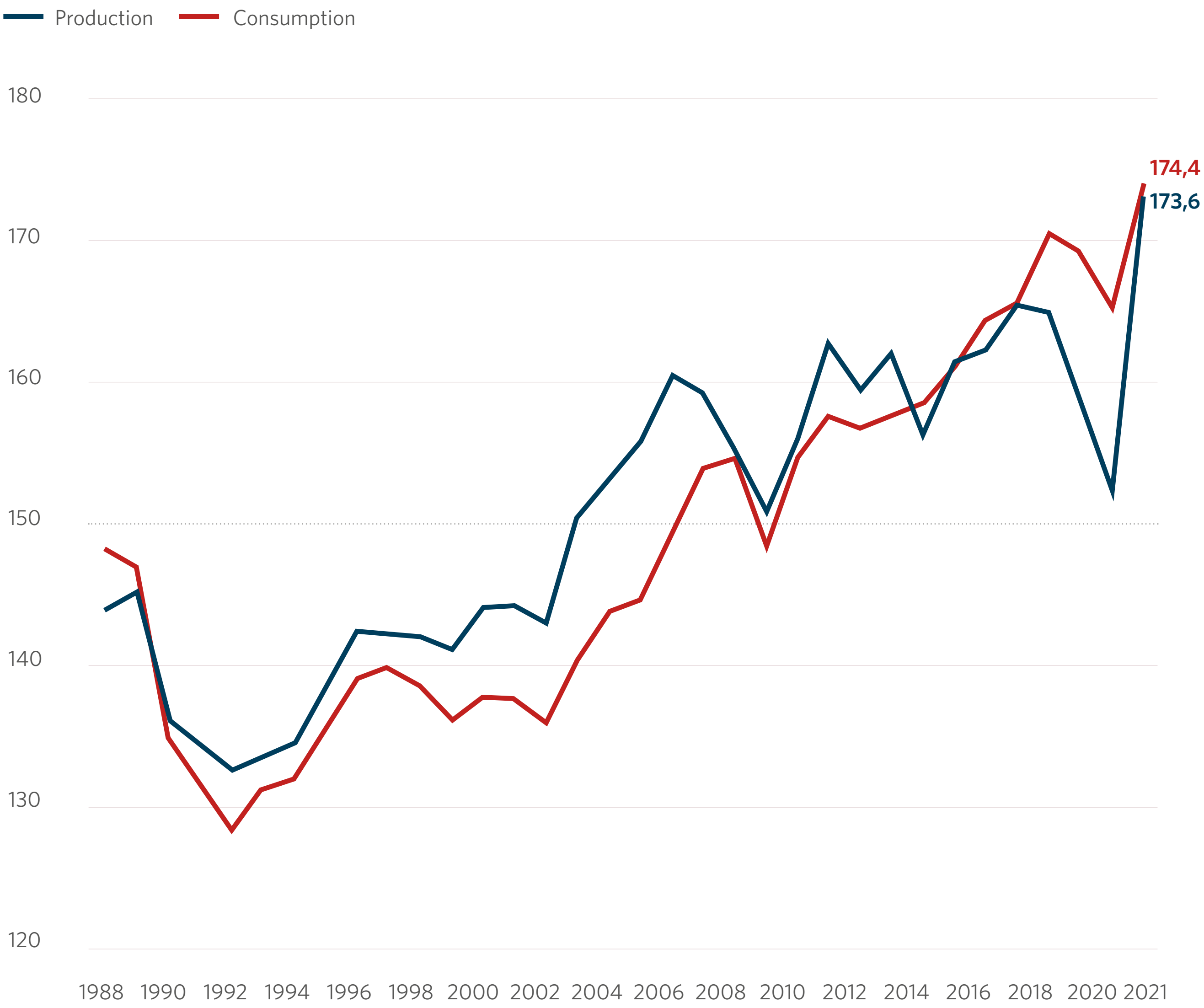
01

Where are we with nuclear power?

Dominik Brodacki, *Polityka Insight*

Successive Polish governments have argued in favour of plans to build nuclear power plants, citing concern for safety and economics. In favour of investment in nuclear power is the prospect of generating a strong impulse for technological progress, including a stimulus for new investments, the development of science, job creation and building a competitive advantage for Polish companies, as well as ensuring low energy prices for end users. An additional factor is the challenge associated with the systematic growth of electricity consumption in Poland. This in the future will be covered to an increasingly smaller extent by generation from domestic energy sources.

ELECTRICITY PRODUCTION AND CONSUMPTION IN POLAND IN THE YEARS 1988-2021 (TWH)

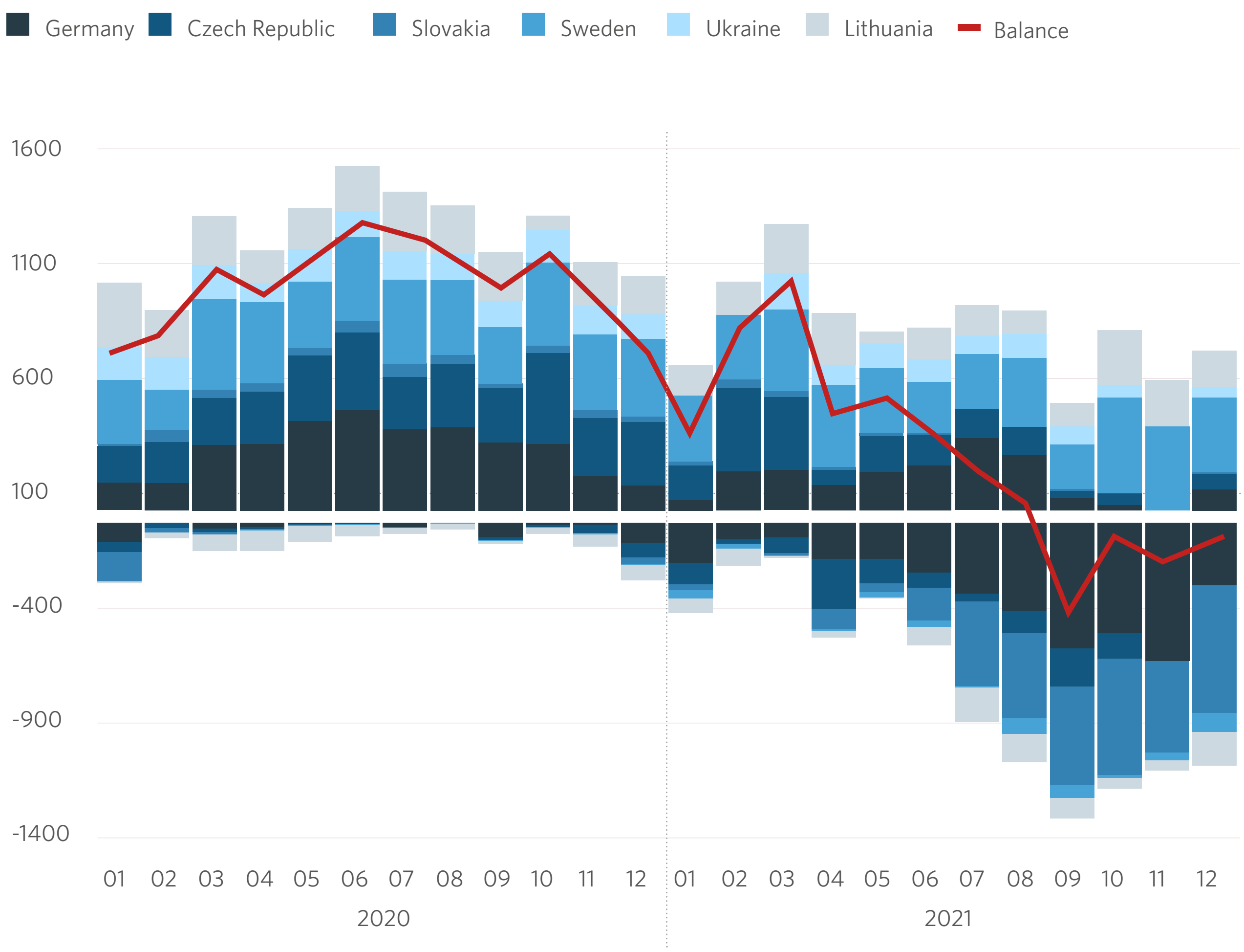


SOURCE: PSE.

According to data from Polskie Sieci Elektroenergetyczne (PSE), domestic electricity production in 2022 amounted to 175.1 TWh (up 0.9 per cent year-on-year). This surpassed demand, which, relative to 2021, decreased by 0.5 per cent, to 173.4 TWh. This means that Poland was a net exporter of electricity for the first time since 2015, supplying more than 1.09 TWh to neighbouring markets. This change – paradoxically – is due to the energy crisis (from the increase in commodity and energy prices and the economic slowdown), the expansion of wind and photovoltaic capacity and economics – energy prices on foreign markets were higher, so Polish electricity was attractive to other countries.

For comparison: as recently as 2021, domestic production covered 99.5 per cent of the demand of 174.4 TWh, while in 2020, Polish power plants managed to cover only 92 per cent of demand, in 2018. 96.2 per cent, in 2017. – 98.9, and in 2016. – 97.6 per cent. The rest was balanced by imports. **In the future, however, it may not be feasible to maintain a surplus of exports over electricity imports.** It is to be expected that with the announced drop in gas prices and increase in the price of CO2 emission allowances, Polish coal-fired power plants will quickly lose their competitive edge, and this will increase Poland's dependence on energy from the West. In the following years, this trend will be reinforced by the necessity to decommission coal-fired units – both for operational reasons and the prospect of losing the possibility of subsidising them from the capacity market in 2025.

ELECTRICITY TRADE IN POLAND IN THE YEARS 2020-2021 (GWH)



SOURCE: OWN COMPILATION BASED ON PSE.

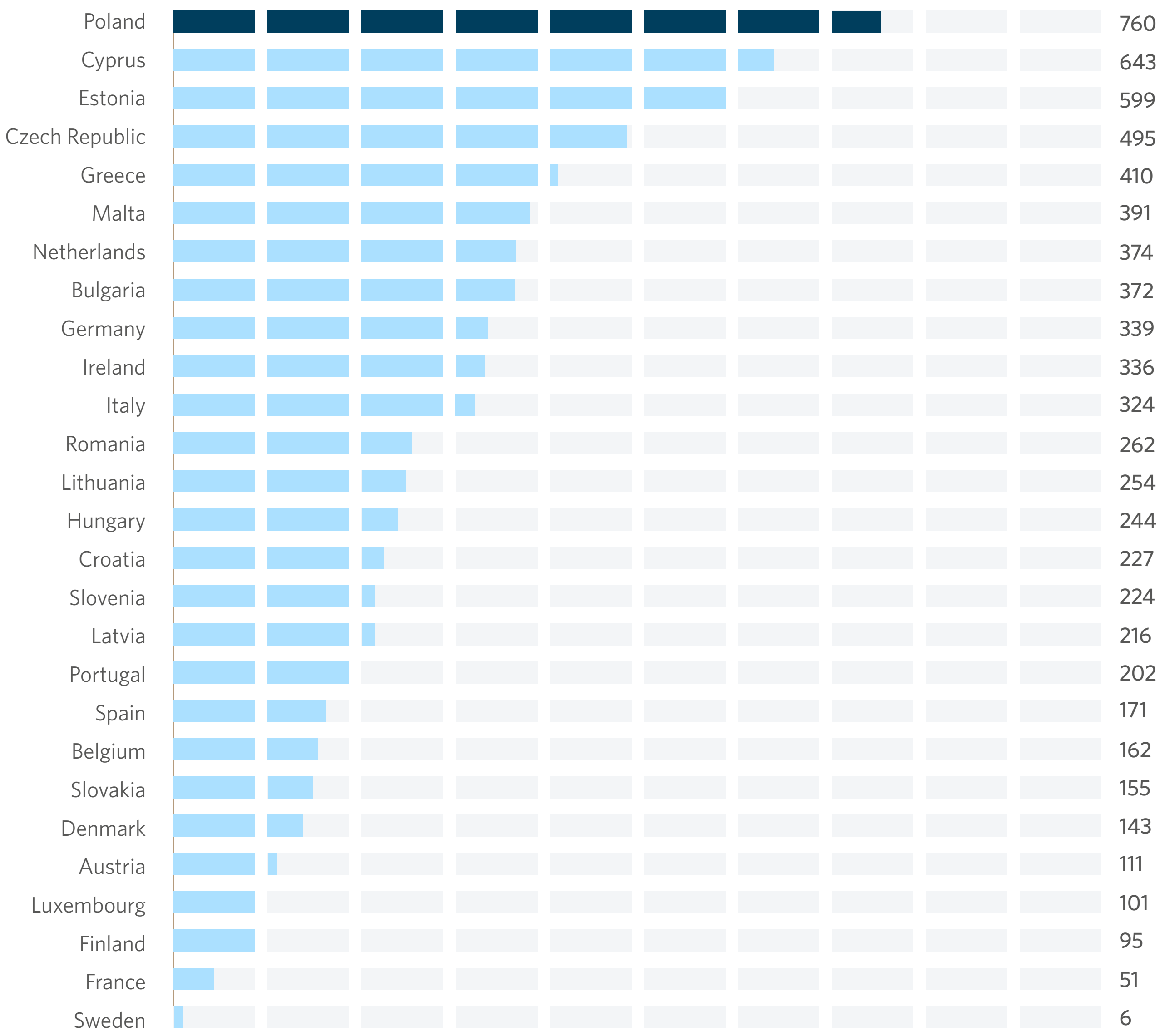
This means that the supply gap in the Polish electricity market will widen. A study carried out in 2021 by the head of the Energy Regulatory Office (URE) shows that while sources with a capacity of 14.2 GW are expected to be commissioned in Poland between 2020 and 2034, units with a total capacity of 18.8 GW will be disconnected from the grid, of which more than 90 per cent will be power plants using coal and lignite. At the same time, by 2034, the generation potential of domestic sources will decrease by approximately 11 per cent (i.e. by 4.6 GW) and the available capacity in the system will decrease by 31 per cent (i.e. by 10.6 GW). The latter will result from the rapid replacement of conventional power plants by RES, which have a much lower so-called availability factor[1]. According to estimates, the inevitable development of wind and solar projects will mean that they could provide up to 71 per cent of the country's electricity in 2030[2]. This, with the decreasing number of dispatchable sources, will, in turn, create new challenges related to balancing the system.

The industry needs a stable source of energy and RES installations cannot provide it on a large enough scale. In turn, the situation in the world (Russia's invasion of Ukraine) necessitates a reduction in investment in gas sources, of which Russia is the supplier. Hence the interest in nuclear power. Moreover, nuclear power plants are able to operate regardless of weather conditions for more than 300 days a year, providing gigawatts of zero-carbon electricity and heat.

Nuclear power is also expected to be the answer to rising domestic electricity prices. This will be caused by the need to import increasing volumes of energy to Poland, as well as the still high dependence of the Polish energy sector on fossil fuels. According to data from the Energy Market Agency (ARE), in 2022 the share of coal in electricity production was 70.6 per cent. In this aspect, a significant advantage of nuclear energy over other conventional sources is the stable cost of nuclear fuel, which is not subject to such large fluctuations as coal or gas prices. As a result, it is much easier to contract their supply several years in advance, as well as to predict the cost of nuclear electricity, as fuel purchase expenses only account for about 10 per cent of the cost.

Nuclear power is crucial to the success of Poland's energy transition. In December 2019, the The European Commission ("EC") announced the so-called European Green Deal, a new strategy for EU development. A key milestone in its implementation was the enactment of the so-called Climate Law in 2021, a regulation sanctioning the EU's drive to achieve climate neutrality by 2050. As a result, it forced a tightening of the EU's greenhouse gas emission reduction targets for 2030 from 40 to 55 per cent. The main tool for its implementation is the Fit for 55 legislative package presented in July 2021, which is a comprehensive overhaul of the EU energy sector. The aim is to raise the EU's target for the share of renewables in gross final energy consumption in 2030 from 32 per cent to 40 per cent, and to reduce emissions from sectors covered by the EU ETS by 61 per cent by 2030, compared to 2005 levels. From 2025 onwards, the so-called ETS2, a new emissions trading scheme that will cover road and maritime transport as well as emissions from buildings, will also come into effect. This will bring the carbon pricing to around 80 per cent of all emissions in the EU, compared to 40 per cent covered by the current ETS.

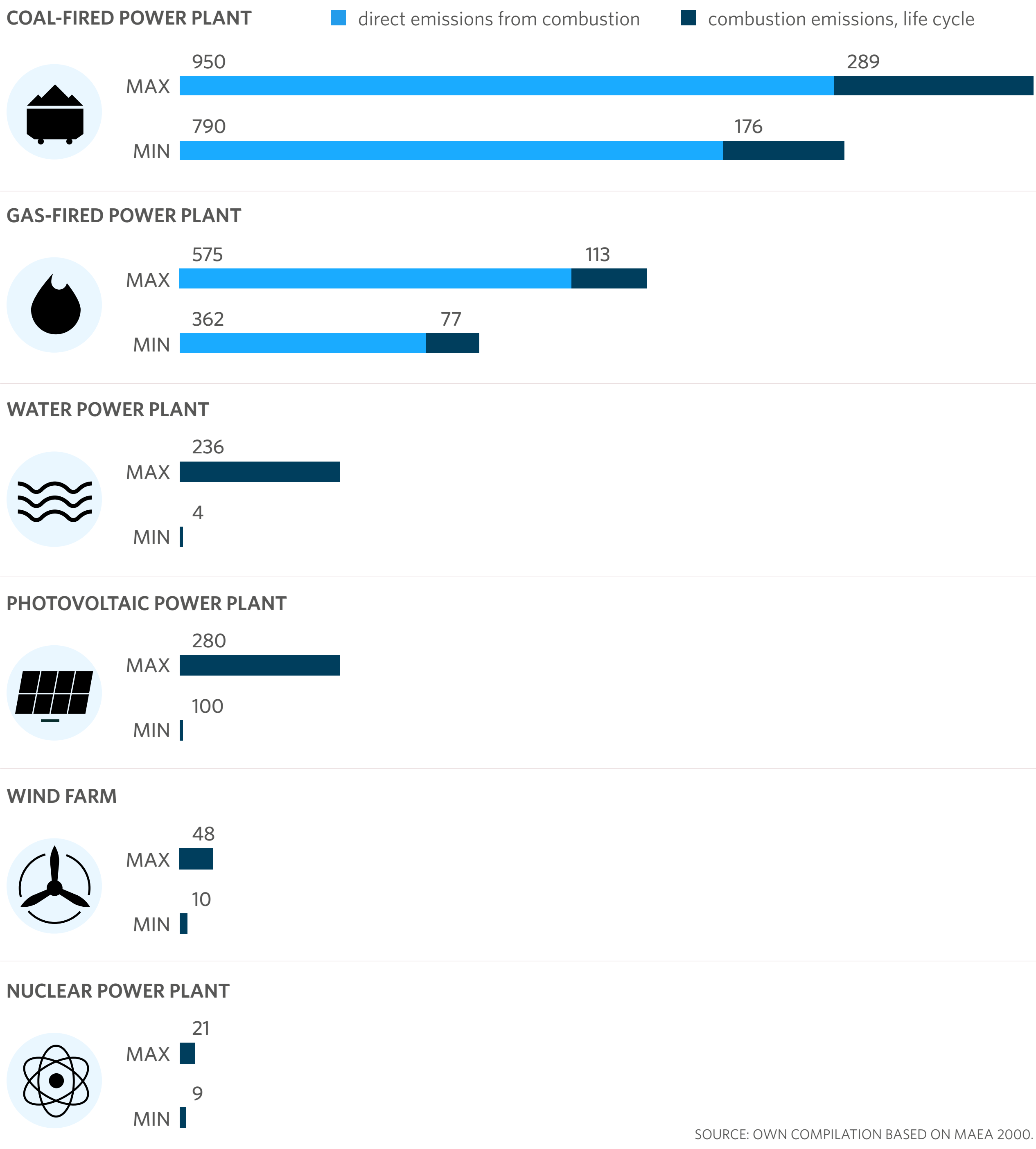
HOW MUCH CO2 IS NEEDED TO PRODUCE 1 KWH OF ELECTRICITY IN EACH EU COUNTRY (GCO2/KWH)



SOURCE: OWN COMPILATION BASED ON DATA OF THE EUROPEAN COMMISSION.

The EU's accelerated transition is envisaged by the REPowerEU plan, the details of which were presented by the EC on May 18, 2022. In order to achieve this, the EU's target for the share of RES in gross final energy consumption in 2030 is to be 45 per cent (compared to the currently proposed 40 per cent). As a result, the capacity of RES installations in the EU should increase from 511 to as much as 1236 GW in 2030 – 169 GW more than the current plans. The Commission also proposes that in 2030, the EU could produce 10 million tonnes of green hydrogen per year, which is expected to require an increase in the capacity of electrolysers to 123 GW. All this will, within a few years, lead to the need to rapidly decarbonise the economy, but also to a significant increase of the share of energy costs in corporate bottom lines, which will translate into their profitability. Although the development of nuclear power is not included in REPowerEU, in the perspective of the next decade, it can help Poland meet the challenges of the plan and provide the economy with access to cheap, zero-carbon electricity.

CO2 EMISSIONS FROM VARIOUS SOURCES OF ELECTRICITY



SOURCE: OWN COMPILATION BASED ON MAEA 2000.

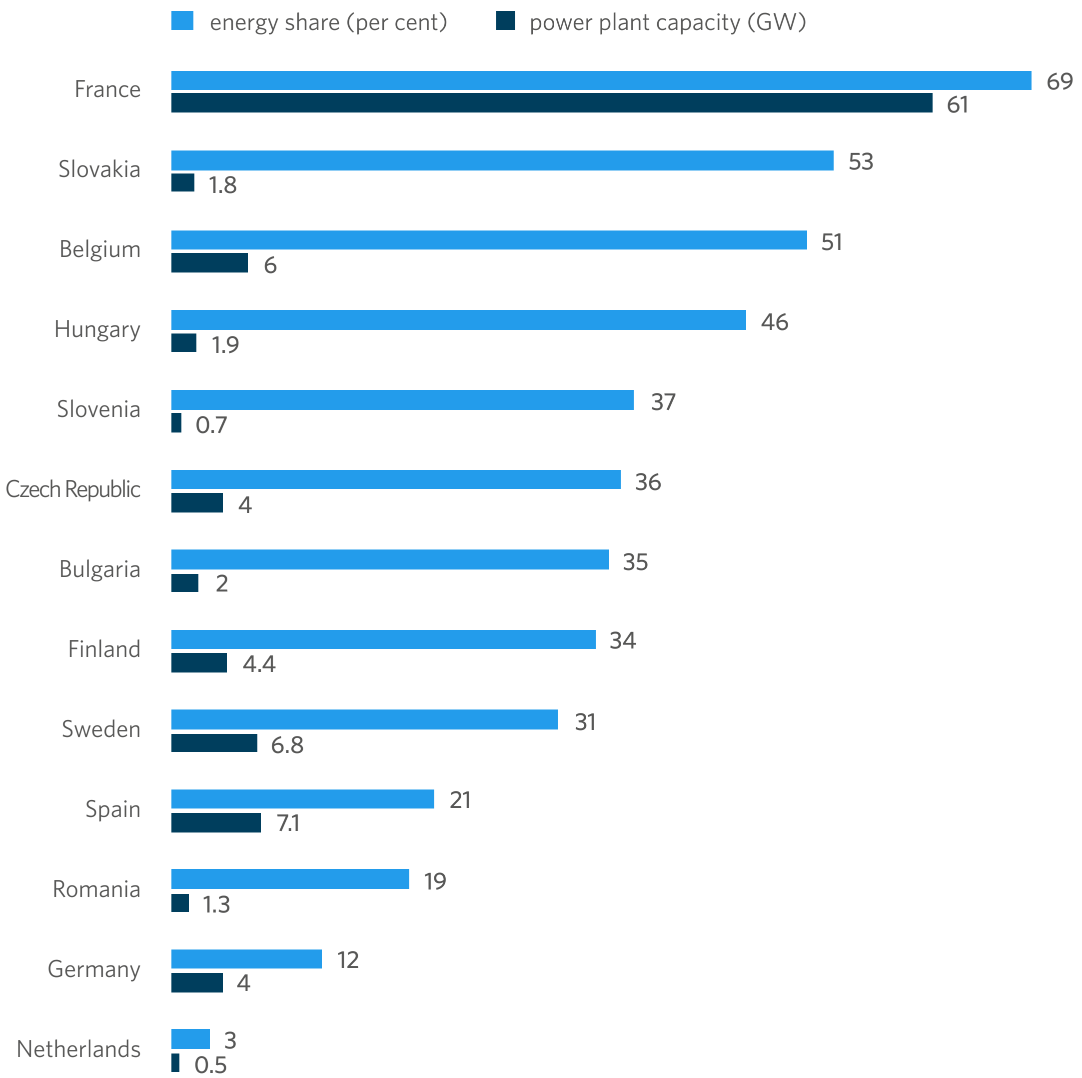
Nuclear power is to guarantee Poland's energy security in the long term. On the one hand, this requires ensuring an uninterrupted supply of electricity (by diversifying the sources of its production and reducing the dependence of the Polish energy sector on electricity imports) and, on the other, diversifying the sources of the necessary resources. The latter is also crucial from the point of view of the uncertain geopolitical situation and the need to reduce the dependence of the Polish economy on coal, gas and oil supplies from Russia. Meanwhile, the raw materials for nuclear fuel production are predominantly sourced from countries with a stable political situation. At the same time, the amount of this fuel needed for the day-to-day operation of the nuclear power plant is small, which facilitates its storage for many years.

Poland's long road to nuclear power

The future of nuclear power is one of the main pillars of discussions on the global energy transition. At the same time, **Poland is one of the few European countries where this sector is undeveloped**, despite the fact that the first nuclear investment plans appeared as early as the mid-1950s. Large-scale nuclear power plants currently operate in 13 EU countries, with a total of 100.6 GW of capacity. In 2021, they accounted for 25.2 per cent of electricity generation, up from 29 per cent in 2011. In 2021, reactors generated 698.9 TWh of electricity, 7 per cent more than in 2020, but 4 per cent less than in 2019[3]. The map p. 16

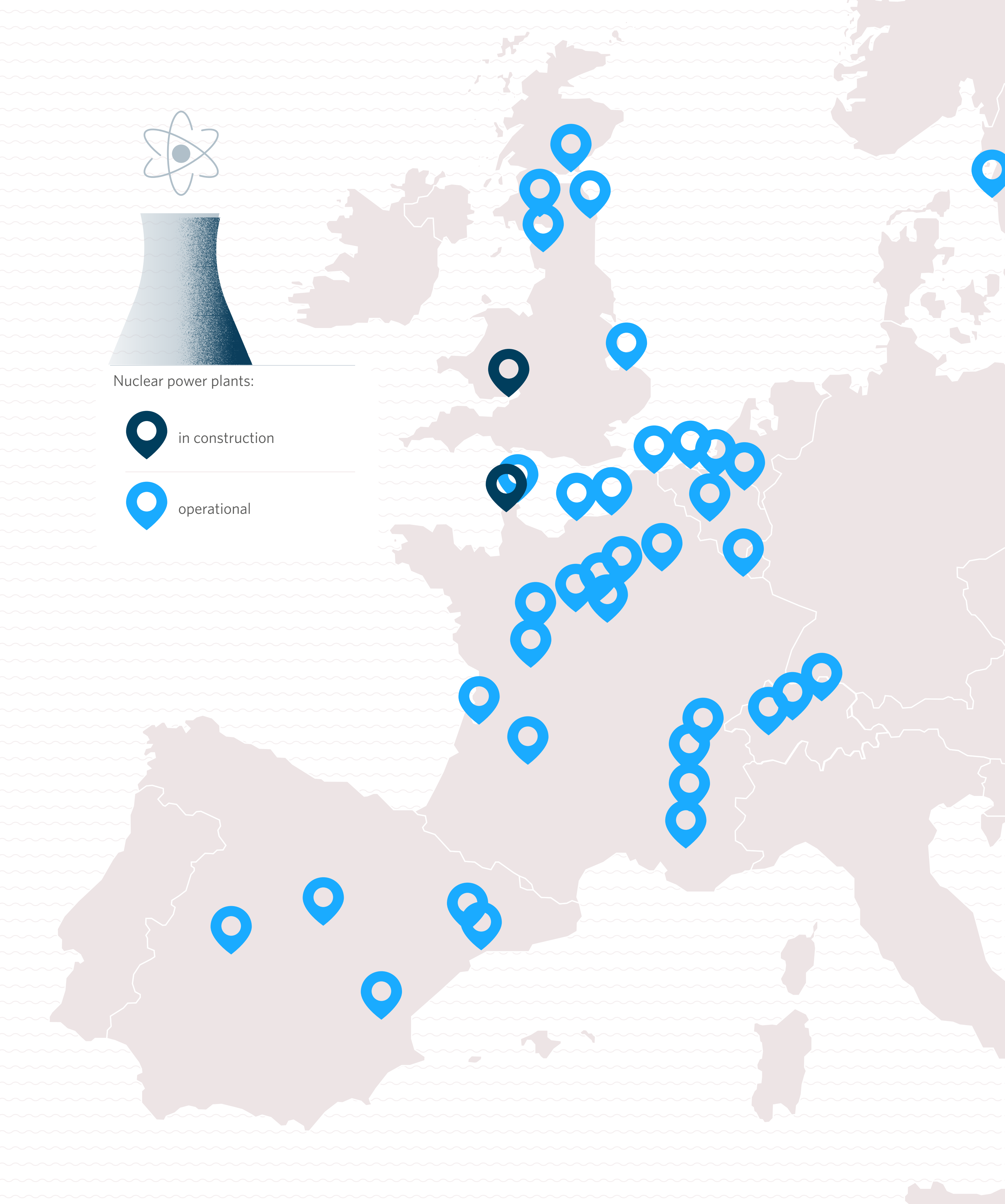
There are currently reactors with a capacity of 2.1 GW under construction in EU countries, with another 7.2 GW at an advanced planning stage[4]. At the same time, there are many reasons to believe that the geopolitical situation and hydrocarbon shortages will strengthen Europe's interest in nuclear energy in the coming years. In the EU, the Czech Republic, France, Poland, Romania, Slovakia, Slovenia and Hungary are most strongly in favour of accelerating investment, while Germany and Austria, among others, remain sceptical in this regard.

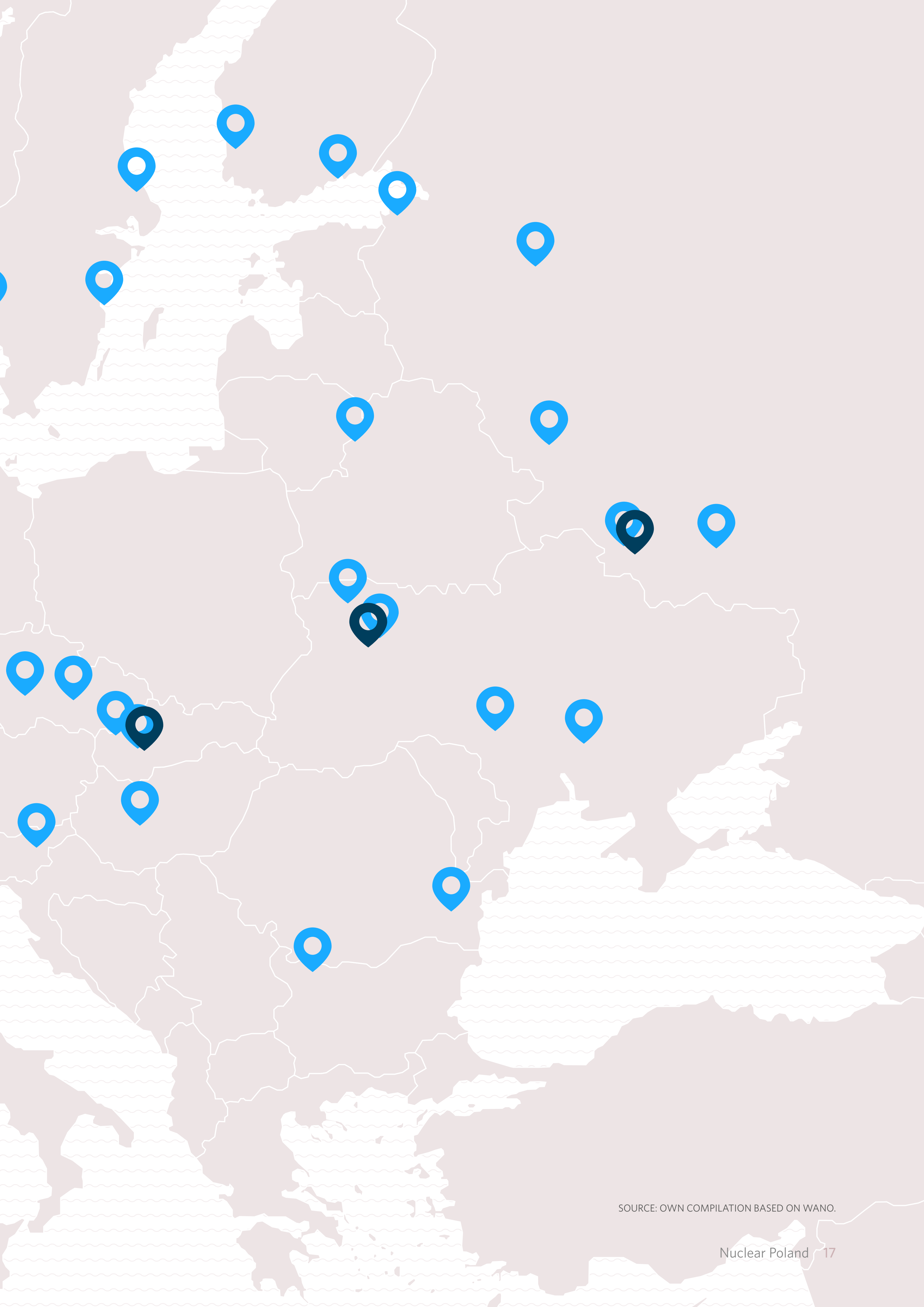
SHARE OF NUCLEAR POWER IN ELECTRICITY PRODUCTION (PER CENT) AND TOTAL CAPACITY OF NUCLEAR POWER PLANTS IN THE EUROPEAN UNION MEMBER STATES (GW) IN 2022



SOURCE: OWN COMPILATION BASED ON EMBER, WORLD NUCLEAR ASSOCIATION.

POLAND ON THE NUCLEAR MAP OF EUROPE





SOURCE: OWN COMPILATION BASED ON WANO.

In Poland, most governments after 1989 had promised to invest in nuclear power. The possibility of its implementation after 2000 was already envisaged by the objectives of the national energy policy up to 2010, adopted in 1990[5]. Meanwhile, in January 2005, Marek Belka's cabinet passed the Polish Energy Policy (PEP) up to 2025, which advocated the construction of a nuclear power plant on the grounds that it was necessary to diversify energy sources and reduce emissions. The first unit was to be commissioned in 2021-2022[6]. The justification for investment in nuclear power was also included in the Polish Energy Policy to 2030 (PEP2030), adopted by the government of Jarosław Kaczyński in 2007 – and preliminary location work began then.

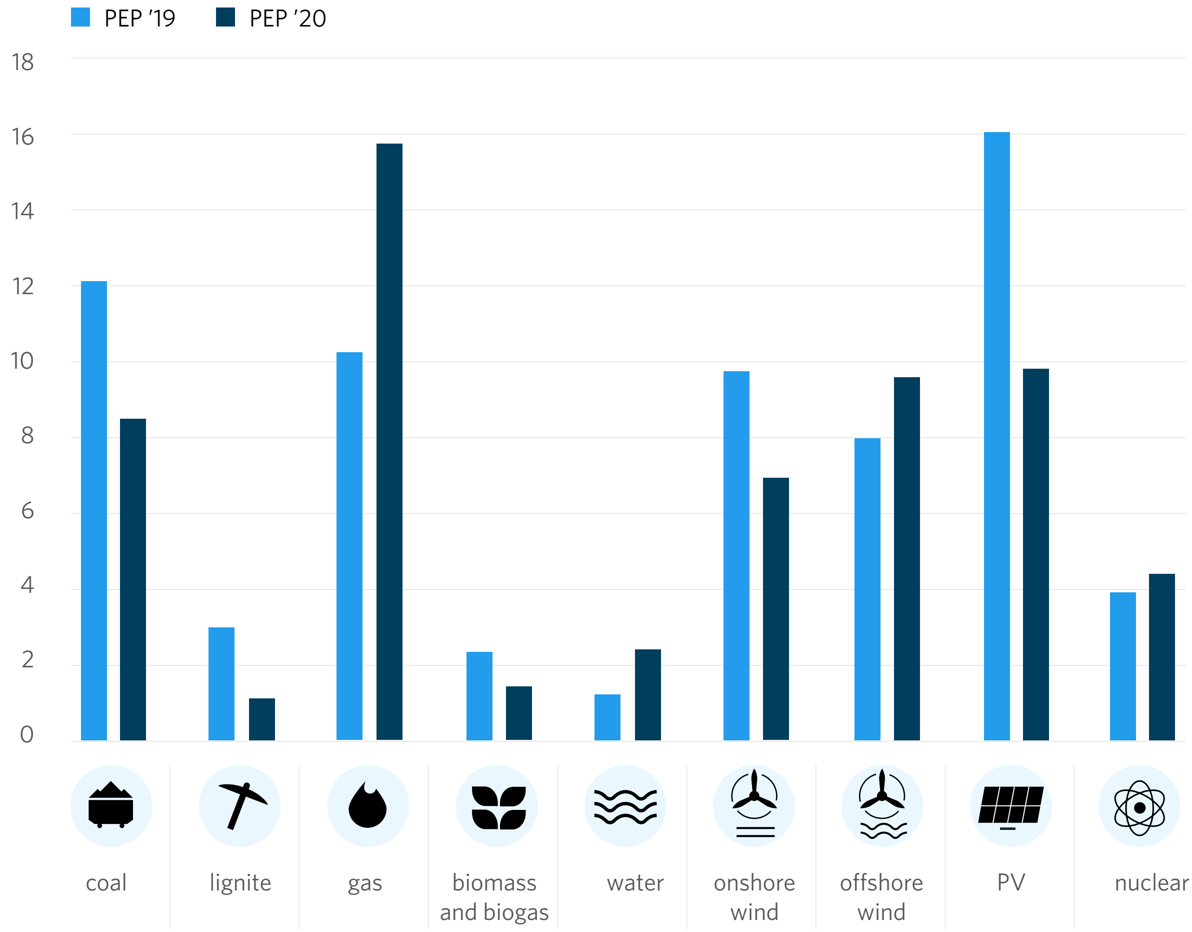
The first concrete plans for nuclear power resulted from the government's Resolution No. 4 on measures to be taken in the field of the development of nuclear energy, adopted on January 13, 2009[7]. It recognised the merits of building at least two nuclear power plants, the first of which was to be operational by the end of 2020. On May 19, 2009, a government plenipotentiary for Polish nuclear energy was appointed with the rank of Undersecretary of State in the Ministry of Economy, following which work was initiated on the Polish Nuclear Power Programme (PPEJ). Also in 2009, the government of Donald Tusk updated the PEP2030 by stipulating that 16 per cent of the country's electricity would come from nuclear power by 2030. The plans at the time assumed that the main investor in nuclear power plants would be PGE, which in 2010 set up a special-purpose vehicle, PGE EJ1.

The first PPEJ was adopted by the government on January 28, 2014[8]. The document was a "roadmap" with a list of objectives and activities to prepare the ground for the investment. The timetable assumed that the first reactor would be built in either Choczewo or Żarnowiec and would be operational by the end of 2024. The second unit was to be built between 2025 and 2030, and a possible second power station would have been operational by 2035.

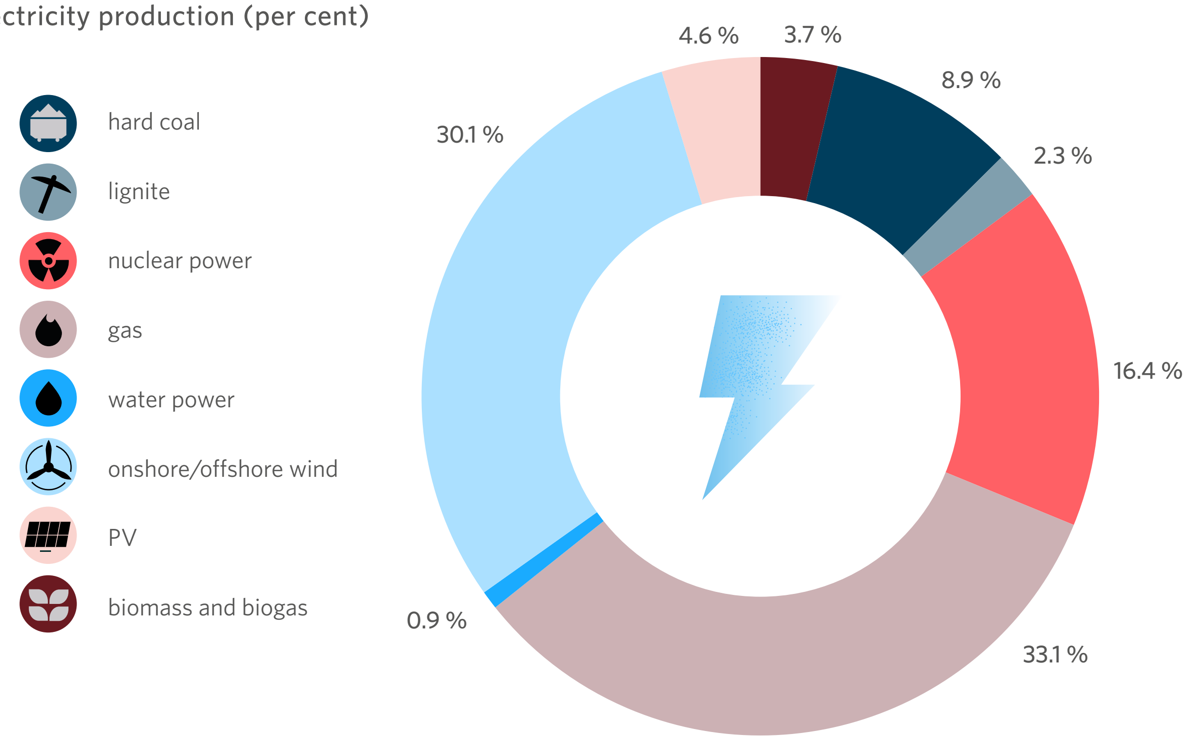
Further plans for the development of nuclear power in Poland resulted from the draft Energy Policy of Poland until 2040 (PEP2040) published in November 2018. It envisages the commissioning of the first unit in 2033, followed by additional units every two years until 2043. Ultimately, two nuclear power plants are to be in operation, each with three reactors with a total capacity of 6-9 GW. This target was confirmed in the final version of PEP2040, adopted on February 2, 2021, and the National Energy and Climate Plan (KPEiK). The latter also assumes that potential uranium deposits in Poland will be identified by 2030, including assessing the possibility of obtaining and commercialising it for nuclear fuel production.

STRUCTURE OF ELECTRICITY PRODUCTION IN POLAND IN 2040 AND STRUCTURE OF INSTALLED CAPACITY IN THE POWER INDUSTRY IN 2040

Installed capacity (GW)



Electricity production (per cent)



SOURCE: OWN COMPILATION BASED ON PEP2040.

CALENDAR OF NUCLEAR POWER IMPLEMENTATION IN POLAND ACCORDING TO PPEJ

2021	choosing of technology for EJ1 and EJ2	
2022	obtaining an environmental decision and location decision for EJ1 (approval of the selection of the location of EJ1)	signing a contract with a technology provider and EPC prime contractor
2023	start of preliminary work and preparatory work at the EJ1 site	initializing works on selection of location of EJ2
2026	obtaining a construction permit and start of the construction of EJ1	
2028	obtaining an environmental and location decision for EJ2 (approval of the selection of the location of EJ2)	
2032	obtaining a construction permit and start of the construction of EJ2	
2033	commissioning of the first unit of EJ1	
2034	nuclear commissioning and synchronization of the second unit of EJ1	
2035	commissioning of the second unit of EJ1	
2036	nuclear commissioning and synchronization of the third unit of NPP1	
2037	commissioning of the third unit of EJ1	
2038	nuclear commissioning and synchronization of the first unit of EJ2	
2039	commissioning of the first EJ2 unit	
2040	nuclear commissioning and synchronization of the second unit of EJ2	
2041	commissioning of the second unit of EJ2	
2042	nuclear commissioning and synchronization of the third unit of NPP2	
2043	commissioning of the third unit of EJ2	

SOURCE: OWN COMPILATION BASED ON PPEJ.

Where are we heading?

The current plans for developing nuclear power in Poland are defined by the PPEJ adopted on October 2, 2020, with an outlook up to 2040. According to the plan, three so-called pressurised light-water reactors (PWRs) of generation III and III+, each with a capacity of more than 1 GW, will be installed in two Polish power stations (EJ1 and EJ2) with a total capacity of 6-9 GW. Their selection was justified by the availability of such units on the market and their low failure rate. According to the timetable adopted in the document, a decision on the specific technology to be used in the Polish power plant was to be taken in 2021 and a decision on the location of NPP1 in 2022. Construction of the first NPP1 reactor with a capacity of 1-1.6 GW is to start in 2026 and be completed in 2033.

The new PPEJ narrowed the list of considered locations for the construction of the first nuclear power plant to the seaside towns of Lubiatowo-Kopalino and Żarnowiec, followed by Choczewo and Kopań. The government justified this on logistical grounds (such as the possibility of transporting materials by sea), high local demand for electricity, the lack of nearby large generation sources and access to large amounts of water for reactor cooling. At the time, it was also accepted that a common power output infrastructure for the nuclear power plant and wind farms in the Baltic Sea could be built. For these reasons, the location of power plants in central Poland, such as in Bełchatów or Pątnów, was also abandoned at this stage.

The document does not include an estimate of the cost of building a Polish nuclear power plant, but it does specify the distribution of its ownership. The State Treasury was to buy 100 per cent of the shares in PGE EJ1 from PGE, Tauron, KGHM and Enea, and then transfer 49 per cent to a foreign partner, who would also provide the technology. The government assumed at the time that all the nuclear units would be built by a single contractor to reduce the cost and duration of the investment.

The PPEJ also clarified the key tasks related to the construction of nuclear power plants. They included the preparation of qualified personnel, the implementation of so-called accompanying investments (e.g. power lines, roads and railways), ensuring high participation of Polish industry in the PPEJ implementation process, strengthening nuclear supervision by the head of the Polish Atomic Energy Agency (PAA) and building public awareness and support for nuclear energy.

In November 2022, the government decided in a resolution that the first nuclear power plant would be built based on AP1000 reactors manufactured by Westinghouse. **Complementing its nuclear power development plans is a project being undertaken by PGE, ZE PAK and the Korean conglomerate Korea Hydro and Nuclear Power (KHNP)**. On 31 October 2022, in Seoul, three companies signed a non-binding letter of intent to explore the possibility of building a nuclear power plant in Pątnów. It would consist of two to four units with Korean APR1400 reactors with a capacity of 1.4 GW each. For this purpose, the parties have started location studies and initiated work on an investment implementation plan. Its preliminary version is expected to include preliminary information on project financing. KHNP intends to involve institutions such as the Korea Development Bank (KDB), the Korea Trade Insurance Corporation (K-SURE), and the Export-Import Bank of Korea (K-EXIM) in the process. The document also sets out guidelines for the location of the power plant, project organisation and construction schedule, as well as proposed cooperation principles for the establishment of a legal framework for licensing and training of personnel.

In 2023, PGE, ZE PAK and KHNP will set up a special purpose vehicle to carry out the investment and are also expected to sign an investment agreement. The companies' declarations indicate that the next several years will be spent completing the necessary documentation and obtaining permits, while the Pątnów power plant itself would be operational in 2035.

What has been done?

As planned, **in March 2021, the State Treasury bought back 100 per cent of the shares in PGE EJ1 from PGE, Enea, KGHM and Tauron for PLN 531 million**. In June of that year, it was renamed Polskie Elektrownie Jądrowe (PEJ) and placed under the supervision of the government's plenipotentiary for strategic energy infrastructure.

In December 2021, PEJ selected the coastal location "Lubiatowo-Kopalino" in the municipality of Choczewo (in the Pomorskie Voivodeship) as the preferred site for the construction of Poland's first nuclear power plant. This was to be determined by environmental and location studies conducted since 2017 also at the "Żarnowiec" site – these showed that the indicated investment site meets all environmental requirements for this type of facility and is safe for residents. The decision was not of a legal nature, but marked the substantive completion of the environmental report. This was submitted to the General Director of Environmental Protection (GDOŚ) in March 2022. It is a key document in the procedure for assessing the environmental impact of the power plant, which is part of the procedure for issuing an environmental decision. The latter has been ongoing since August 2015, but was suspended from 2016 until June 2022, precisely because of the protracted work on the environmental report. As part of it, a public and transboundary procedure on the construction of the nuclear power plant was launched on October 11, 2022, during which the authorities of Lithuania, Latvia, Estonia, Germany, the Czech Republic, Slovakia, Sweden, Finland, Hungary, Russia and the Netherlands can comment on the environmental report. So far, Latvia and Estonia have formally submitted no concerns or comments.

The date for the environmental decision is not known, although the current assumption is that the GDOŚ proceedings in this case should be completed by June 30, 2023. Meeting this deadline is not certain due to the possible protraction of cross-border consultations. This in turn is due to the risk of challenges to the investment by some countries. Once the decision has been made, PEJ is expected to focus on design work and obtaining administrative approvals for the construction of the power plant. This includes the issuing of a licence for the construction of a nuclear facility by the head of the PAA, followed by the issuing of a construction permit by the voivode.

From the point of view of investment in conventional nuclear power, the key process is the selection of the reactor supplier and contractor. France's EDF submitted a bid in October 2021, Korea's KHNP in April 2022 and the US Westinghouse in September 2022.

On November 2, 2022, the government adopted a resolution on the construction of large-scale nuclear power plants in Poland[9]. It stipulated that the first 3750 MW nuclear power plant would be built in the area of the municipalities of Choczewo or Gniewino and Krokowa and that 1.1-GW AP1000 reactors manufactured by Westinghouse would be installed there. For this purpose, it accepted a conceptual and implementation report (CER) prepared by the US side. The government also obliged the Minister of Climate and Environment, PEJ and the government plenipotentiary for strategic energy infrastructure to take measures to implement the investment, and the Minister of Finance to ensure that the investment is financed “in a way that reduces electricity prices and takes into account the interests of end consumers”. The document was prepared on the basis of the October 2020 Polish-US agreement on cooperation to develop the nuclear power programme[10].

The resolution refers only to the first of the two power plants planned under the PPEJ, with construction to start in 2026 and be completed in 2033; it does not refer to the Pątnów nuclear power plant project to be built by PGE, ZE PAK and KHNP. The government only stressed the need to speed up the implementation of the second “state” power plant, but did not indicate where it would stand or who would supply the reactors for it. However, it publicly declares that it could be Westinghouse, KHNP or EDF, with the choice of one of these companies more likely to be made after the 2023 general election. The government is also indicating that a power station could be built near Bełchatów, where lignite deposits are expected to cease to be exploited in the early 2030s. Kozienice and Połaniec are also among the locations under consideration.

The activities in the political, administrative, and technological areas were complemented by the development of a number of regulations setting the framework for the development of nuclear power in Poland. Key in this aspect is the act of November 29, 2000 (Nuclear Act)[11]. It defines the way in which activities relating to the peaceful use of nuclear energy are carried out, including the management of nuclear materials, equipment producing ionising radiation, radioactive waste or spent nuclear fuel. It also regulates the powers of the nuclear safety and radiological protection authorities, the principles of civil liability for nuclear damage and Poland’s fulfilment of its international obligations.

In addition, since July 2011, the so-called nuclear special law has been in force. The purpose of its enactment was to shorten the investment process related to the implementation of the successive stages of nuclear power plant construction. An amendment to the act came into force in 2023. It was designed to accelerate procedures by another 12-18 months in relation to the estimated time of investment implementation on the basis of previously binding provisions. Some legal conditions of nuclear power development in Poland are discussed in more detail in chapter two of this report.

What we still do not know?

The decisions taken so far on the construction of Polish nuclear power plants do not predetermine either how they would be financed or the details of the business models under which the investments would be made. In the case of “state” projects, the PPEJ does envisage maintaining a minimum 51 per cent Treasury stake in PEJ and handing over the rest to a foreign partner, which is also expected to provide the technology. However, the officially communicated arrangements with Westinghouse do not predetermine whether the company will actually participate to such a large extent in the investment.

The question of the contractor for Poland’s first nuclear power plant also remains unresolved – the government’s resolution of November 2, 2022, only determines the technology provider for it. The most likely scenario is for Westinghouse to form a consortium with the US company Bechtel for this purpose. An alternative scenario involves the need for an open tender to select the contractor.

The cost of building a nuclear power plant and how it will be covered is also not officially known – the government does declare that this could be in the range of PLN 90-100 billion. Moreover, the method of selling electricity from the power plants remains unresolved, e.g. whether it will be multi-year PPAs (as in the US), a contract for difference (as in the UK) or, perhaps, a tariff model.

SMRs – will they replace or complement big nuclear plants?

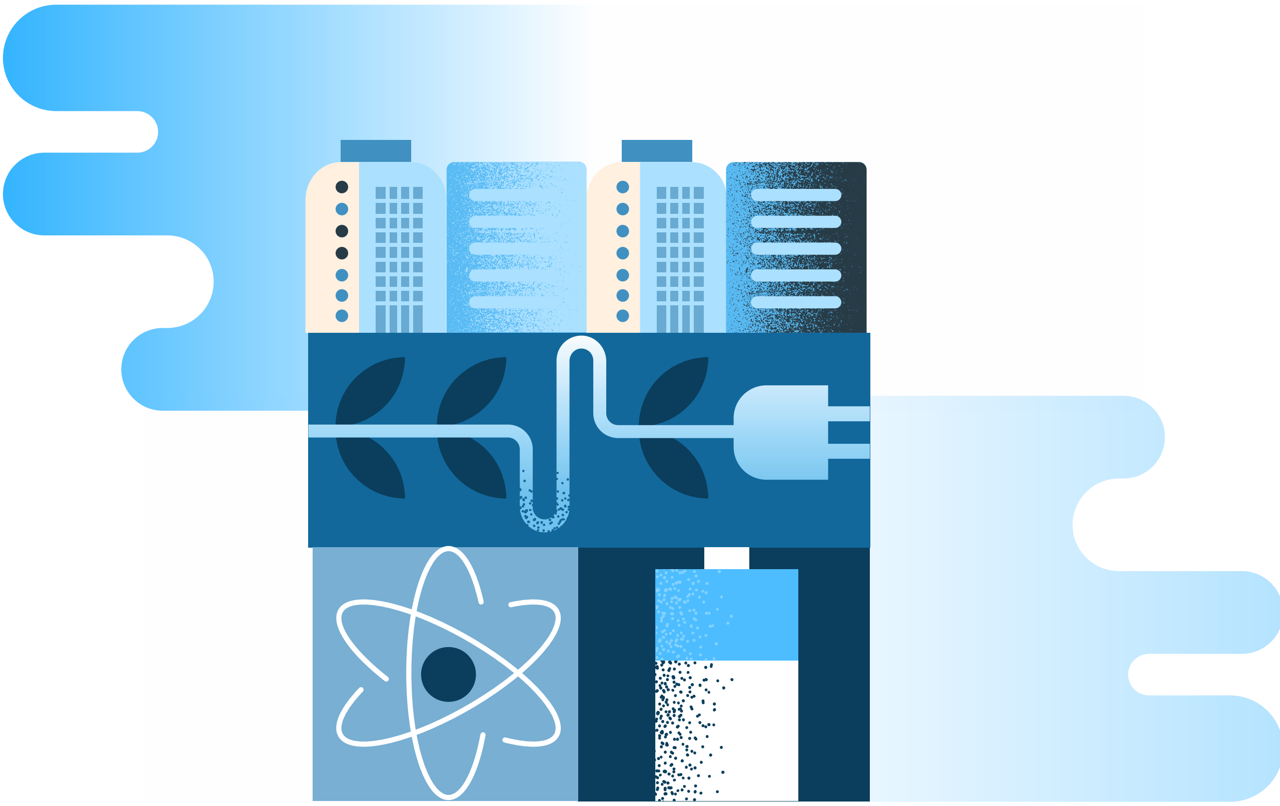
With the development of plans to build large-scale nuclear power plants in Poland, interest in Small Modular Reactors (SMRs) has been growing for several years. In comparison to traditional nuclear units, SMRs are primarily smaller in size. Their advantage is supposed to be their small size and modular nature, which is intended to reduce construction costs and time and reduce the risks associated with their operation. In addition to electricity – like the large units – the small reactors will also be able to produce heat and pure hydrogen. Commercialisation of this technology is possible in the second half of the 2020s at the earliest. Its potential use in Poland has been taken into account in strategic documents, including the Strategy for Responsible Development and the Energy Policy of Poland to 2040. Its updated version assumes that nuclear power will generate 22.6 per cent of energy in 2040, versus 16 per cent planned so far. This will be possible thanks to the development of SMRs (taking place in parallel to the construction of conventional power plants), supported by their potential use in industry, heat and power generation[12]. In 2040, the capacity of Poland's nuclear power plants is expected to be 7.8 GW, up from the previously assumed 4.4 GW. Of this, small reactors will account for 2.1 GW. The first SMR is to be commissioned by the end of the decade (owned by ORLEN Synthos Green Energy) and deliver 1 TWh of electricity to the grid in 2030. SMRs as a prospective technology has also been identified in the Strategy for Heat to 2030 with an outlook to 2040.

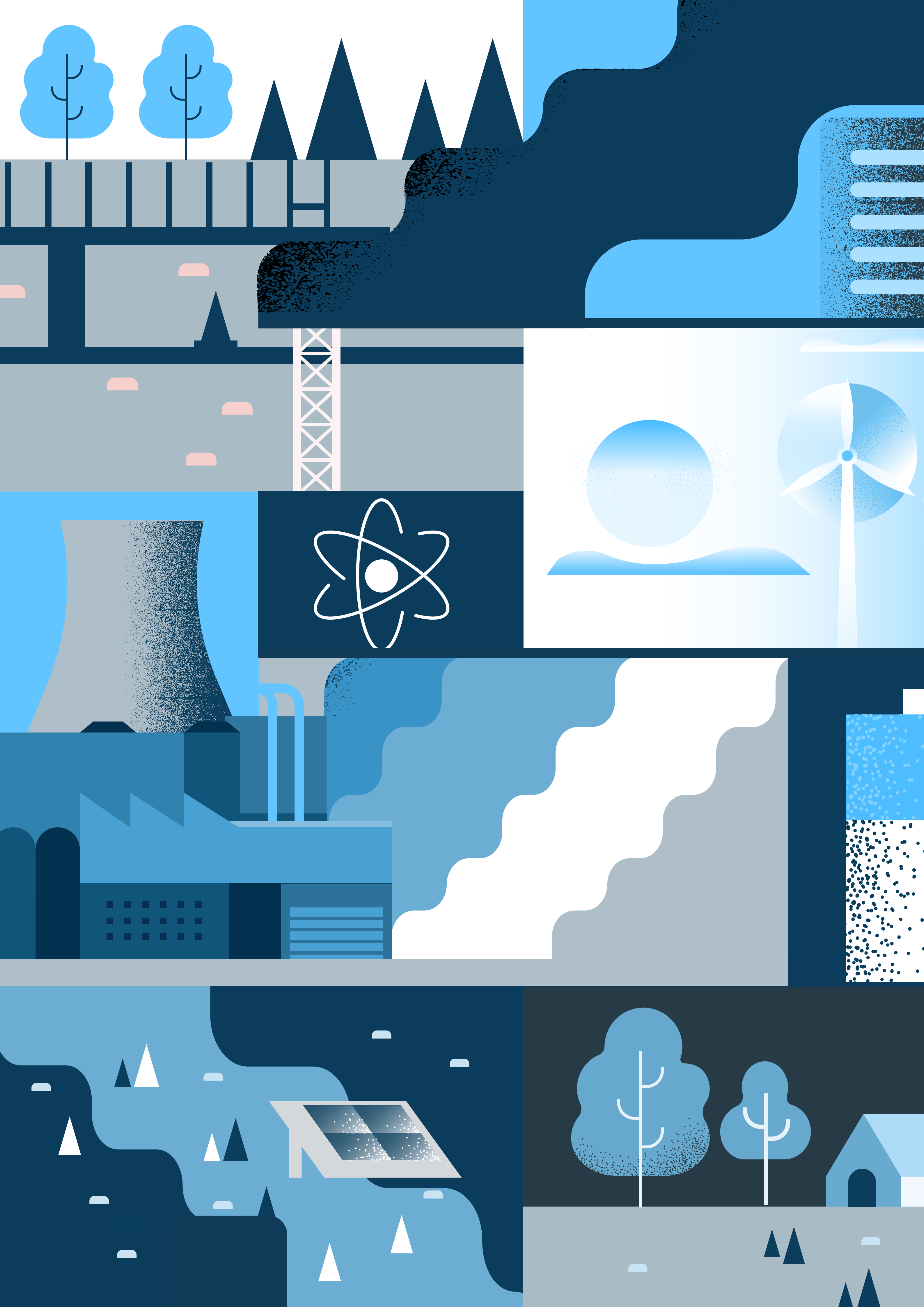
According to the International Atomic Energy Agency (IAEA), more than 70 SMR designs are currently under development around the world. Only over time will we know which ones finally make it to market. Advanced designs are being developed in the US and Canada by the US-Japanese GE group Hitachi Nuclear Energy and NuScale Power, and in the UK by Rolls-Royce. The former has a design (BWRX-300) based on GE's boiling water reactor (BWR) design. NuScale Power is working on a 77MW gross capacity water-pressure reactor. The unit is to be enclosed in a capsule weighing 700 tonnes, 23m high and 4.5m wide, even larger than a conventional reactor. The first unit is expected to be built in the city of Idaho Falls in 2029, while Rolls-Royce's SMR is expected to come online a year later. It is to have a capacity of 470 MW and is based on a pressurised water reactor.

Polish industry is interested in US and UK SMRs. In September 2019, Synthos reached an agreement with GE Hitachi Nuclear Energy to build the BWRX-300 reactor in Poland, and in May 2020 it signed an agreement with the US-based Ultra Safe Nuclear Corporation (USNC) for the development of microreactors (MMRs). The chemical company was granted the status of GE Hitachi technology developer in Poland, which opened up the possibility for it to enter into subsequent SMR development agreements with PKN ORLEN. Cooperation with ORLEN was formalised in March 2022, when the two formed a joint venture under the name ORLEN Synthos Green Energy. In July of that year, it submitted an application to PAA for an assessment of the BWRX-300 reactor technology. And at the end of March 2023, ORLEN Synthos Green Energy signed an agreement with the Tennessee Valley Authority and Ontario Power Generation to accelerate the deployment of SMRs. The agreement provides for a joint investment worth USD 400 million in the GEH BWRX-300 reactor project.

KGHM wants to acquire SMRs from NuScale. In February 2022, the companies concluded an agreement to this effect, which was preceded by their preliminary agreement of September 2021. In July 2022, the copper miner was also the first in Poland to apply to PAA for a general opinion on the determination of selected conditions allowing the construction of a 462 MW nuclear power plant consisting of six modules of 77 MW gross capacity each.

Meanwhile, Rolls-Royce made its first SMR development agreements in February 2023. At the time, the corporation signed a letter of intent with the Świętokrzyska Grupa Przemysłowa Industria, stipulating that the parties would cooperate on the construction of up to three small reactors, each with a capacity of 470 MW. After 2030, they are to supply electrolysers with a total capacity of 250 MW, which is expected to produce 50,000 tonnes of hydrogen per year. This is one of the goals of the Central Hydrogen Cluster, of which Industria is a member. In addition, Enea, Tauron and Unimot are among the companies that have declared interest in SMRs.





02

Conditions for nuclear power development in Poland

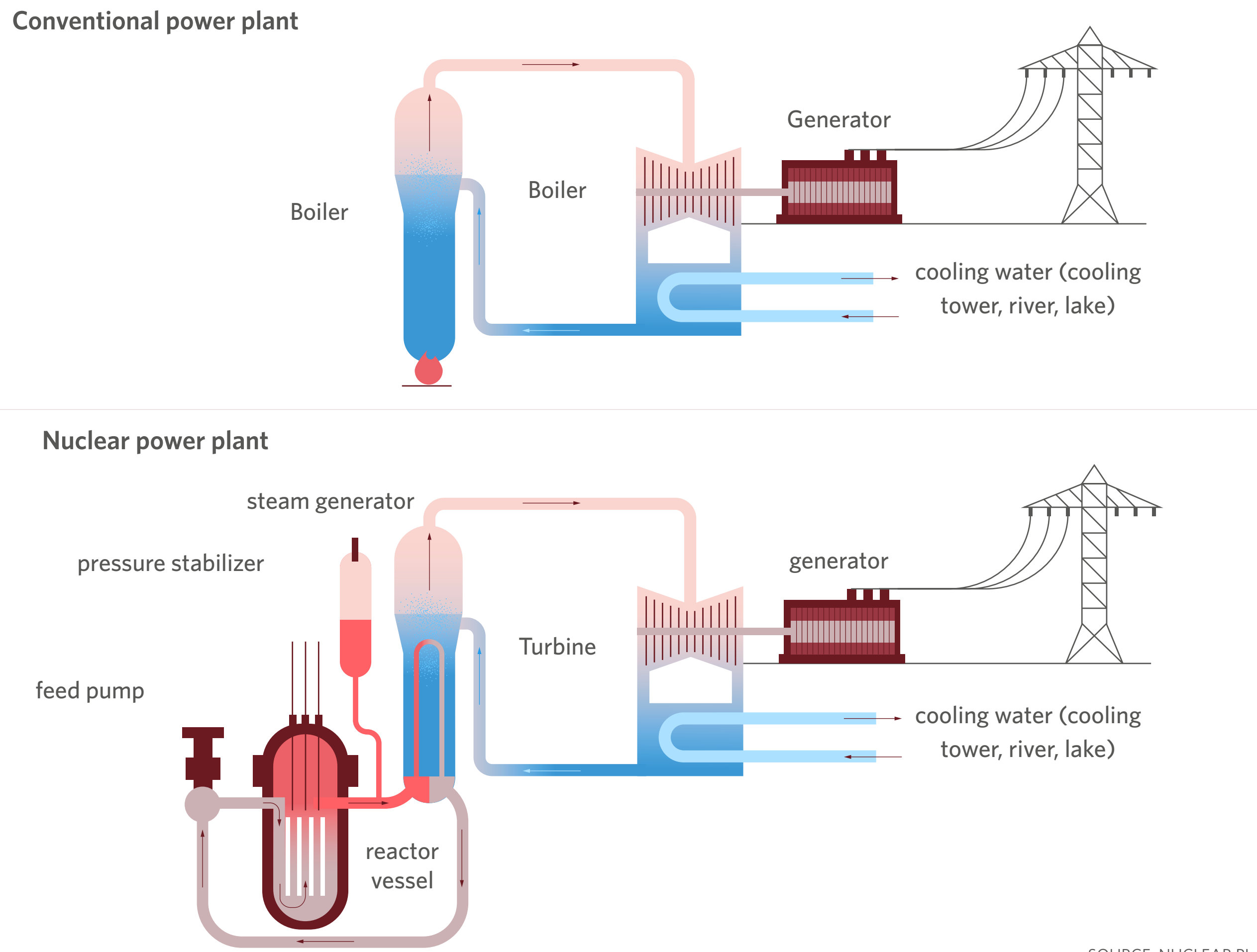
The course, pace and nature of nuclear power development depends on many variables. However, its implementation – as a technology of particular socio-economic importance – must be preceded by a high-level calculation and take into account conditions of a technological, economic, legal, environmental and social nature. These are complex.

TECHNOLOGICAL CONDITIONS

Dominik Brodacki, Polityka Insight

Let us start with how a nuclear power plant works. To some extent it is similar to a conventional thermal power plant – both rely on the steam-water cycle to produce electricity. In the latter – in a nutshell – electricity is generated from the chemical energy contained in a fuel, such as coal, lignite, oil or gas. When the fuel burns, water is heated and steam is produced, which enters the turbine and drives the shaft. This in turn, as it spins, generates electricity and, as a by-product, also heat, which must be constantly discharged through the cooling system. An analogous process takes place in nuclear reactors, except that it requires a different heat source – in this case, the heat is not produced by burning fuel, but by the fission reaction of the uranium atoms[13].

COMPARISON OF THE PRINCIPLE OF OPERATION OF A CONVENTIONAL AND NUCLEAR POWER PLANT



SOURCE: NUCLEAR.PL.

The fission of uranium involves forming it into so-called pellets and placing it in special tubes (fuel rods), where it is exposed to neutrons. The result is the formation of two nuclei of lighter elements, gamma radiation and neutrons. These undergo further processes during which they emit energy. The fission neutrons cause the fission of other uranium nuclei and a chain reaction, which is controlled in the reactor by so-called control rods. Their task is to sustain the reaction while slowing down the fission of uranium – for this purpose, the control rods are made of special neutron-absorbing materials (e.g. cadmium, boron) and add these materials to the fuel and coolant. Sustaining the reaction, on the other hand, requires a so-called moderator, i.e. a substance that slows down the neutrons in the process of their scattering. Most often, this role is played by water, which also provides the appropriate temperature in the reactor.

During the chain reaction, heat is also generated. This heats the water, which is transformed into steam either immediately (in boiling reactors) or only after it has been fed into the steam generator. In both cases, the steam drives turbines whose movement causes the rotors that generate electricity to turn[14].

New reactors available on the market

Currently, so-called Generation III or III+ units have become popular. They are the result of an evolutionary development of Generation II units and, unlike them, have better safety features, new heat removal systems that do not require additional power supply, and reinforced structures that can withstand the impact of objects such as a large passenger aircraft. In addition, Generation IV reactors are in the research phase. These are to operate at much higher temperatures than water reactors, and are also to use gas (e.g. helium), sodium, lead or molten salts to cool them.

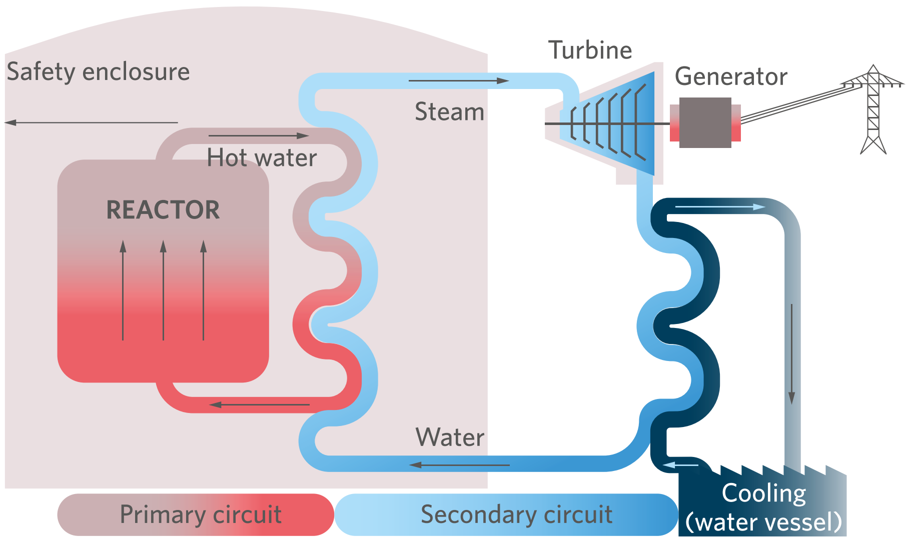
Of the 437 nuclear reactors in the world (as at the end of 2021), 303 are pressurised water reactors (PWR) and 31 are boiling water reactors (BWR). Of the 56 units under construction (with a total capacity of 58.1 GW), PWR designs accounted for 48 units with a total capacity of 52.1 GW[15].

BWR reactors include units of the ABWR and SWR-1000 types. They are characterised primarily by the use of a single water circuit (steam-water circuit). They consist of a vessel in which the core is placed. In turn, fuel cartridges consisting of several hundred fuel and control rods are inserted into it. Their main function is to control the operation of the reactor by regulating its power. The operation of the rods involves the emission of heat, which is removed by the water. This then goes directly to the steam turbine in the form of steam, whose movement generates electricity. The steam is condensed in the steam turbine and then returned to the reactor as a liquid.

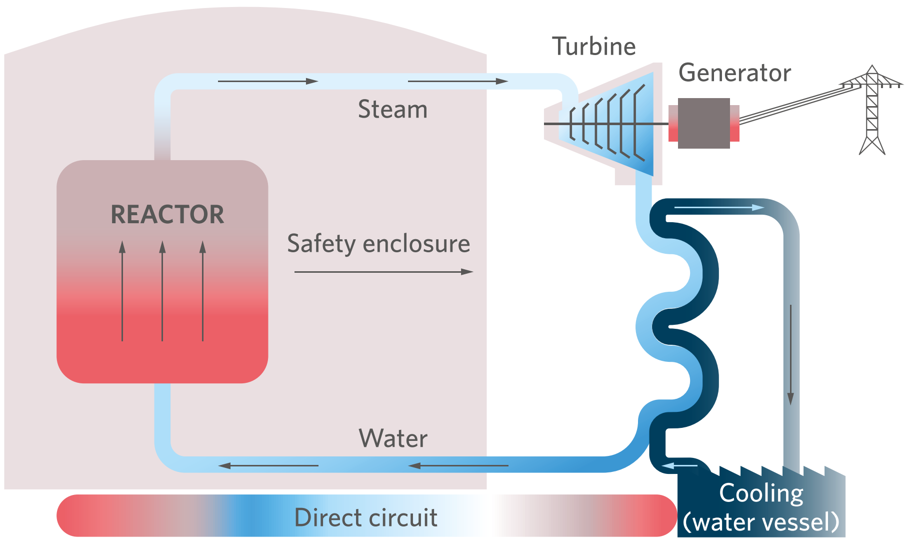
PWRs use two water circuits: a primary circuit (so-called water circuit, providing the circulation of the reactor) and a secondary circuit (steam circuit). An additional system, as in BWR units, is the condenser cooling circuit. In these designs, hot water is routed through the primary circuit to the steam generator. There it is enclosed in special tubes which, by giving off heat, cause the evaporation of the water from the secondary circuit. The water from the primary circuit then returns to the reactor, while the steam from the secondary circuit drives the turbine.

COMPARISON OF PWR AND BWR

PWR



BWR



SOURCE: NATIONAL CENTRE FOR NUCLEAR RESEARCH.

The second key difference between PWRs and BWRs is that in the former the control rods are retracted from above and in the latter from below. In this respect, a feature of PWR units is the possibility that the rods may fall down on their own if power is lost. Nevertheless, in day-to-day operation, inserting them from below is more effective due to the lighter power density at the top of the reactor. The most important Generation III+ reactor designs available on the market include the EPR (Framatome), AP1000 (Westinghouse), APR1400 (KHNP), ACR-1000 (Atomic Energy of Canada) and ESBWR (GE-Hitachi). The latter design is successfully based on the BWRX-300 small scale reactor (SMR) technology.

Safety of nuclear power plants

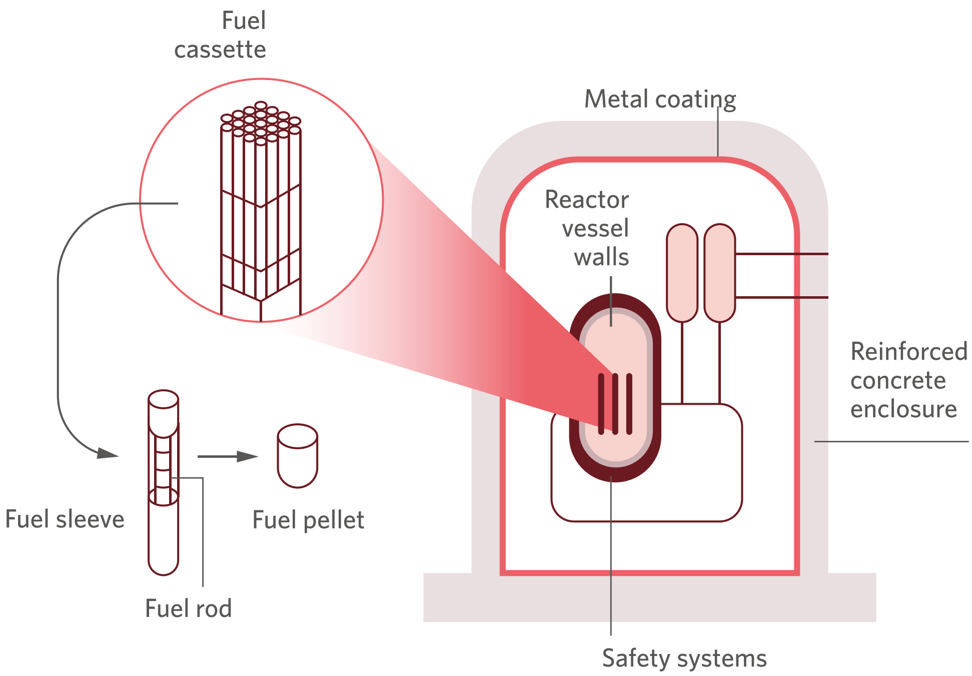
Nuclear power plants are among the safest sources of electricity generation. In this respect, each reactor must meet stringent standards in terms of:

- resistance to external factors,
- control of the fission reaction,
- ensuring adequate cooling of the core and
- separation of radioactive substances from the environment.

With regard to the former, it is particularly about protection against terrorist attacks and natural disasters such as earthquakes or tsunamis. Both the physical barriers (e.g. concrete and steel reactor containment, fences, electronic sensors) and the structure of the nuclear installation itself provide protection against such events. According to the redundancy principle, the components are multiplied (at least three times) and placed at a sufficient distance from each other to minimise the risk of their simultaneous failure and the shutdown of the entire plant.

One of the main principles in the design of nuclear power plants and facilities is the so-called defence-in-depth rule. It involves the use of successive physical barriers between the fuel in the reactor core and the surroundings, so as to minimise the risk of it getting outside the facility. As a result, even if one component fails, the rest of the structure will ensure its safety and uninterrupted operation. The first barrier is the fuel material, which takes the form of a pellet that keeps harmful substances inside its structure. The second is the so-called fuel sleeve, i.e. the special tubes in which the fuel lozenges are placed, the third is the walls of the reactor vessel, the fourth is the primary circuit, the fifth is the internal bunker and the sixth is the reinforced concrete casing, which is about 1.3 m thick[16].

REACTOR'S SAFETY BARRIERS



SOURCE: OWN COMPILATION BASED ON ME.

The safety of nuclear power plants also comes from the fact that they use natural forces. Generation III and higher units use so-called passive safety systems, i.e. systems that do not need external energy. One example is the use of water as a moderator and coolant – the change of liquid to steam when the temperature inside the reactor rises causes the chain reaction to extinguish itself (due to the impossibility of carrying it out). Also key is the phenomenon of so-called convection, in which water – thanks to the temperature difference – circulates in the reactor's cooling system even after the reactor is shut down. In turn, the hermetic nature of the unit's casing means that, after evaporation, the liquid is delivered to special tanks from where it is reused after condensation. This continues to remove heat from the unit and prevents it from overheating. The systems used in modern reactor designs allow them to operate autonomously in this mode for up to several days. Gravity, on the other hand, is used in cases of emergency shutdown of the reactor by means of safety rods. In pressurised reactors, rods filled with a substance that interrupts the chain reaction are suspended above the reactor chamber by magnets. A possible power failure causes them to stop working, which lowers the rods and automatically shuts down the reactor[17].

The safeguards currently in place physically prevent a catastrophe similar to that at Chernobyl in 1986 or Fukushima in 2011 from occurring. For example, in the first case, the technology of the unit did not allow the reactor to shut down automatically in the event of a disruption in its cooling process (which is now ensured by the use of the laws of physics). In the second, the damaged reactor was not protected by a reinforced concrete enclosure (the sixth barrier) and was not equipped with passive systems to cool the unit after a sudden shutdown[18].

The safety of nuclear power plants is further ensured by stringent regulations, which have been standardised for more than 175 countries under the aegis of the IAEA. In Poland, the PAA is responsible for their observance.

Ionising radiation

Radiation is a naturally occurring phenomenon in the universe. One type of radiation is ionising radiation. It is the result of a process whereby the radiation energy penetrating matter causes an electron to detach from an atom, which in turn leads to the formation of negative electrons and positive ions. During the operation of reactors, ionising radiation is generated and emitted due to the accumulation of large quantities of highly radioactive isotopes in its core. Their escape makes it difficult to build and operate power stations according to the so-called defence-in-depth principle.

During normal operation of the unit, small amounts of radioactive substances are emitted outside the structure. These are in both gaseous (e.g. argon, krypton, xenon) and liquid form. In the immediate vicinity of the facility, however, the radiation dose is practically neutral to humans – on an annual basis it is 0.01-0.02 mSv (millisievert), which is many times less than that generated by natural objects, e.g. soil, water, air. This compares with an X-ray scan of 0.1 mSv and a whole-body CT scan of 50 to 100 mSV[19]. People who regularly travel by air are also exposed to much higher amounts of ionising radiation. PAA data shows that in Poland the average annual dose of ionising radiation per person is about 3.3 mSv, of which 2.4 mSv comes from natural sources[20].

The scientific consensus is that staying even for many years in the vicinity of a nuclear power plant has no negative impact on human life and health, including no increased risk of contracting any diseases. At the same time, the level of radiation generated by them is constantly monitored by nuclear regulators and international institutions, like the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

The role of the nuclear power plant in the electricity system

Historically, nuclear power plants have been designed to operate in a baseload regime, i.e. ensuring the supply of a relatively constant amount of electricity to the system. This is due to both their technological characteristics and economic factors – the cost of building such plants somehow forces them to maximise their annual load, which in many countries exceeds 90 per cent. This means that during this time they operate at close to nominal power.

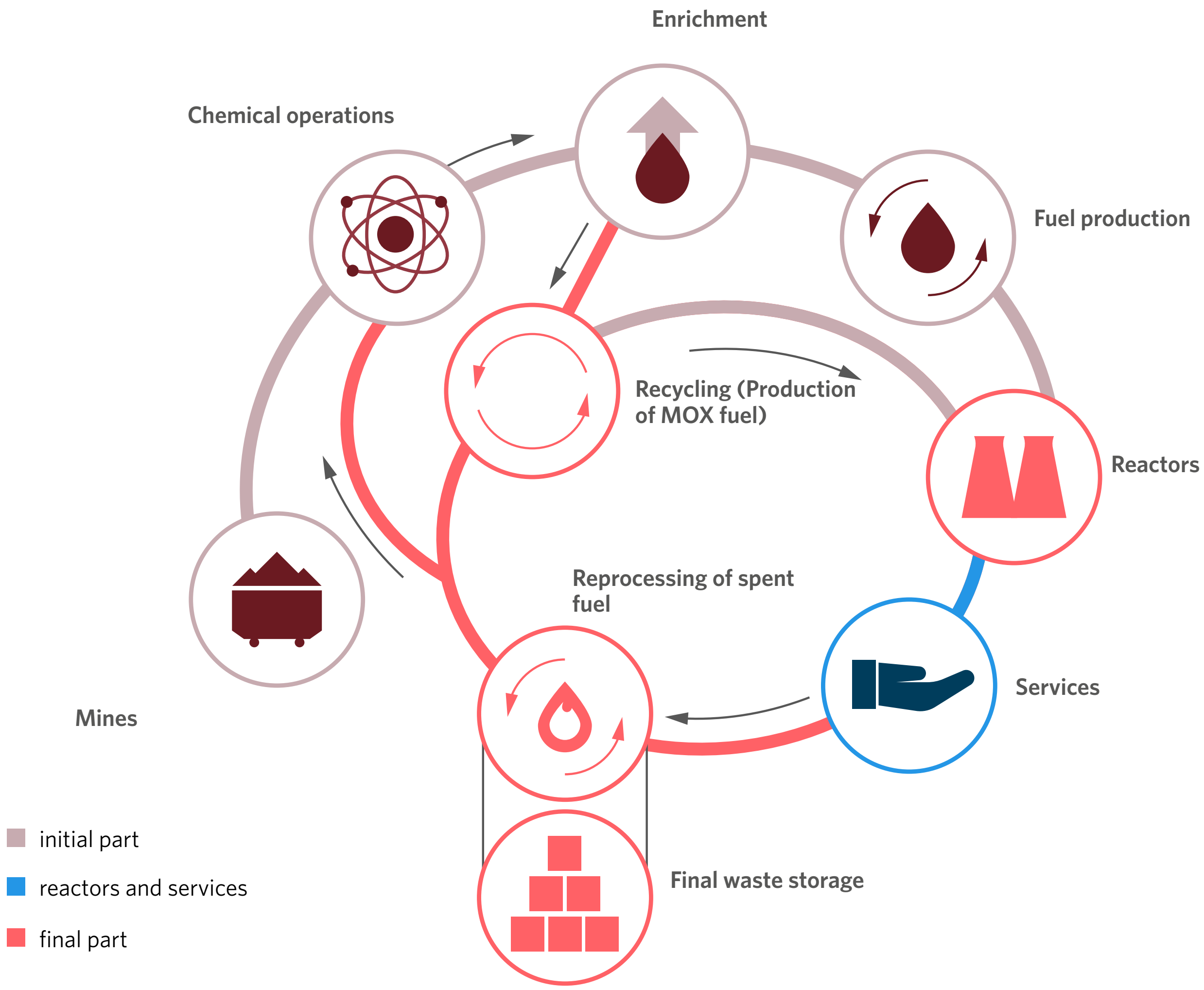
However, the latest designs are also potentially suitable for regulatory operation, i.e. covering peak power demand, for which practically only gas-fired and pumped storage power plants were formerly used. Moreover, their adaptation to so-called load following operation is theoretically already taken into account at the unit design stage. This is due to the use of automatic power control systems, allowing the reactor to operate with a smaller load (of up to 30 per cent) in order to balance the system even on a daily basis. This is a major advantage of this technology over RES plants, which are currently not suitable for such tasks. This is particularly important in countries with a significant share of nuclear power in the mix, such as France, where it exceeds 70 per cent[21].

One of the most flexible units on the market is the AP1000 reactor. It has an acceptable daily power variation from 100 per cent to 50 per cent within 2 hours, the possibility to maintain power at 50 per cent from 2 to 10 hours or to increase power to 100 per cent, within 2 hours. The allowable power step change is +/ – 10 per cent between 15 and 100 per cent of nominal power. The EPR reactor, on the other hand, is capable of adjusting power between 20-100 per cent of its nominal value[22].

Procurement of nuclear fuel

In order to carry out nuclear fission reactions to produce energy, nuclear fuel is required. It is a chemical compound containing isotopes of the fissionable element. Most commonly, it is a derivative of uranium, which, after extraction from the ore, is milled to form the so-called yellowcake (U308) and then converted to UF6. UF6 is in turn enriched in the isotope U-235. The raw material is then used to produce nuclear fuel. This process involves converting the enriched uranium into small pellets, which are placed in so-called “sleeves” (special zirconium alloy tubes) which, when sealed, become fuel rods. The latter, together with the control rods, form the so-called fuel assembly. In PWRs there are 100-200 such fuel assemblies consisting of 179-264 fuel rods.

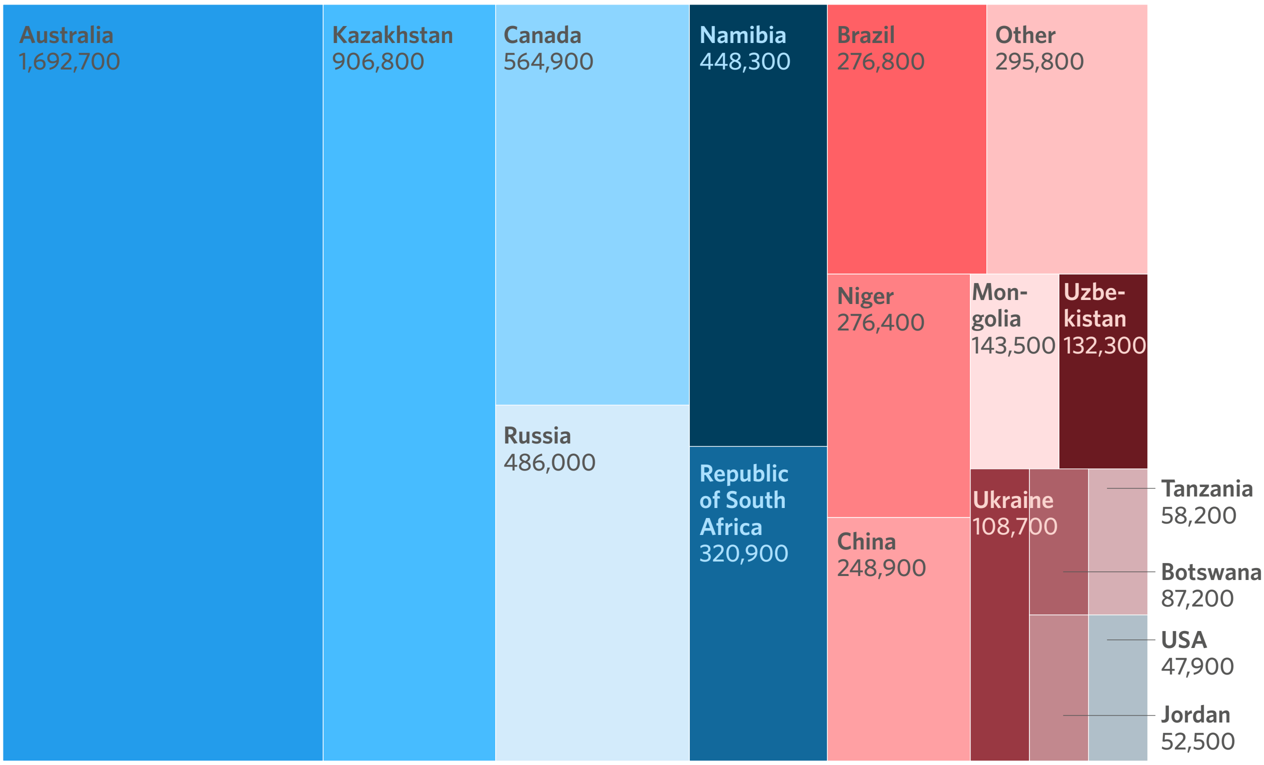
NUCLEAR FUEL CYCLE



SOURCE: OWN COMPILATION BASED ON NCBJ.

Obtaining nuclear fuel requires access to uranium and the technology to produce nuclear fuel from it. The uranium market is highly concentrated, with Kazakhstan, Canada and Australia accounting for around 70 per cent of global production. Conventional deposits are assumed to be economically viable at an extraction cost of no more than USD 130/kgU U3O8. According to OECD data, deposits meeting this criterion currently amount to around 5.7 million tonnes. In contrast, the World Nuclear Association in 2022 estimated that this figure fluctuates around 6.14 million tonnes, of which 28 per cent of the resource is located in Australia, 15 per cent in Kazakhstan, 9 per cent in Canada, 8 per cent in Russia, 2 per cent in Ukraine and 1 per cent in the US[23]. This means that, with current demand of around 63,000 tonnes of uranium per year, its conventional reserves are sufficient for 150-200 years. Documented deposits in Poland amount to approximately 7.26 thousand tonnes. They are mainly located in the Sudety Mountains, the Świętokrzyskie Mountains, Podlasie and Warmia. Considering that a 1 GW reactor consumes about 137 tonnes of the uranium per year, this means that domestic supply could ensure its supply for about 53 years.

URANIUM RESOURCES BY COUNTRY (TONNES)



SOURCE: OWN COMPILATION BASEN ON OECD NEA AND IAEA.

The world's uranium reserves are mainly located in politically stable countries with an allied or neutral attitude towards Poland. This is a key factor in ensuring the supply of nuclear fuel to Polish power plants, which will largely have to come from imports.

When it comes to choosing a uranium supplier, the origin of the uranium and the ability to diversify where it is mined are crucial. In this respect, Kazakhstan's Kazatomprom is the largest player on the market, accounting for around 25 per cent of global production (2021 figures), along with France's Orano, Russia's Uranium One and Canada's Cameco (9 per cent each), Uzbekistan's Navoi Mining and China's CN/NC (7 per cent each) and the US' General-Atomics/Quasar (5 per cent). Cameco and Orano operate the world's largest uranium mine, Cigar Lake, in Canada (10 per cent of world production), while Kazaktomprom and Cameco own the Kazakhstan Inkai 1-3 plant (7 per cent)[24].

Conversion of uranium to UF6 is offered by commercially operating plants in Canada (Cameco), France (Orano), Russia (Rosatom) and China (CN/NC). In addition, the ConverDyn plant in the US, which has been closed since 2017, is scheduled to restart in 2023. The European Supply Agency estimates that as early as 2024, global uranium conversion capacity will be insufficient to meet demand. At the same time, experts emphasise that, in the case of the EU, a possible supply gap will be able to be bridged by the planned capacity expansion at the French Philippe Coste plant, among other things[25].

In recent years there has been a large surplus of uranium enrichment capacity worldwide. The largest plants belong to Orano, Rosatom and Urenco. The first company mainly operates in France, Germany, the Netherlands, the UK, the US and Russia. Rosatom has four plants in Novouralsk, Zelenogorsk, Angarsk and Seversk, and Urenco in the UK (Capenhurst), Germany (Gronau) and the Netherlands (Almelo)[26]. The largest player is the Rosatom-controlled TVEL, with a production capacity of 28 million SWU/year (separative work unit). In contrast, Urenco has a capacity of 13.7 million SWU/year and Orano and CN/NC 7.5 million SWU/year. According to current projections, by 2040 global demand for enriched uranium could increase from the current 51.2 million SWU/year, to 76.5-100.7 million SWU/year, depending on the pace of nuclear power development, especially SMRs[27].

The final stage of converting uranium into fuel rods is the production of nuclear fuel. The fuel rod assemblies are calibrated for specific reactor types. For Poland, it is crucial that the main technology suppliers offer it extensive options for importing nuclear fuel. In the case of Westinghouse, it will be able to be supplied from, for example, the US and Sweden. It currently supplies it to Ukraine, among others. KHNP, on the other hand, offers to supply fuel from South Korea through its company KEPCO Nuclear Fuel (KNF), followed by technology transfer and the construction of a local production facility in Poland.

An estimated 96 per cent of the mass of used nuclear fuel is reusable – as it is not subject to incineration. It is recycled by cutting the fuel rods into smaller pieces, dissolving them and then extracting the remaining uranium and plutonium for use in re-fuel production. Commercial capacities in this area are available in countries such as France, Russia, Japan, the UK and India.

Handling of nuclear waste

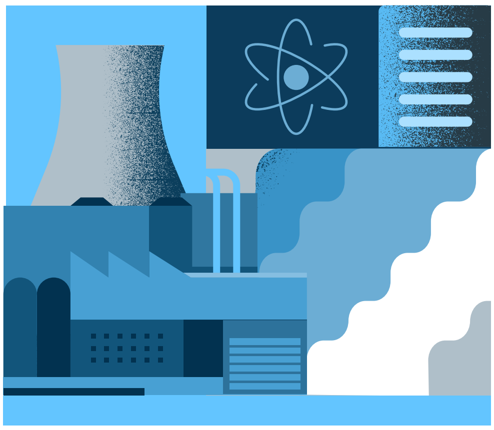
A side effect of nuclear reactors is waste, which is spent nuclear fuel containing a number of highly radioactive substances (e.g. fission products of uranium and plutonium isotopes). They may also be other contaminated substances or materials that are not suitable for further use – such waste is generated in Poland, e.g. as a result of the use of radioactive substances in industry, medicine or scientific research. Due to radiation levels exceeding the background radiation, the waste requires special handling in order to isolate it from people and the environment for a long time for the decay of radioactive isotopes. For example, even 10 years after fuel burn-up, the radiation dose rate is still more than 100 Sv/h, while the lethal dose to humans is about 5 Sv[28].

Radioactive waste is classified according to its half-life or by the activity of the radioactive elements. The first subdivision distinguishes between temporary (very short-lived) waste (half-life less than three years), short-lived waste (3-30 years) and long-lived waste (more than 30 years). In contrast, the second criterion is the concentration of radioactive isotopes – a distinction is made between high, intermediate and low-level waste. The latter are most commonly found in industry, medicine and pharmaceuticals. Due to their low level of contamination, they only need to be isolated with simple protection measures, such as rubber gloves. Medium-level waste, on the other hand, is e.g. scrap metal or sludge. They are most often generated in industry and require storage in special concrete enclosures.

High-level waste is generated in nuclear power plants. They emit large amounts of heat over many decades and thus require cooling and shielding. For a few years or so, spent nuclear fuel can be stored on site in special pools filled with water. Over time, however, it must be transferred to dry tanks with thick walls and, after a few decades, to a geological repository up to several kilometres deep. Such facilities can be found in countries such as the US, France, Sweden and Finland. Switzerland decided to build one in 2022**.**

The targeted aggregation of nuclear waste in geological formations has been identified as one of the conditions for including nuclear power in the EU taxonomy. In the delegated act 2022/1214, adopted in February 2022, the EC referred to the opinion of the Joint Research Centre[29], which pointed out that it is "a state-of-the-art solution that is widely accepted by the expert community worldwide as the safest and most sustainable option for the final management of high-level radioactive waste and spent fuel"[30]. Subsequently, countries have been required to include the construction of such facilities in their plans by 2050.

Low – and intermediate-level waste is already being generated in Poland, and most of the activities related to its disposal and storage are carried out by the Radioactive Waste Neutralisation Facility in Świerk near Warsaw. The National Radioactive Waste Repository (NSRF) in Różan near Narew is used for the storage of short-lived low – and intermediate-level waste and the temporary storage of long-lived waste[31]. The management of nuclear waste is defined by the National Nuclear Waste Management Plan adopted by the government in 2015 and updated in 2020. National Plan for Radioactive Waste and Spent Nuclear Fuel Management. It stipulates the construction of a new National Radioactive Waste Repository by 2035, as well as a Polish Underground Research Laboratory, on the basis of which a Deep Radioactive Waste Repository (SGOP) would be built[32].



ECONOMIC CONDITIONS

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Łukasz Sawicki, Ministry of Climate and Environment, Poland

Each investment in a nuclear power plant requires a massive amount of capital – and it would be good for Poland if each one was carried out with the participation of domestic (and not just foreign) contractors. As of today, most Polish investors and SPVs have declared their intention to include Polish industry in the supply chain as much as possible. **According to estimates, at the stage of construction of the first nuclear power unit, the involvement of domestic companies may be as high as around 40 per cent.** As the subsequent units are built, it will rise to around 70 per cent, as confirmed publicly by the companies that submitted bids to supply nuclear technology to Poland[33]:

- EDF has established contacts with a hundred Polish companies, certified 70 of them and proposes to involve them in its other projects in Europe. It has declared that initially their share in the construction of the Polish power plant would be around 50 per cent, and eventually 65-70 per cent.
- Westinghouse has held talks with 500 Polish companies, including those already in the nuclear business; it pledges so-called local content of 50 per cent, which, in the case of the construction of the first units, would translate into orders worth more than PLN 100 billion.
- In addition to local content of between 40 and 70 per cent, KHNP announces the construction of a nuclear fuel production plant in Poland, among other things.

According to the Polish Economic Institute, **with the involvement of domestic companies at 70 per cent, the estimated value of local content would be as high as PLN 130 billion.** It is estimated that Polish subcontractors are able to manufacture the main equipment (their cost is 32 per cent of the project cost), and handle most of the engineering and construction work (41 per cent of the project cost). This means that the construction and operation of nuclear power plants is estimated to translate into a 1-2 per cent increase in Polish GDP by 2043[34]. But, it should be assumed that in the initial period of nuclear power development, the share of Polish companies will be much lower, although as the sector develops it will probably start to increase systematically.

Information and support activities for Polish companies potentially interested in participating in the investment are coordinated by the Ministry of the Economy (Department of Nuclear Energy – DEJ). In 2021, the ministry prepared the latest edition of the *Polish Industry for Nuclear Energy* catalogue, grouping companies that either have the competencies needed for such projects or can acquire them with reasonable effort. They gained experience in the energy sector in Poland and abroad, including nuclear power. The directory included 338 Polish companies, 78 of which were involved in 40 nuclear projects in 24 countries. For example, 25 Polish companies worked on the construction of the Finnish Olkiluoto-3 power plant, slightly fewer on the Flamanville-3 investment in France or Hinkley Point C in the UK. These companies mainly represent the engineering, electrical and automation industries, but also civil engineering, metallurgy and metal processing, installations, engineering and the chemical sector. It should be noted that the technical and organisational requirements placed on the players are comparable in the nuclear sector to those in the aerospace industry. The implementation of projects in this area contributes to the development of many modern industries, technical progress and scientific development of the country[35]. On March 7, 2023, the Ministry of the Environment started work on updating the catalogue of Polish companies for the nuclear sector.

At the request of the Ministry of Climate and Environment, informational meetings and competence trainings are being organised for businesses interested in participating in the construction of a Polish nuclear power plant. They are conducted by experts associated with potential technology suppliers to Poland. Their aim is to familiarise the business with the technical and business requirements, to raise competence, but also to improve communication and certification of Polish entities, to provide them with clear guidelines, and to agree with general contractors on their minimum participation in the project.[36] It should be stressed that not all companies have to fulfil the certification condition – it depends on the stage at which they join the investment and the type of services or products they provide. In addition, the Ministry of Climate and Environment co-organises meetings and seminars with the Korean, British and Spanish nuclear industries. In December 2022, 180 people from 100 Polish companies completed such training[37].

This notwithstanding, foreign companies interested in building a nuclear power plant in Poland (Westinghouse, KHNP, EDF, GE) are working to include Polish companies in their supply chains. Some of these have tangible results in the form of contracts at foreign nuclear power plant construction sites.

Some constraints for Polish companies are the relatively small capital capacity, size of the organisation, financial condition, difficulty in complying with safety standards and quality requirements, lack of suitably qualified staff and problems with certification[38].

The implementation of new quality systems (agreed during certification with the technology supplier) is a lengthy and capital-intensive process (even two to four years). Over the next few years, Polish companies will therefore be able to prepare for future cooperation with a general contractor by making the necessary changes (organisational, competence, quality management). This will allow them to be included in the approved suppliers list, which gives them a chance of being awarded the contract. The lack of certainty of being awarded a contract in view of the often enormous financial and organisational effort required may be a demotivating factor for Polish enterprises to take part in preparations for this investment project, especially in the face of strong competition from foreign companies.

The technical and organisational requirements vary depending on the area of operation of the power plant itself: the highest for the nuclear part, i.e. mainly the reactor room (e.g. ISO 19443, ASME NQA-1), followed by increasingly less stringent requirements for the conventional part (the control room), the power output, the remaining infrastructure and the buildings and structures around the power plant (auxiliary buildings, so-called balance of plant). The experience of Polish companies with the nuclear technology itself is relatively small, but their participation is possible in the conventional part. Also, Polish research and development units seem to be well prepared for tasks in nuclear power – they have accreditations and certifications, e.g. PAA, PCBC, PCA, UDT, and experience from cooperation with many international organisations (IAEA, NEA OECD). However, nuclear competence is least developed in all stages of the value chain (not only design and construction, but also operation and decommissioning)[39].

A challenge for Polish contractors may be the simultaneous implementation of several nuclear projects based on different technologies. It will also result from the differences in industry standards (e.g. American ASME and French RCCM) and the supply chains of each technology supplier. Only a handful of Polish companies will be able to adapt to more than one reactor type, and even then only in the case of significant technological or standardisation similarities. On the one hand, a large number of projects may generate an investment boost and increase the chances of orders. On the other hand, investors and general contractors may not be able to attract many Polish companies for each project – as these will be overloaded with tasks at competing investments. This means that the average share of Polish companies may be smaller than expected.

Competition for subcontractors may increase the price of services on the market and lead to an overall increase in the cost of all nuclear investments. The involvement of foreign companies will not lower prices due to their alignment with the domestic market. The latter may also be resonated by higher service prices in the West. In turn, companies from Central and Eastern Europe will be partly involved in investments made simultaneously in their own countries.

Availability of personnel

Another condition on which the implementation of nuclear power depends is access to an adequate number of specialists. The Polish human resources market for the nuclear industry is underdeveloped due to the lack of operating reactors. There is a shortage of specialists with competence and experience in the preparation and implementation of such investments, and those who are, are scattered around companies such as:

- companies carrying out nuclear contracts abroad,
- foreign and national design firms,
- special purpose companies,
- subcontractors for location studies,
- construction, installation and production companies,
- coal and gas power industry,
- public sector.

The latter includes control and inspection institutions, supervisory institutions, scientific and research institutes acting as Technical Support Organisations (TPOs) and universities educating and training specialists and providing services to other entities. A small number of high-class Polish specialists are available abroad. Special-purpose companies (investors) use consultancy services from foreign companies to a certain extent, but their quality varies. **At the end of 2022, selected Polish technical universities began the process of reactivating or creating faculties closely related to nuclear energy.** Postgraduate studies are offered by several technical universities and the Warsaw School of Economics. In addition, in cooperation with special purpose vehicles (PEJ, OSGE), universities have decided to intensify education and establish full engineering faculties. Vocational education (various technician specialisations) is also being rebuilt. In line with the Polish Nuclear Power Programme, the Ministry of Climate and Environment is preparing a Human Resources Development Plan for the Nuclear Power Industry to help coordinate efforts in this area.

The market for nuclear professionals will come under increasing pressure in the coming years. A large number of domestic nuclear projects will result in strong competition among investors for workers, especially those with good industry credentials and experience. This may make it much more difficult and slow down the execution of the projects whose investors will not be able to engage an adequate number of competent specialists. In addition, the public sector, including regulatory-inspection institutions (PAA, UDT, GDOŚ) and coordinating institutions (Ministry of Climate and Environment), which will be the first and most affected by the outflow of staff, may prove to be a major problem. In the extreme, this could paralyse their work (especially the PAA) and hinder the implementation of all nuclear projects, or lead to shortcuts being taken. As the law imposes obligations to issue decisions (permits, permissions) in a timely manner, offices may find themselves in a situation where investors' applications are considered only in a superficial manner, without deeper analysis, and decisions are in practice only a formality, without substantive verification of the submitted documents.

Staff outflows also threaten the research institutes that are supposed to act as OWTs. The PAA will have to rely more on procuring expensive expert services abroad. The loss of specialists may also mean temporary difficulties in operating research facilities such as the Maria reactor at the National Centre for Nuclear Research (NCBJ), which will not only slow down scientific research but, above all, may jeopardise the production of radiopharmaceuticals in Poland, and finally worsen the financial situation of the NCBJ itself. It will also make it more difficult to train staff for the nuclear power industry, as the institutes cooperate with universities and vocational schools in this area. The universities may also lose some of their research and teaching staff, which will exacerbate the problem of training for the entire sector.

Preventing a permanent loss of human resources and actual competencies in the public sector requires a significant change in human resources policy, both for specialist and lower and middle management positions. This must be combined with an increase in salaries to their corporate sector level and an expansion of non-wage benefits. Making up the public sector employment deficit will be difficult, costly and time-consuming. Although it takes a few years to train basic specialists, it will not provide them with the experience of staff who have left. The public sector will have to spend considerable resources not only on staff training, but also on counteracting the excessive staff turnover that has occurred over the past decade in several entities in the Polish nuclear sector. It has seen significant funds spent on educating professionals who have left their current employer or even the industry as a whole. In this respect, the lack of ample time for training will also be a powerful challenge.

In conclusion, the accumulation of many nuclear projects in a short period of time and the small market of nuclear specialists in Poland may become a significant problem for all state institutions and a significant number of private entities. This is particularly relevant in the context of increasing nuclear investor activity in the Polish labour market.

Financial needs and possibilities

Nuclear power plants are capital-intensive investments with long lead times and returns[40]. As a result, they are overwhelmingly implemented with smaller or greater state involvement.

The ability to finance Polish nuclear projects will be determined by the following factors:

- the number of nuclear projects and their capital requirements,
- how the projects are financed,
- expectations of domestic and foreign financial institutions with regard to state guarantees,
- constraints on the provision of state guarantees,
- business models adopted, including ways to ensure revenue and debt servicing,
- EU policy and EC decisions on state aid and the energy market.

SOME DECLARED NUCLEAR INVESTMENTS IN POLAND*

Investor	Investor	Total gross power (MW)	Construction period
PEJ	AP1000	3,750	2026 – 2037
PGE+ZE PAK+KHNP	APR-1400	5,600**	2030 (?) – 2039 (?)
EDF (?)	EPR	3,440	2026-2034 (?)
OSGE	BWRX-300	23,700	2029-2036
KGHM	NuScale VOYGR	462	~2030<
RESPECT ENERGY	Nuward	340 (?)	~2030<
ŚGP INDUSTRIA	Rolls-Royce	7,990	~2030<

SOURCE: OWN COMPILATION
* DATA BASED ON NON-BINDING DECLARATIONS BY INVESTORS
**CONSTRUCTION OF 4 UNITS IN PĄTNÓW ASSUMED

The table below shows the plans of various Polish investors for nuclear power plants. It can be roughly estimated that the capital expenditure for individual projects will take on the following order of magnitude (excluding financing costs)

- AP1000 (PEJ) – PLN 90 bln[41]
- APR-1400 (PGE+ZEPAK+KHNP) – PLN 122 bln[42]
- EPR (EDF) – PLN 80 bln[43]
- BWRX-300 (OSGE) – PLN 405 bln[44]
- NuScale VOYGR (KGHM) – PLN 40 bln[45]
- Nuward (Respect Energy) – [46]data unavailable, assumed in line with BWRX-300 (some PLN 6 bln)
- Rolls-Royce – PLN 210 bln

The total expenditure on these projects could exceed PLN 900 billion. Assuming financing costs increase by around 20 per cent, the total amount between 2026 and 2039 will be more than PLN 1 trillion.

A typical financing structure for nuclear projects is 20-30 per cent equity and 70-80 per cent debt. In this report, we have assumed that debt will average 70 per cent for all projects. There are many potential sources of funding available, and we discuss the most important ones below:

1 **Capital Group of the Polish Development Fund.**

The mission of PFR, as a Polish financial institution, is to implement programmes that increase the long-term investment and economic potential and support equal opportunities and environmental protection. One of the tasks carried out by PFR is to support infrastructure investments (also of the greenfield type) through their financing (ownership and creditor instruments). An example of this is the support for the construction of a 910 MW coal-fired power unit at the Jaworzno power plant. The financing (acquisition of shares in a special purpose vehicle) in 2017 amounted to PLN 880 million (PFR exited the investment in 2021). Assuming that the nuclear power plant is subsidised in proportion to its rated capacity, one unit with Westinghouse technology could count on an ownership share of more than PLN 1.16 billion. In turn, taking into account that nuclear power contributes to the reduction of CO2 emissions of the entire electricity system (generating future savings in emission permit expenses), it can be estimated that the level of co-financing could be at least doubled, to potentially over PLN 2.3 billion.

In September 2022, PFR took up PLN 120 million worth of bonds issued by R.Power (power producer and developer of PV farms). In the same period, Gaz-System received funding worth PLN 1 billion (subordinated loan) to finance investments of key importance for energy security (diversification of gas supply sources). The development of nuclear power also serves to strengthen energy security, so PFR is an entity that can potentially finance nuclear projects.

PFR also supports photovoltaic and wind projects, such as the 200 MW Kleczew Solar&Wind project. In January 2023, PFR Investment Fund FIZAN provided a subordinated loan of up to PLN 90 million for this investment. Using a proportional approach, support for the construction of one unit can be expected at the level of PLN 540 million, and given that the capacity factor of nuclear power is at least three times higher, the amount of possible support rises to more than PLN 1.6 billion.

In 2021 (latest data available), CG PFR invested around PLN 28 billion in more than 30 projects, including infrastructure and energy projects. A dedicated fund (PFR Green Hub) has been set up to finance the energy transition by supporting green investments. So far, however, nuclear energy has not been included among the latter, although it meets some of the criteria (e.g. low-carbon energy). The PFR Green Hub had an investment fund of PLN 200 million in 2021, and the envisaged participation in projects is both subordinated lending and participation in the company's capital. That year, PFR and BOŚ signed an agreement on financing green investments in the thermal power industry.

2 Mobilisation of free funds in accounts.

According to NBP statistics for 2021, (the latest available data) accounts of:

- non-financial enterprises accumulated cash and deposits worth PLN 458 billion,
- investment funds that are not money market funds – PLN 17 billion,
- insurance institutions and pension funds – PLN 11 billion,
- other financial intermediary institutions – PLN 38 billion,
- government institutions – PLN 337 billion,
- households – PLN 1407 billion.

Together, this amounts to PLN 2,268 billion.

The possible encouragement by state and private institutions to invest just 1 per cent of these funds in financial instruments (ownership or creditor instruments) issued by the entity building the nuclear power plant would make it possible to pool almost PLN 23 billion. Voluntary investment in an infrastructure project of such great importance to the economy would also certainly contribute to building and consolidating public support for nuclear power in Poland. Similarly, for investment and pension funds (including foreign ones) – particularly those with a long investment horizon – this could be an attractive proposition, although it is likely that such entities would only be willing to invest at a later stage of the construction of the nuclear unit.

Repeated declarations by the NBP authorities indicate that the institution is ready to financially support the construction of nuclear power plants in Poland. Yet, so far, neither the central bank's capabilities in this regard nor the possible financing method have been presented.

3 Other financing sources.

These could be:

- IBNI (International Bank for Nuclear Infrastructure), an international investment bank being set up on the initiative of governments and financial and consulting institutions to finance investments by the nuclear industry,
- export credit agencies from the country of the technology supplier and even the government or designated institutions,
- Polish and foreign banks, e.g. PKO BP, BOŚ,
- NFOŚiGW (for nuclear power infrastructure) with national and European environmental funds.

Challenges related to state guarantees

As a rule, financial institutions require a guarantee from the State Treasury (SP) for the entire extent of the financing they provide (Polish regulations allow for a guarantee of up to 100 per cent for investments of particular importance to the national economy). This would mean that the SP guarantees required to be granted could amount to around PLN 801 billion (70 per cent of the PLN 1144 billion). For comparison, in 2022, all outstanding liabilities under the SP's guarantees and sureties amounted to PLN 470 billion, and are expected to amount to PLN 811.8 billion in 2026[47].

An investor seeking SP guarantees must meet a number of conditions, including[48]:

- pay a commission fee for issuing the surety or guarantee (but no fee is charged for processing the application itself);
- provide security for SP in the event of claims arising out of the performance of the guarantor's obligations;
- the principle of risk-sharing between the guarantor and the lender (bondholder) applies: sureties and guarantees may be granted up to 50 per cent of the obligation (50 per cent of the principal of the obligation together with 50 per cent of the interest and other costs directly related to the obligation) or 60 per cent of the obligation (in the case of sureties and guarantees granted by BGK on behalf of and for the account of SP). Exceptionally, in the case of a project of particular importance for the national economy, security or defence of the state, the government may grant a surety or guarantee up to a value higher than 50 per cent of the liabilities;
- sureties and guarantees of the State Treasury, as well as of state legal persons, must be granted taking into account the provisions on state aid.

State guarantees are state aid and must be approved by the EC. Based on the example of the construction of the new nuclear unit at the Dukovany power plant in the Czech Republic, it can be concluded that the Commission has been restrained in giving its approval to assistance instruments.

Laws place restrictions on the granting of SP guarantees. A final "barrier" to excessive (potential) state indebtedness is the Polish Constitution, which states in Article 216(5) that "No loans may be contracted or financial guarantees and sureties granted, as a result of which the state public debt will exceed 3/5 of the value of the annual gross domestic product (...)."[49] An analogous provision relating to state public debt is found in the Public Finance Act (Articles 74 and 86(1)(3)(d)). This debt also includes the amounts of "outstanding liabilities under sureties and guarantees not included in the state public debt, as well as (...) outstanding liabilities under sureties and guarantees not included in the debt of the State Treasury". However, the first restrictions are at the level of the state public debt-to-GDP ratio of 43 per cent (the so-called stabilising expenditure rule). This is the threshold beyond which the Ministry of Finance (MF) can refuse to provide SP guarantees to investors or financial institutions involved in the nuclear project for fear of having to reduce public spending – especially as much of it is rigid in Poland.

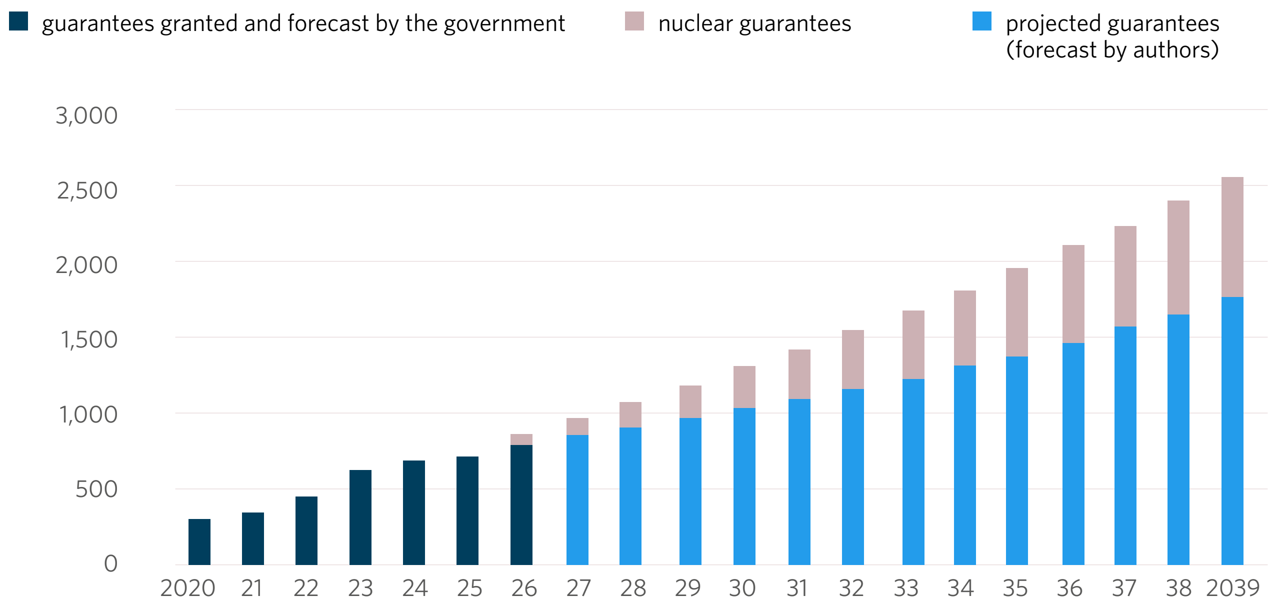
There is also a limit to the allowable amount of sureties and guarantees provided by the SP recorded each year in the Budget Act. In the case of the 2023 law, the limit is PLN 200 billion[50], similar to the previous year.

The government's decision to grant guarantees will also be influenced by the assessment of the investment risk, i.e. the risk of guarantees moving from potential (outstanding) to maturing. Risks include the maturity of the technology in question, the experience of the contractors, the credibility of the investor, revenue risk (energy market, business model) and staff resources. The greatest risks are projects with technologies that are unproven in construction and operation (or proven on the basis of similar but not identical technical designs), that do not have contractors with experience and good references, but also projects with a bad management history, that do not have guarantees of revenues from energy sales and that have problems in recruiting competent staff.

Potential (unmatured) liabilities under sureties and guarantees issued by public finance sector entities at the end of H1 2022 amount (according to estimates) to PLN 380.8 billion, compared with PLN 360.5 billion at the end of 2021 (13.7 per cent of GDP) and PLN 306.8 billion (13.1 per cent of GDP) at the end of 2020. Liabilities under sureties and guarantees issued by the SP accounted for the dominant share of potential liabilities. At the end of H1 2022, this was PLN 364.4 billion, and at the end of 2021, PLN 356.3 billion (13.6 per cent of GDP) versus PLN 302.9 billion in 2020 (12.9 per cent of GDP)[51].

Having taken into account the estimated need for SP guarantees between 2026 and 2039 (PLN 801 billion), as estimated above, we present a breakdown of these, together with a projection with other SP guarantees that have already been granted and may be granted in future years.

PROJECTED SP GUARANTEES INCLUDING NUCLEAR INVESTMENT GUARANTEES (IN PLN BILLION)



SOURCE: OWN COMPILATION BASED ON: DEBT MANAGEMENT STRATEGY OF THE PUBLIC FINANCE SECTOR IN 2023-2026, MINISTRY OF FINANCE, WARSAW, SEPTEMBER 2022

The above chart implies that SP guarantees count towards public debt. If they are provided for all nuclear projects in the amounts estimated above, the debt-to-GDP ratio will rise rapidly when GDP growth is low (real risk of entering recession). The average annual growth rate of guarantees (CAGR) without nuclear investment between 2023 and 2026 is expected to be 6.17 per cent, while average annual GDP growth between 2023 and 2025 will be 1.93 per cent[52]. Therefore, the growth of guarantees without taking into account nuclear investments will already be three times faster than GDP growth year-on-year in the coming years. This may lead to exceeding the MF's prudential thresholds and block the issuance of further guarantees, possibly even before 2030. The MF itself indicates in its document that the need to execute guarantees or sureties granted by entities of the public finance sector is a potential threat to the implementation of the *Public Finance Sector Debt Management Strategy in 2023-2026*[53].

An element linked to the constraints on nuclear financing and SP guarantees is also the exchange rate risk. A large proportion of guarantees (40-60 per cent) are likely to be in foreign currencies, mainly dollars and euros. Exchange rate risk may affect current estimates of guarantee amounts. Some foreign (mainly European) banks may provide loans in PLN, but the cost of such a loan may be higher than the cost of a loan in euros.

Business models in nuclear energy

More than a dozen business models have been used in the sector to date. Below are the three that are currently being implemented or planned for new EU and UK nuclear projects, as well as the SaHo Model developed in Poland.

1 Contract for Difference – CfD

Applied to Hinkley Point C (UK) and Cernavoda 3&4 (Romania). In it, the state guarantees a fixed energy sale price (strike price) for the power plants. The energy is sold on the market without an offtake guarantee and at a market price. If this price is lower than the price guaranteed by the government, a specially designated entity (settlement manager) subsidises the generator with the difference. If it is higher, the generator has to return the excess to the settlement manager. The duration of the guarantee depends on the type of source – 35 years was assumed for the Hinkley Point C project. In addition, the state can provide loan guarantees and sureties. The strike price can be changed in certain cases, including when, due to the intervention of the transmission system operator, the nuclear power plant (NPP) operates at a lower capacity than agreed in the contract between the investor and the state. In such a situation, the strike price is increased accordingly to compensate for the losses incurred by the NPP owner as a result of reduced energy production. The equivalent of this model in Poland (additionally with an auction element) has been applied for onshore and offshore wind farms.

2 Czech model or Czech CfD

These are the names adopted for the new business model developed in 2020 for the Dukovany-5 project in the Czech Republic. It is a heavily modified CfD model in which a government-controlled dedicated trading company has been added to the system. It is to buy all the energy produced at the Dukovany-5 unit, thereby providing a guarantee of energy off-take. The company will resell this energy on the market. If it generates losses in the financial year, it will be able to receive compensation from the settlement manager or a subsidy from the state budget (this is new to the CfD system). In addition, the state is to provide a low-interest loan to the investor. This model has been notified by the investor and the Czech government to the EC, which is currently examining its legality and compliance with state aid rules and market competitiveness rules. According to the government and investor's declarations, the above solutions will not be applied to future nuclear projects.

3 Tariff model (including UK RAB)

Applied in the US in some states (e.g. Georgia and South Carolina) and in the EU for district heating, gas and water supply (local natural monopolies), and planned in the UK for new NPPs. It involves the energy market regulator periodically setting a fixed charge that energy consumers pay to the power plant investor in the form of, for example, a separate line item on their energy bill. The charge is calculated by the regulator on the basis of the reasonable costs of the investment together with a fair profit for the investor. In theory, it has full insight into the costs and can impose restrictions on them (i.e. not include them in the tariff), but it does not have full control over the investor's decisions. The assumption is that any cost overruns that the regulator does not take into account in the tariff update must be covered by the investor from his own resources. In practice, this is difficult to enforce, as the investor is guaranteed a certain rate of return at the outset of the investment and risks mainly lost potential benefits. A characteristic feature of the tariff model is that the collection of the fee starts already at the investment preparation stage, or at the latest at the start of construction, and not just after the start of electricity production. In theory, this reduces financial risks and capital costs, which should ultimately translate into lower energy production costs and lower bills for end consumers. In fact, the investor finances the investment with free capital for him from the tariff fee. The investor also has the right to withdraw at any time, by which he can force the state to take over the project or abandon it. Such a situation occurred on the VC Summer project in the US in 2017, where the withdrawal of the main investor resulted in the complete abandonment of the half-completed construction and the need for energy consumers and taxpayers to pay the so-called "sunk costs" of USD 9 billion. The tariff model in the UK version of the RAB has not been used in the energy industry to date.

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"There is a consensus that while the Contracts for Difference (CfD) model has enabled the development of renewable energy in the UK, it is not suitable for nuclear projects, which involve high upfront capital costs and a long construction and operating period. A solution to facilitate nuclear investment is the Regulated Asset Base (RAB) model, introduced in 2022 into the Nuclear Energy Financing Act in the UK, which has been successfully used to finance large-scale infrastructure investments, including Terminal 5 at the Heathrow Airport. The RAB model would be expected to reduce the cost of financing nuclear power plants in the early stages of project development by ensuring that the project is co-financed by electricity consumers, who would pay an additional charge through their energy suppliers, and through a package of government support. It is widely expected that the RAB model will be used for the Sizewell C power station project."

4 SaHo Model

A new Polish model developed for nuclear power, but also applicable to other infrastructure projects. This is an umbrella model in which the state or its equivalent (e.g. in the form of a large private company with access to cheap capital and able to take on most of the investment risk), called the primary investor, builds a power plant and then sells it to energy consumers (called end-investors), who from then on have the right and obligation to take power and energy in proportion to their ownership titles (shares or stake). During the operation phase, the power plant operates similarly to the Finnish Mankala model and the US energy cooperative. The sale of shares can take place gradually during construction or at the end, just before the power plant is connected to the grid. End investors can purchase shares individually (in the case of large consumers) or through aggregators, e.g. energy cooperatives of households and small businesses. CIn principle, in the SaHo Model, any end-user can directly or indirectly be a co-owner of the NPP. The shares can be traded relatively freely under state supervision, i.e. the end-investor has the option to sell them to another energy consumer. After selling shares in one nuclear unit, the state can use the funds used to build another unit and thus significantly reduce the cost of the nuclear programme – a mechanism that has come to be known as re-use of funds. The SaHo model is almost entirely based on mechanisms used in similar models in Finland (Mankala), the US (Electric Membership Corporations), the Netherlands and Germany (municipal energy), as well as in Poland (industrial energy, TAMEH company). It currently has many versions, some of which are adapted to the requirements of specific investment projects implemented in Poland.

LEGAL CONDITIONS

Baker McKenzie team

The primary source of legislation regulating the operation and licensing of nuclear power plants is the Nuclear Act of November 29, 2000, which replaced the 1986 legislation. Its enactment resulted from the need to adapt Polish legislation to the changing regulatory environment associated with Poland's joining international organisations. Although the current Nuclear Act, e.g. in its drafting structure, is based on its predecessor, the number of necessary changes called for the enactment of a new law.

The complexity of the investment process related to the construction of the nuclear power plant prompted the legislator to also enact the **Act of June 29, 2011, on the preparation and implementation of investments in nuclear power facilities and accompanying investments** (Special Act). This was justified at the time on the grounds that "construction of nuclear power plants in the current state of the law would be an extremely difficult undertaking, if feasible at all". The primary purpose of the Special Act was hence to define the rules and conditions for the preparation and implementation of investments in the construction of nuclear power facilities and accompanying investments.

Both pieces of legislation have been altered by the amendment to the Special Act (the "amendment"), which has been in force since April 13, 2023. According to the Explanatory Memorandum, its primary purpose is to "introduce a number of changes to streamline the process of preparation and implementation of investments in the construction of a nuclear power plant" in the timetable set by the government of Mateusz Morawiecki.

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The implementation of any direct greenfield investment, let alone a nuclear power plant, is a complex, intricate process, requiring the efficient coordination of various expertise and areas of activity. From a legal perspective, in addition to strictly construction or environmental permits, related to the location and construction of the power plant, depending on who is the entity providing the technology, who is operating it, different regulatory obligations will arise under the law on trading in technologies of strategic importance for state security. A separate universe in this type of investment is the commercial contracts and related tax, financial or related analyses and negotiations related to particular legal provisions. Greenfield is a new point on the supply chain map for the developer, operator and individual suppliers. Securing key contractors at a sufficiently early stage of the project is essential for an effective and timely launch of the investment. Similarly, at a very early stage, it is worth guaranteeing the financing of the project (this is where the EU and the compromise classifying nuclear power as environmentally sustainable comes to the rescue) and an adequate supply of skilled workers.

Regulatory lifecycle of a nuclear power plant

The construction and operation of a nuclear power plant involves a number of obligations of a public law nature. These stem mainly from the Nuclear Act and the Special Act. Their number is directly proportional to the complexity of the investment and the scale of the risks it theoretically generates. In simple terms, the Special Act defines the key permits and decisions required to implement a nuclear project, as well as the manner and deadlines for obtaining them. Among the most significant administrative acts issued on the basis of this Act, the following can be singled out:

- a fundamental decision, i.e. a key administrative decision conditioning the implementation of the project, issued by the minister responsible for energy, which is "an expression of the state's political acceptance of the construction of a nuclear power plant by a specific investor, at a specific location and using a specific reactor technology"[54];
- a decision on the location of an investment project for the construction of a nuclear energy facility ("location decision").

A nuclear power plant, like other projects of this and similar magnitude, also requires:

- a decision on environmental conditions (colloquially "environmental decision"),
- a construction permit,
- an occupancy permit or, once needed,
- a demolition permit, if needed.

Both the environmental decision and the said permits are issued on the basis of their respective regulations[55], subject to the special regulations contained in the Nuclear Act and the Special Act.

In addition to the above, the implementation of investments in nuclear sources is governed by procedures for obtaining opinions and permits in terms of the Nuclear Act. This law focuses on the issues of:

- nuclear safety,
- radiological protection,
- physical protection or nuclear material safeguards, as well as on
- other areas of nuclear power plant operation requiring specific supervision by competent authorities, e.g. the PAA head.

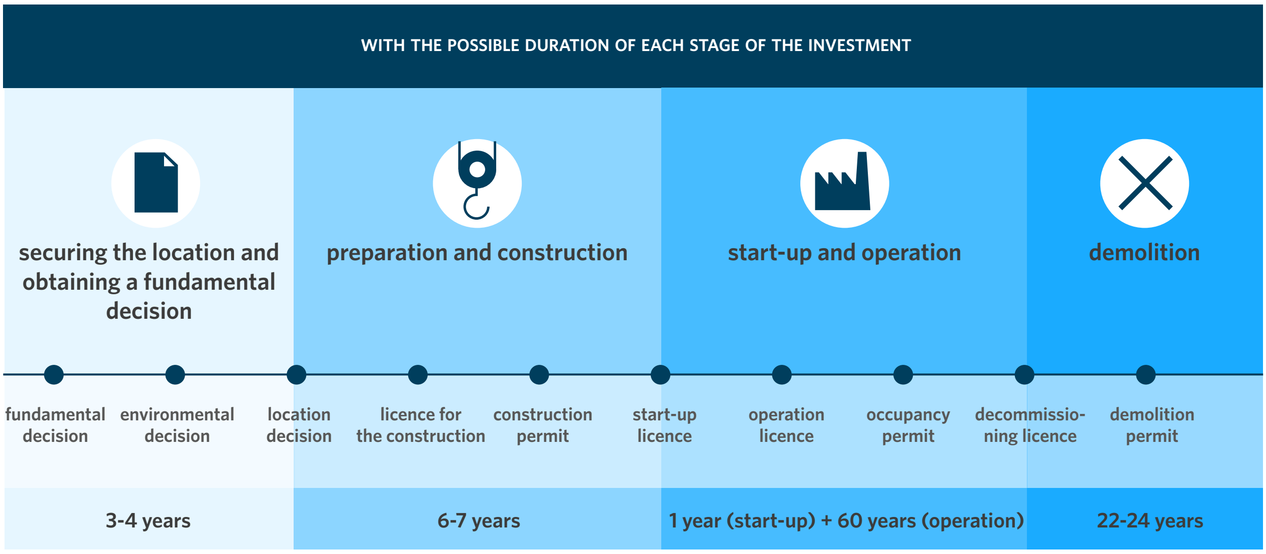
First and foremost, appropriate licences must be obtained for exposure-related activities, i.e., licences for the construction, start-up licence, operation or decommissioning of nuclear facilities (issued by the head of PAA). For example, for the construction of a nuclear facility, it is not sufficient to obtain a regular construction permit from a governmental authority, but it will also be necessary to obtain a licence for the construction from the head of PAA.

The Nuclear Act stipulates that foreign authorities are also involved in the licensing process. For example, before applying for a start-up licence a nuclear facility, the applicant will have to obtain the relevant EC opinion.

With regard to the generation of electricity in the nuclear power plant itself, the Act of April 10, 1997, "Energy Law" (the Nuclear Act does not contain a separate regulation in this regard) will be applicable. On its basis, the investor will seek to obtain a grid connection and a licence to generate electricity.

The amendment to the Special Act significantly changed the licensing process for a nuclear power plant. Key in this respect was the location of the fundamental decision at an earlier stage of the investment and construction process. This is to reduce the investment risk associated with going through the location procedure (which involves conducting complex environmental studies) without the state's initial "approval" to implement a specific investment at a given site, expressed precisely in the fundamental decision. In addition to changing the sequence of obtaining these administrative decisions, the amendment provides measures that should shorten the investment implementation process. These include the right to submit an environmental decision in the course of the procedure for issuing a location decision (instead of before the application for a location decision) or the possibility of temporarily operating a nuclear power plant after obtaining a start-up licence and before obtaining an operation licence. These changes should be viewed favourably from the point of view of the speed of the investment process.

“MILESTONES” IN THE REGULATORY LIFE CYCLE OF A NUCLEAR POWER PLANT



BEFORE OPERATING THE FACILITY, IT IS NECESSARY TO SECURE THE APPROPRIATE AUTHORIZATION TO CARRY OUT ACTIVITIES RELATED TO EXPOSURE AND OBTAIN A CONNECTION TO THE ELECTRICITY GRID AND A LICENCE FOR ELECTRICITY GENERATION BASED ON THE PROVISIONS OF THE ENERGY LAW.
SOURCE: COMPILED BY BAKER MCKENZIE.

Impact of regulation on the speed and direction of nuclear power development

1 Site selection and safeguarding the interests of third parties

Construction of nuclear power plants requires regulation of how legal titles to the property on which it is to be built are to be secured – as is the case with other large-scale energy and public purpose infrastructure projects (e.g. construction of the Central Airport, CPK). It is crucial that this process is carried out in a way that is as fair as possible (while limiting undue negative interference with third party rights) but also efficient, especially in view of the deficit in installed capacity in the future, Poland’s dependence on hydrocarbon imports and the need to continue the energy transition.

The Special Act established the legal framework for obtaining permits for nuclear power plants, including a decision to determine the location of a nuclear power facility, which is the basis for the actions of the investor and the State Treasury towards third parties, including carrying out possible expropriations.

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In the application for a decision on the location of a nuclear power facility, the investor will present a list of properties in three groups. The first group will include plots where the power plant will be located, the second group will include plots covered only by its impact, and the third group will include plots where it will be necessary to place accompanying infrastructure of the power plant, e.g. for power transfer. Once the investor has submitted the application, the voivode (as the authority responsible for issuing the location decision) will notify all parties to the proceedings, including owners and perpetual usufructuaries of the properties affected. Once the notice is served for these properties, the issuing of building permits ceases and, if owned by the the State Treasury (Skarb Państwa, "SP"), they cannot be the subject of dispositive actions either. All other location proceedings, such as the issuing of development conditions, are suspended.

This procedure does not have a "surprise effect" – the interested parties should learn about the planned project at the latest when issuing the environmental decision, the receipt of which precedes the application for the issuance of the location decision and may be a harbinger of future expropriations. Importantly, since the entry into force of the amendment to the special act, the issuance of a location decision must also be preceded by obtaining a fundamental decision, which is a document of a political rather than administrative-technical nature, as mentioned above.

The investor is not free to choose the location of the nuclear power plant. According to the amendment, in the application for a fundamental decision, the investor is to indicate only the municipalities where he plans to build the facility. Of these, the "acceptable" municipalities will only be indicated by the Minister for Energy (currently the Minister for Climate and Environment). The investor will then apply to the head of the PAA for a preliminary site assessment. Given the specificity and importance of these decisions, the process of determining the location of a nuclear power plant is mainly political-administrative in nature, also due to the importance and characteristics of such an investment (including the scope of its potential impacts or the area of implementation) and the institution of expropriation used in its implementation.

In the investor process, it is crucial to inform those affected by a future expropriation well in advance to ensure that they have the opportunity to protect themselves against such an eventuality or to use appropriate recourse tools. Any potential loss of property should instead be fairly compensated. The legislation guarantees that the first condition is met – owners and perpetual usufructuaries of properties located within the planned nuclear power plant will be parties to the proceedings for both the environmental decision and the location decision. On this basis, they will be able to expect the risk of expropriation in the future, as this status gives them not only permanent access to information about the proceedings, but also the tools to appeal. Unlike most other decisions issued during the development of a nuclear power plant project, the location decision will also not be subject to immediate enforceability.

There may be concerns about the provisions in terms of ensuring fair compensation to owners, especially with regard to its equivalence. The amount of compensation is determined by the voivode (provincial governor) within two months of the location decision becoming final. According to the regulations, it cannot exceed the value of the real estate or the deprived rights in rem. This, in turn, is determined on the basis of an appraisal report prepared as of the date of finality of the location decision. Although the decision is unappealable under the administrative procedure, in the event of dissatisfaction with the amount of compensation, a complaint may be lodged with the common court. Its filing does not suspend the execution of the decision, but this mode gives broader protection to the expropriated persons, as the courts may examine not only the formal validity of the expropriation decision, but also the validity of the property valuation. However, the limitation of the amount of compensation to the value of the property raises concerns. It would seem fair to add some kind of bonus for the expropriated persons, at least in the case of having to be forcibly relocated. However, neither the Special Act nor its amendment has changed the provisions in this regard.

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It is worth noting that changes to such a model for determining compensation were announced at the end of 2022 with regard to expropriations for CPK, the subject of much controversy. As a form of fairer compensation, it was announced that the amount of compensation calculated on the basis of the value of the property would be increased accordingly by 20-40 per cent. In addition, it was stipulated that a minimum amount would be set, which would be sufficient to purchase a new residence. However, such changes have still not been made and the CPK Act in its current wording, like the Special Act, limits the amount of compensation for expropriation to the value of the property.

2 Tackling the lengthy investment process

The primary source of legislation on the construction, operation or licensing of nuclear power plants is the Nuclear Act, supplemented by the Special Act. The latter was intended to implement appropriate mechanisms to guarantee a smooth investment process.

Of the numerous permits and administrative decisions required during the planning, construction and operation of a nuclear power plant, the key ones in the investment process are:

- environmental decision,
- location decision,
- fundamental decision,
- construction permit.

Under the first of the "streamlining" mechanisms, the Nuclear Act sets out deadlines for the issuance of individual decisions related to the implementation of the nuclear power plant, i.e. the location decision and the construction permit, among others. This is 30 days from the date of initiation of the proceedings, and 45 days in the case of an environmental decision. Failure to meet the deadlines will result in a fine of PLN 500 for each day of delay. Although the amendment[56] envisages its increase to PLN 1,000, it can be assumed that still such a sanction will not effectively discipline the authority remaining in delay – all the more so as the penalty is revenue for the state budget anyway. In contrast, fines imposed on countries by EU institutions can amount to millions of euros, e.g. for each day of non-compliance with a ruling of the Court of Justice of the European Union (CJEU).

The legislator has also defined a specific regime in the process of appealing against the decisions listed in the Special Act (with some exceptions in the case of the environmental decision). It has introduced differences in this respect in relation to the measures contained in the Code of Administrative Procedure (KPA). For example, the time limit for lodging an appeal against a decision was shortened from 14 to 7 days from the date of delivery, and the time for the authority to consider the appeal was shortened from one month to 14 days. In addition, the Special Act precisely defines the compulsory elements of an appeal – these are the indication of the pleas in law, the definition of the essence and scope of the demand that is the subject of the appeal, and the citation of evidence justifying the demand. This is an important difference to the KPA, which stops short of indicating that an appeal does not have to contain a detailed statement of reasons and it is sufficient if it shows that the party is not satisfied with the decision received. This procedure should ensure that potential appeals are well thought out and concrete. This, in turn, may reduce the risk of deliberate paralysis of the proceedings by parties opposing the implementation of the investment, e.g. by taking actions that have no rational justification (which is sometimes the case in standard investment processes).

The Special Act also introduced procedural improvements at the stage of possible administrative court proceedings. It establishes deadlines for the consideration of cases before the Voivodeship Administrative Court and the Supreme Administrative Court, which are 30 days and 2 months, respectively, from the day the courts receive the relevant documentation. Although these deadlines are instructive in nature, their definition at the statutory level as an element of "mobilisation" of the court is to be welcomed, especially as proceedings before the administrative courts (taking into account both instances) can last years.

The Special Act also imposes the rigour of immediate enforceability on certain decisions issued in the course of the investment process, and limits the possibility of their annulment or declaration of invalidity. However, the implementation of nuclear power in Poland within the assumed timetable is still a demanding task, so a decision was taken to introduce more far-reaching procedural improvements, implemented in the Special Act by means of the amendment.

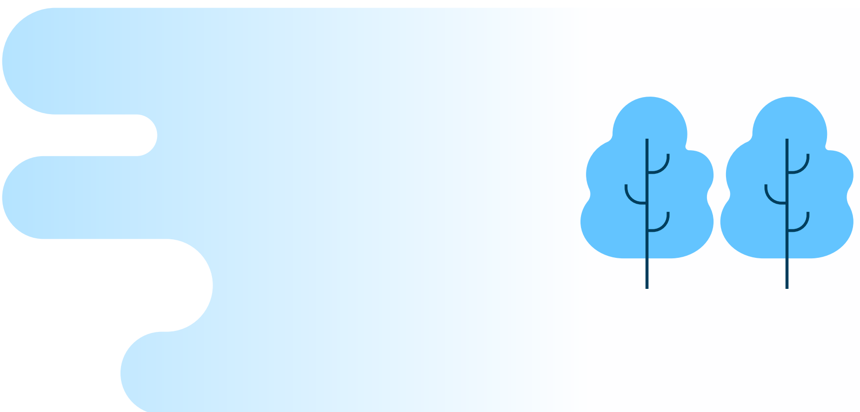
One of the most important changes is the extension of the catalogue of accompanying investments. As a result, projects important for the operation of the nuclear power plant will be able to be implemented on the basis of the aforementioned procedural improvements provided for in the Special Act. This status may be given to all investments necessary for the construction, or operation, of a nuclear power facility (e.g. power networks and connections). Importantly, in establishing a catalogue of accompanying investments, the drafter also recognised the potential of hydrogen production, distribution or storage facilities.

William-James Kettlewell, Baker McKenzie, Brussels

Within the context of the ongoing discussions at EU level on the conditions for considering hydrogen as a renewable, it is worth emphasising that on the basis of the RED II Directive on the promotion of the use of energy from renewable sources, hydrogen produced by electrolysis powered by NPPs is not "green" (renewable) hydrogen. It is worth noting, however, that as part of the pending revision of the gas directive, it is proposed that member states could use "low-carbon hydrogen" (including nuclear-generated hydrogen, referred to as purple hydrogen) to meet specific RED II targets. In practice, this would have similar benefits to recognising purple hydrogen as "green" hydrogen, although it would still not fully recognise such hydrogen as a renewable fuel. Work on the indicated draft is ongoing – we are currently awaiting the European Parliament's position after the first reading.

The amendment also provides for moving the fundamental decision to the beginning of the investment process. Thus, it will be issued before obtaining the location decision, which responds to the demands of the doctrine criticising the previous order of obtaining investment decisions. This is a procedure that is also beneficial for investors, who – under the previous regulations – had to commit funds to obtain a fundamental decision before obtaining the fundamental decision, which could later prove unnecessary if the state did not approve the project. The most important changes resulting from the amendment also include the exclusion of the application of Article 127 (3) of KPA to the fundamental decision – this means that there will be no right of appeal against the decision in the form of a request for reconsideration.

In summary, the legal mechanisms used in the Special Act (taking into account the amendment) should be assessed, in principle, positively. At the same time, the Administrative Law provides for the possibility of introducing more far-reaching improvements, e.g. the institution of tacit settlement of a case (after the deadline for consideration of the case has been exceeded and no objection has been raised by the authority, the case is deemed settled in a way that takes into account the party's request). However, it seems that the nature of nuclear investments and the number of risks associated with them do not support the introduction of such legal solutions.



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In the EU, the Net-Zero Industry Act is being drafted. It is intended to promote EU projects to achieve climate neutrality, including through measures to facilitate their rapid implementation and increase access to finance for such projects. The aim is that by 2030, EU companies will cover 40 per cent of the EU's annual green technology needs. However, it only applies to strategic technologies, among which the EC has included photovoltaics, onshore and offshore wind, batteries and energy storage, heat pumps and CO2 capture technologies (CCUS). In addition to this list, a longer list of zero-carbon technologies has been formulated. It includes: modern nuclear technologies, including SMRs, fusion technologies, alternative fuels and energy efficiency technologies. This measure should be seen as a positive signal for stakeholders in nuclear energy development.

3 Cross-border consultations – opportunity or threat to nuclear plans

The construction and operation of a nuclear power plant involves an extraordinarily detailed environmental impact assessment. It should take into account a number of factors, especially the risk of a potential accident, the effects of which may extend beyond the national territory. In Poland, the main source of law in this respect is the Act of October 3, 2008 on the provision of information on the environment and its protection, public participation in environmental protection and environmental impact assessments (the EIA Act).

According to the regulations implementing the EIA Act, nuclear power plants belong to "projects which may always have a significant impact on the environment". Therefore, the above procedure (preceding the obtaining of an environmental decision) is always mandatory in their case. In addition, if a project could have a significant impact on the environment outside the territory of the country where it is to be implemented, the competent authority for issuing the environmental decision (in this case, the General Director for Environmental Protection – GDOŚ) is obliged to carry out proceedings concerning cross-border environmental impact ("transboundary procedure"). This procedure was initiated in the case of plans to build the first Polish nuclear power plant in the Choczewo municipality. This is because the environmental documentation shows that, due to the location of the power plant, its transboundary radiation impact in the event of an accident must be taken into account[57].

The transboundary procedure for the Choczewo power plant has involved 11 countries, known as "affected parties". It cannot be ruled out that its timeframe will be extended-due to Germany's position in which some federal states are opposed to the project, raising safety and environmental concerns. An analysis is therefore required as to whether the provisions on the transboundary procedure equip affected parties with the means to realistically affect the implementation of the project on the territory of the project state (so-called parties of origin).

Claire Dietz-Polte, Baker McKenzie, Berlin

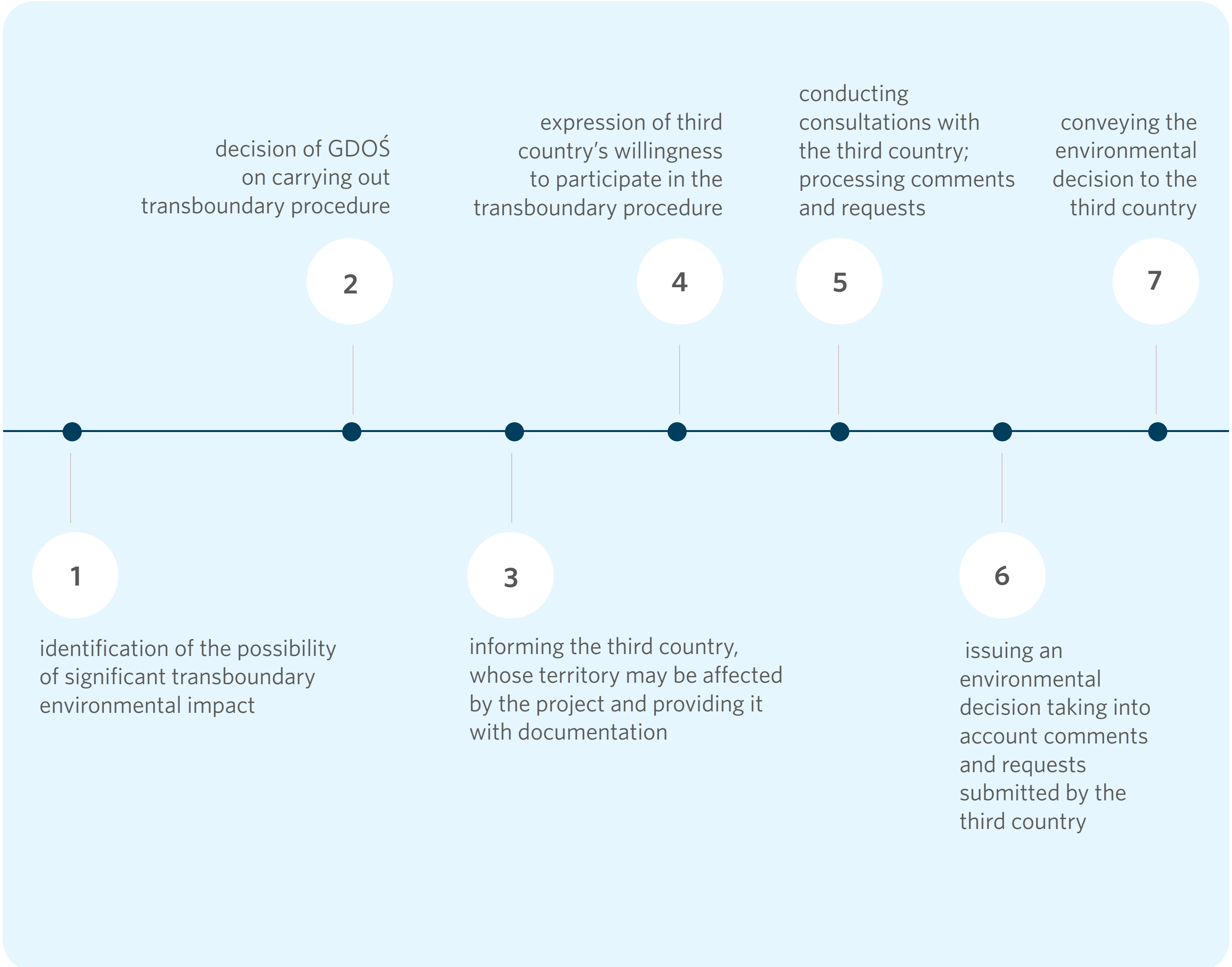
It is noteworthy that the last nuclear power plant on German territory was commissioned in 1989, and in 1998, a phasing out of nuclear power was agreed at the political level in Germany. This is reflected in the German Nuclear Act, which explicitly states that new licences for the construction of nuclear power plants will no longer be issued. The plan to phase out nuclear power in Germany is gradually being implemented – the operating plants were to be closed by 2022, although this deadline has been extended to April 2023 due to the energy crisis related to the war in Ukraine. Germany's last nuclear power plant was shut down on April 15, 2023.

The legal framework for the transboundary procedure is set by the EIA Act and the convention on environmental impact assessments in a transboundary context, known as the Espoo Convention (it entered into force for Poland on September 10, 1997). Poland is also bound in this respect by international agreements signed with Germany and Lithuania[58].

Once GDOŚ identifies the possibility of a significant transboundary environmental impact of a given project, this information is sent to the countries potentially interested in participating in the transboundary procedure. Then the affected party can confirm its willingness to participate in the procedure and proceed to agree on the dates of its individual stages. As part of the exchange of further documents, notably the environmental impact report, consultations are held during which measures to eliminate or reduce transboundary environmental impacts are discussed. An environmental decision is then issued based on the comments and conclusions received. The comments and conclusions of the third country are to be considered and taken into account when issuing this decision, and the decision itself should not be issued until the transboundary procedure has been completed. Once the environmental decision has been issued, GDOŚ shall provide the country participating in the transboundary procedure with a translated version of the decision to enable it to see how the results of the proceedings have been considered and taken into account when issuing the decision.

The above procedure naturally prolongs the procedure for the environmental decision and is not without influence on its content[59]. However, in the context of the concerns raised in public about the possibility of blocking the construction of the nuclear power plant in Choczew, it should be underscored that, although the provisions discussed here impose on the state implementing the project the obligation to "consider and take into account comments", they do not equip the affected party with the power to directly halt the implementation of the project in question. Nor do they provide it with the possibility of definitively prejudging its nature (e.g. by affecting the planned capacity or other parameters of the power plant), entirely against the will of the state planning the construction of the project.

TRANSBOUNDARY ENVIRONMENTAL IMPACT PROCEEDINGS



SOURCE: COMPILED BY BAKER MCKENZIE.

So, despite the lack of specific mechanisms to "discipline" the party of origin at the statutory level, it is important to be aware that failure to take into account comments and requests made by the affected party may be considered a violation of international law, including the Espoo Convention. Although the Espoo Convention itself does not provide for direct sanctions for violations of its provisions, thanks to its approval in 1997 by the European Community, the provisions of the Convention (in relations between countries of the EU) have been incorporated into EU directives[60]. Thus, each member state must apply it subject to a complaint to the CJEU[61].

! Germany's dispute with Poland could result in a complaint against it to the CJEU. This scenario could materialise if the countries' negotiations to agree on an acceptable range of comments for Poland from the German side failed. As of the time of publishing this report, based on media information, the risk of such a fiasco can be assessed as low.

In the first instance, the EC has the power to bring such a complaint. Its consideration culminates in a judgment of the CJEU. If it is not complied with, a financial penalty may be imposed on the member state in separate proceedings. Also, any country may bring an action before the CJEU against another country if it considers that it has failed to comply with one of its obligations under EU law. Such proceedings are extremely rare – states generally avoid them for diplomatic reasons. Nevertheless, their course is not fundamentally different from cases initiated by the Commission. Recently, a direct action was brought against Poland by the Czech Republic in case C-121/21 (concerning the Turów lignite mine). The Czechs accused Poland of failing to correctly implement precisely Directive 2011/92/EU by extending the mining concession without carrying out an environmental impact assessment, including a transboundary assessment.

Both the EC and a member state can request that the CJEU order "necessary interim measures"[62]. They can only be ordered by the judge if it is shown that:

- their application is prima facie justified in law and in fact, and that
- they are of an urgent nature in the sense that their order and enforcement before the outcome of the main case is necessary to avoid "serious and irreparable damage" to the applicant's interests.

In doing so, the likelihood of its occurrence must be demonstrated by the applicant. This is the kind of harm that would result from a refusal to order the requested interim measures if the complaint in the main proceedings were subsequently upheld. For example, in the high-profile case of the EC's complaint against Poland concerning the protection of natural fauna habitats in the Białowieża Primeval Forest, in order to demonstrate the urgency of the application, the Commission argued that the felling of trees there was having a negative impact on those habitats. The damage alleged to have occurred as a result of the felling and removal of the old-growth forest could not have been remedied if the complaint had subsequently been upheld (due to the objective impossibility of restoring the areas affected by the felling to their original condition[63]). Such measures were also imposed in the Turów mine case – Poland was obliged to immediately cease lignite mining there[64].

An order issued by the CJEU to order interim measures is non-appealable and it is the duty of the member state to enforce it. It is a type of order which is extremely harmful to the implementation of the investment – it may lead to its actual suspension until the completion of the proceedings on the merits. These in turn may take several months or even several years. Hence, both the Espoo Convention and the directive on transboundary environmental impact assessments emphasise cooperation and extensive consultation between states.

> **!** This means that the impact of the transboundary environmental impact proceedings on the implementation of the nuclear power plant project is significant, if not critical.

4 Integration of the nuclear power plant into the NPS

Many regulatory challenges are also associated with the integration of nuclear power plants into the National Power System (NPS). Despite legal solutions to streamline the investment and construction process for the implementation of nuclear investments, their duration still exceeds that of other large-scale infrastructure projects, including grid projects. Consequently, the electricity system environment may change during the multi-year investment process. For this reason, it is important to continuously coordinate the cooperation between the relevant electricity grid operator and the investor during the process – this may become possible through the amendment, as discussed below.

Reliable operation of the electricity grid plays a key role in ensuring the safety of a nuclear power plant at every stage of its operation: from start-up through normal operation to the period after reactor shutdown. Problems along the line between the grid and the generating unit can have catastrophic consequences – it was the prolonged unavailability of electricity and the failure of the power supply systems that contributed significantly to the Fukushima nuclear disaster in 2011[65]. In addition to safety issues, the correct interaction of the plant with the electricity grid improves the economics of nuclear power plant operation, which ultimately affects end users.

The connection and derivation of power from the nuclear power plant at the location preferred by PEJ ("Lubiatowo-Kopalino" in the Choczewo municipality) is one of the basic assumptions of the Transmission Network Development Plan 2023-2032 (PRSP), prepared by Polskie Sieci Elektroenergetyczne (PSE)[66]. Specific investment tasks correspond to this assumption: construction of the infrastructure necessary to supply the site, substations and power lines, including the 400 kV line. The total outlays for implementing network investments important for the nuclear power plant are estimated by PSE at around PLN 3 billion.

The implementation of the ambitious plans set out in the PRSP requires a favourable regulatory environment. Investments consisting in the construction or expansion of transmission networks constitute one of the categories of so-called "associated investments" **and can be implemented on the basis of the provisions of the Special Act, or on the basis of a special act dedicated to strategic electricity network investments** (the so-called Transmission grid special act)[67]. The choice of legal regime is left to the investor, in this case PSE. The amendment limits the freedom to choose the procedure and provides explicitly that PSE's network investments in relation to the first Polish nuclear power plant are to be carried out on the basis of the Transmission grid special act[68]. This is probably an advantageous solution, as large-scale electricity network projects are precisely what is being implemented under this legislation. It is therefore a law that is well known to PSE and has been tested in practice many times. In addition, it is proposed that PEJ should be the coordinating entity for the implementation of associated investments[69]. One of the company's most important tasks in this regard is to draw up a consolidated schedule for the implementation of the first nuclear power plant, together with associated investments (in addition to the expansion of the electricity network, this will also include the construction of railway lines and hydrotechnical infrastructure). Once approved by the government plenipotentiary for strategic energy infrastructure, it will become a document binding the entities involved in the above-mentioned investments, including PSE.

5 Liability for nuclear damage

Despite the statistically near-faultless operation of nuclear power plants worldwide, the issue of liability for damage caused by ionising radiation remains a highly topical issue. It is an important issue not only for those directly involved in the construction and operation of reactors (for whom information about the associated risks is crucial from the point of view of legal and business analyses), but also for the general public, and thus potential victims. **The confidence that there are effective mechanisms to protect them can strengthen public support for the development of nuclear power.**

The Chernobyl accident is emblematic of the dangers posed by the use of nuclear energy, which confirmed the then still theoretical considerations of the differentiated effects of nuclear accidents and their transboundary nature. It had a significant impact on the development of the Nuclear Act and contributed to the revision of the principles of civil liability for damage caused by nuclear accidents. This disaster was reflected in the revision of international conventions on the indemnification of nuclear damage: The Vienna Convention[70], developed under the aegis of the International Atomic Energy Agency (IAEA), and the Paris Convention[71], associated with the OECD. The aftermath of the disaster was the establishment of a comprehensive liability regime for nuclear damage. These conventions established two separate, albeit based on identical principles, civil liability regimes for damage caused by nuclear accidents[72]. States party to the Paris Convention were therefore not parties to the Vienna Convention and vice versa.

Thanks to the efforts of the IAEA and the Nuclear Energy Agency (NEA) a joint protocol on the application of the Vienna Convention and the Paris Convention was adopted at the OECD[73]. On its basis, rules were established for dealing with nuclear damage whose consequences would be dealt with in several jurisdictions. As a rule, if a nuclear accident occurred in the territory of a state party to the Vienna Convention (e.g. Poland), victims from states party to the Paris Convention (e.g. Germany) may avail themselves of the protection provided by the Vienna Convention and vice versa, with only one of the listed conventions being applicable to the nuclear accident in question. The legal framework of the international nuclear liability regime is further supplemented by the Convention on Supplementary Compensation for Nuclear Damage (CSC)[74]. States that have not acceded to the Paris Convention or the Vienna Convention may also accede to it.

The principles of liability for nuclear damage expressed in the international conventions are reflected in national legislation – not only of the states party to the convention in question, but also of third countries where nuclear power plants are operated (e.g. Japan or South Korea). However, national legislation in this area remains unharmonised.

- **First, not all states have acceded to the conventions.** The Vienna Convention was signed by 44 states[75] and the Paris Convention by 18. On top of that, not all signatories have ratified the conventions or the amending protocols[76].

- **Second, the provisions of the conventions leave states a certain amount of freedom** in shaping the detailed rules of liability and room for interpretation of the provisions.

- **Third, national laws do not always correspond to the provisions of the conventions.** For example, the Polish Nuclear Act, which – unlike the Vienna Convention and the Paris Convention – does not differentiate between the principles of liability for nuclear damage occurring outside a nuclear installation (off-site) or on its premises (on-site).

Poland has joined the system of international cooperation developed under the auspices of the IAEA. However, it is worth noting that even before the ratification of the Vienna Convention, the provisions of the first Polish law on nuclear safety (i.e. the Nuclear Act of April 10, 1986) were modelled on the convention provisions[77].

Select principles of civil liability for nuclear damage

The international regime of liability for nuclear damage is based on several principles, the overriding aim of which is to protect the interests of those injured by nuclear accidents. It has been established that the compensation procedure is to be simplified as much as possible – victims should not have to search for the direct perpetrator of the nuclear damage, prove its fault or demonstrate how the nuclear accident or disaster occurred. At the same time, liability rules should not create such burdens or risks for nuclear operators that would effectively discourage them from entering the nuclear sector.

The five principles of responsibility that will apply to Polish nuclear power plants are highlighted below. Although there are various exceptions to them worldwide, it can be presumed that they are part of the international standards of responsibility in the sector.

- **Principle No. 1 Exclusive liability of the operator for nuclear damage.**
  This means that no other entity can be held liable for it, and any action by an injured party against a third party will, in principle, be subject to dismissal. The operator is responsible for repairing nuclear damage caused both by itself and by third parties, including nuclear technology suppliers or subcontractors. Although this principle is an international standard, it is not practised in all countries using nuclear energy. Much controversy has been generated, for example, by the solution adopted in India, where, in some cases, the nuclear legislation there entitles the operator, who has already paid funds to the victims, to seek reimbursement of the compensation paid from nuclear material suppliers[78]. This is a rule similar to the so-called operator's recourse claim provided for in the Vienna Convention, under which the economic burden of compensation for the damage is transferred to third parties who contributed to the damage.

» **Principle No. 2: Strict liability.**
The operator of a nuclear installation is liable on a strict liability basis and therefore irrespective of its fault or lack thereof. This protects the interest of the affected persons, who are not required to prove that the operator has committed specific negligence or irregularities – such proof could be considerably difficult to provide, if only because of the lack of technical expertise of the affected persons.

» **Principle No. 3: Circumstances excluding liability.**
The liability of the operator of a nuclear installation is almost absolute. Its operator can only absolve itself from liability for nuclear damage if it can show that it occurred as a direct result of an extraordinary event, which the law treats as a condition excluding liability. Under the Nuclear Act, these circumstances include hostilities and armed conflict. A broader catalogue of circumstances excluding liability is provided for in the Vienna Convention, which, in addition to armed conflict and hostilities, mentions civil war and insurrection[79], as well as in the Paris Convention, which additionally identifies natural disasters of an exceptional and serious nature[80]. The Nuclear Act further provides that the court may fully or partially exonerate the operator from the obligation to compensate for the damage suffered by an injured person who has contributed to its occurrence or enlargement[81]. In addition, unless the contract with the recipient of nuclear material provides otherwise, during the transport of such material, the responsibility shall lie with the operator of the nuclear installation from which the material was shipped.

» **Principle No. 4: Quantitative limitation of liability.**
A special feature of the Nuclear Act is the introduction of a limited amount of liability for the operator of a nuclear installation. This has the effect that once a certain pool of funds has been exhausted, the operator is not obliged to pay further compensation. A particularly stringent liability of the operator is provided for in the German Nuclear Act, which not only does not set an upper limit on the operator's liability (except for liability for damage to property), but also provides for its liability for damage resulting from force majeure. The principle of limitation of liability is also abandoned in the Japanese Nuclear Act.

» **Principle No. 5: Financial security for indemnity claims.**
The payment of compensation is to be guaranteed by financial security in an amount corresponding to the quantum limit of the operator's liability. Under the Nuclear Act, the burden of compensation payment rests with the insurer and, alternatively, the State Treasury. The minimum guarantee sum of the obligatory liability insurance with respect to one event resulting in nuclear damage is the PLN equivalent of 300 million SDR (Special Drawing Rights, i.e. an international unit of account created by the International Monetary Fund)[82]. If the claims of the injured exceed the indicated amount, the operator should create a so-called liability limitation fund, which is subject to distribution in accordance with the ruling of the Warsaw Regional Court.

Nuclear accident and nuclear damage

The legal definitions of nuclear accident and nuclear damage are fundamental in determining the scope of liability of the nuclear operator. **If the damage in question does not qualify as nuclear damage, it will be compensated under the general rules and not under the specific regime provided for in the Nuclear Act and the Vienna Convention.** The event to which nuclear liability is linked is a nuclear accident.

Under the Nuclear Act, **a nuclear accident is any failure of a nuclear device that causes nuclear damage or an imminent threat of such damage**[83]. Nuclear damage, on the other hand, is damage to persons, property or the environment that is caused by ionising radiation released as a result of a nuclear accident or ionising radiation combined with other interactions of a hazardous nature (e.g. poisonous, explosive). This means that nuclear damage can be the consequence not only of the impact of ionising radiation alone or contamination by radioactive substances, but also the consequence of a fire or explosion that co-occurs with ionising radiation. The legislator has not defined a closed catalogue of nuclear damage, which, given the difficult-to-predict consequences of nuclear disasters, is a favourable solution. A slightly different methodology for describing nuclear damage has been adopted in the UK.

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There is no definition of nuclear damage in the UK Nuclear Act. Instead, the law imposes certain basic duties on the operator of a nuclear power plant and sets out categories of claims that can be made by victims to obtain compensation for the operator's breach of its basic duties. Compensation is available for economic losses arising from personal injury or property damage, or loss of income deriving from a significant impairment of the environment.

6 Nuclear fuel life cycle

Ensuring appropriate, safe and long-term management of spent fuel and radioactive waste is among the priority technological and legislative challenges of nuclear power. This is because they remain radioactive and pose a potential threat to humans and the environment for thousands of years. The procedure for locating deep disposal sites for radioactive waste requires selecting an area changes to which can be predicted for the next 10,000 years.

Due to the extremely hazardous nature of radioactive waste, it is the subject of numerous regulations contained in acts at international, European and national levels. The most important acts include:

- **at the international level,** the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management of September 5, 1997 (ratified by 85 countries);
- **At European level**, two Euratom Directives: Council Directive 2006/117/Euratom of November 20, 2006, on the supervision and control of shipments of radioactive waste and spent fuel and Council Directive 2011/70/Euratom of July 19, 2011, establishing a community framework for the responsible and safe management of spent fuel and radioactive waste.

In Poland, the implementation of the above documents took place in the Nuclear Act and relevant implementing acts, e.g. the Regulation of the Council of Ministers on radioactive waste and spent nuclear fuel.
The most important objectives of these regulations are to ensure appropriate standards for the storage, treatment and disposal of radioactive waste and to strictly control its transport. Particular attention is paid to any attempt to export radioactive waste from developed countries to so-called developing countries. For example, EU countries are banned from exporting spent fuel to African, Caribbean and Pacific countries that are parties to the Cotonou Agreement[84] and to countries without the administrative and technical capacity to adequately manage such waste. A ban on the export of radioactive waste south of 60 degrees south latitude (i.e. to Antarctica) has also been widely adopted. In addition, countries that are party to the aforementioned Joint Convention have the right to ban the import of radioactive waste into their territory.

The treatment of spent nuclear cells is divided into two stages. The first is the storage stage at the site where the cells have been used, which in future will also be the site of Polish nuclear power plants. The second is the disposal stage, when the waste will be sent for storage or processing. This division is due to the specific nature of the nuclear fission process, which is a process that generates enormous amounts of heat, as well as the properties of the isotopes used in the reactors, whose radioactivity decreases over time. Spent nuclear cells must therefore be properly cooled and stored to reduce their radioactive values before they are sent for further management and disposal.

The containers in which spent cells are stored are subject to strict guidelines, The containers in which spent cells are stored are subject to strict guidelines, setting standards for the quality and integrity of the containers, as well as the appropriate segregation of radioactive waste. The latter is essential because different elements can have vastly different half-lives and thus different necessary storage periods. The activity of storing spent fuel is regulated and requires a licence for activities involving exposure, issued by the President of the PAA.

Once the first stage of spent fuel management has been completed, the actual disposal of the waste proceeds. Solid radioactive waste is suitable for disposal, i.e. storage in such a way that no subsequent recovery is envisaged. Importantly, **responsibility for shipped radioactive waste rests with the operator of the nuclear installation** and, in the case of transboundary shipments, with the country of origin of the waste. The organisational unit where the waste was generated will also be obliged to finance its storage.

The construction of a fully functional radioactive waste repository in Poland depends on a number of factors and political decisions. In principle, such facilities are divided into surface and deep facilities. The former are only suitable for the storage of low – and medium-level and short-lived radioactive waste. Deep repositories, on the other hand, can store all types of waste. However, irrespective of the type of repository, the repository must be licensed for exposure-related activities involving the construction, operation or closure of the repository. The location of landfill sites is, in turn, subject to careful review so that they are not threatened by violent natural phenomena and taking socio-economic factors into account. A possible decision on the location of a public purpose in the form of a radioactive waste repository will be verified in terms of radiological and physical protection by the head of the PAA and physical protection by the head of the ABW. Consultation with these authorities will, moreover, be required already at the stage of placing the repository in the local spatial development plan.

A surface or deep repository ready to receive waste for at least 11 months of the year can apply to become a National Radioactive Waste Repository. Currently, this type of repository is located in Poland in Różan and is a surface repository. According to the *National Plan for Radioactive Waste and Spent Nuclear Fuel Management*, this repository is scheduled to be closed between 2038 and 2040 and replaced by a deep repository. This will allow permanent storage of high-level waste, which is only temporarily stored at Różan.

The National Management Plan reflects Poland's implementation of its obligation to prepare a nationwide plan for radioactive waste, which was imposed on EU Member States after the Fukushima disaster in 2011. The content of the plans is communicated to the EC, which has the opportunity to give its opinion on them. The obligation to draw up plans was a response to the disorganised structure of radioactive waste management within the EU, motivating member states to improve and giving the EC control tools. It should be noted that after decades of nuclear power plant operation, the amount of radioactive waste within the EU is not small – according to the 2019 EC report, in 2016 it was 2.5 million m^3, of which less than 1 million m3 is stored and the rest neutralised.

Large-scale nuclear power and SMRs

Despite the industry's demands, the Polish legislator did not decide to introduce regulations specifically for SMRs in the amendment to the Special Act. The proposal to introduce their legal definitions was rejected because of the early stage of development of these technologies. A similar position was taken on the proposal to simplify the licensing process for SMR installations – it was pointed out that, due to the lack of previous licensing and operating experience, the introduction of specific arrangements for small reactors would not mean less work for the State Atomic Agency. Maintaining the existing licensing process, i.e. a process essentially tailored for large-scale nuclear facilities, was considered necessary at least for investments in the first small reactors. However, SMRs will benefit from the postponement, introduced by the amendment, of the fundamental decision to the beginning of the licensing process, which will reduce investment risks, also for this technology. However, it cannot be ruled out that the ambitious goals for the development of SMRs in Poland and the many ongoing research and development activities in this area will force an adjustment of the legal environment to the market need. While providing greater investment security for SMRs is a step in the right direction, it does not seem sufficient to enable the widespread use of such reactors in Poland. In particular, it seems that small reactors, whose construction and manufacture will potentially involve much smaller financial and time outlays, as well as lesser environmental risks, should not follow the same investment path as large-scale nuclear power plants. It may therefore be rational to adapt the regulatory requirements to the specifics of these plants in the future.

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The lack of a specific law for SMRs affects not only Poland but the entire European Union. Neither international nor European law excludes this technology, it just has not yet managed to give it an individual legal framework. In the absence of dedicated legislation, it is natural to apply international treaties and European and national regulations accordingly. These, however, are overly scaled in many areas and do not suit investments with a smaller impact than a classic nuclear power plant. Therefore, the adaptation of regulations for SMRs, their licensing, location and implementation, even if not necessary for their establishment, still seems justified. In light of the current April 2023 PEP2040 proposal with 2.1 GW of SMR capacity by 2040, and therefore at least seven operating reactors, regulatory changes seem more urgent and should perhaps take the shape of a separate law to promote energy generation from small nuclear reactors.

ENVIRONMENTAL CONDITIONS

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Every element of human activity has an impact on the environment and therefore requires control. In the case of nuclear power plants, an assessment of this impact is provided by a legally required procedure in which an Environmental Impact Assessment Report is produced. This is the main document describing the investment and the extent of its impact – a complex volume running to thousands of pages.

The most important positive impact of nuclear power is that it contributes to the protection of the climate and decarbonisation of energy. Globally, nuclear power, by producing energy in a stable way, prevents almost 1 Gt of CO_2 emissions every year. This is a significant figure, especially as the total anthropogenic CO_2 emissions are almost 37 Gt per year. SMRs, the construction of which will also require an Environmental Impact Assessment, will have a fairly similar impact.

However, let us start by establishing a definition of the term "impact" – it means the influence of one element on others. In terms of nature conservation, however, only so-called significant impacts are relevant, i.e. those which have a real impact on the whole ecosystem or any of its elements. Insignificant impacts are not included in the documentation and are not considered by the administrative authorities and environmental institutions.

According to the EIA Act, impacts can be distinguished between:

- direct,
- indirect,
- secondary,
- cumulative,
- short-term,
- medium-term,
- long-term,
- permanent
- temporary, and
- positive and
- negative
- impacts on the objectives and the object of protection of the Natura 2000 area and the integrity of the area, as well as environmental impacts.

Their definitions are mostly in line with intuitions and do not require detailed discussion. However, it is worth noting that short-term impacts are usually limited to days, medium-term impacts to months and long-term impacts to years. Impacts on the objectives and conservation objectives of a Natura 2000 site means, in practice, impacts on species or habitats that score A, B or C in the Standard Data Form (SDF). This is important as many species may be found on one Natura 2000 site and only one will be the subject of protection (with a grade A, B or C). In other refuges, it is sometimes the case that all species found are given one of these grades.

> **!** An example of the positive impact of a nuclear power plant is the Caribbean manatee in Florida. This species, which was endangered in the 1970s, now uses the warm water discharge zones as a wintering site, contributing significantly to the growth of the population.

Impacts during nuclear fuel extraction

At present, Poland does not intend to obtain nuclear fuel on its own or to carry out enrichment. The environmental impact at this stage depends on the extraction method. Extraction using the in situ leaching method has a negligible impact on the landscape and causes virtually no dust emissions, but if conducted incorrectly, it may be a source of groundwater pollution. The method involves injecting a special solution and taking it from the other side of the deposit to recover the uranium.

With opencast mining, the most significant risks are dust emissions, noise, land seizure or lowering of the groundwater table (the so-called depression funnel around the excavation) and the large amount of stored waste rocks. With underground (deep) mining, the most significant impact is the lowering of the groundwater table. The mine workers themselves are exposed to dust and increased radiation due to gas (radon) released from the rocks.

Impacts during project implementation

The construction of a nuclear power plant is essentially no different from other large-scale developments. Its environmental impacts are similar to the construction of other thermal power plants or similar large-scale industrial facilities.

During this phase, the primary impacts will be emissions of noise, dust and gaseous pollutants and vibrations, light pollution, land occupation, destruction of natural habitats and species habitats, the presence of people and machinery, and alteration of water relations, including periodic turbidity.

The extent and significance of each impact varies according to the geography of the construction site: type of substrate, terrain, water resources, vegetation or other factors, so on each site their catalogue and ranking in terms of significance looks slightly different.

It is important to emphasise that at this stage there are no specific impacts or, according to popular opinion, potential impacts within the nuclear power plant, including impacts by radioactivity. This situation is due to the lack of nuclear fuel on site.

Impacts during the operation of a nuclear power plant

During the operation of a nuclear power plant, we can distinguish several main impacts of the plant, one of which is specific to them:

- thermal impact
- land occupation
- impact of structures, including electricity grids
- impact on water
- impact with light
- radiation

The most significant of these is the thermal impact. When an operating plant discards excess heat energy, it does so in two ways: by releasing the energy into the atmosphere or water bodies. In the first case, this is done via cooling towers. The heat, together with the evaporated water, enters the atmosphere, where it is eventually dispersed. This is a method that does not affect water bodies, but is highly intrusive into the landscape and sometimes requires significant water intake. In the second case, water is extracted from a reservoir (lake, sea, river), heated and discharged back into the reservoir, where the thermal energy is dissipated. This has the advantage of higher efficiency, a much smaller scale of impact on the landscape, but in the case of a poorly located facility, the thermal impact of the water on the receiver can stretch for kilometres.

For coastal sites, the scale of the impact is significantly smaller, due to the size of the receiver to which the thermal energy is returned. It is worth mentioning that even elevated water temperatures do not affect whether a plant is able to cool its reactor. Restrictions on some plants during low water or heat waves are strictly due to water permits, not physical conditions. Often such limitations can be circumvented by expanding the cooling system accordingly. Given that in many countries peaks in electricity demand occur in winter rather than summer, fuel campaigns and maintenance are planned or often it is cheaper to simply shut a unit down for a short period.

During the operation phase, the land occupation is significantly smaller than during construction, as the auxiliary and assembly yards created during construction are no longer needed and can be restored. In terms of this impact, nuclear power plants hold the record for concentration of energy production on occupied land. For example, the German Grohnde power plant with a capacity of 1360 MW and a production of several TWh per year occupied an area of only 24 ha.

The impact of the construction comes down to possible collisions with birds or bats. In this respect, the nuclear power plant, at least in the first years of its existence, may also pose a threat to migrating animals. Like any facility where people are present, it also generates domestic wastewater in small quantities, which is released into water bodies after treatment.

Another impact is the release of biocides, anti-corrosion additives and anti-scalants into the open part of the refrigeration system. All of these agents are intended to prevent the pipes from becoming overgrown with biofilm and to keep the heat exchanger system efficient. They are added in quantities calculated to minimise environmental impact, and selected so that they decompose as quickly as possible and do not accumulate in the environment. These are often calcium hypochlorite, ozone, hydrogen peroxide or other chemical compounds with a short biological breakdown period.

The impact of light arises from the need to permanently illuminate the entire site of a power station, for safety reasons. This impact, which was ignored until recently, is now attracting the attention of scientists and practitioners because it appears that permanent lighting disrupts the diurnal rhythm of animals in the environment, changes their habits and sometimes affects their metabolism. It also affects migrating animals.

! All of the above-mentioned impacts are non-specific, i.e. any thermal power plant – burning coal, gas, biomass – has the same impact.

A specific, but negligible, impact of a nuclear power plant is radiation. It is limited to the area of the so-called nuclear island, a small, specially designated part of the plant. Outside it, and in the areas surrounding the plant, there is no elevated radiation. There is also negligible radionuclide emission during its operation, and the magnitude of this emission is limited to tenths of a gram per year and consists of isotopes mostly with half-lives calculated in single days. These emissions have no impact on nature, people or the surrounding area and their inclusion in this text should be regarded as a curiosity rather than a fact of significance.

Impacts during decommissioning of a nuclear power plant

Decommissioning is a mandatory process and is planned from the early stages of plant construction. The decommissioning plan is analysed during the licensing of the plant and the final version is created after the final discharge of nuclear fuel. The most important element of such a plan is to protect workers and the environment from exposure to radioactive materials. Importantly, each time the decommissioning plan is based on standards set by the International Atomic Energy Agency.

The costs of decommissioning a nuclear facility are covered by a special fund financed by the sale of the energy produced. This means that the funds for this are already guaranteed at the commissioning stage and will be available in sufficient quantity at decommissioning, as long as the plant is not shut down prematurely.

The process of decommissioning a nuclear facility is often very protracted. This is due to the fact that, after the final removal of the highly radioactive nuclear fuel, some elements of the nuclear island show increased activity. This, in turn, decreases to radioactive levels over a period of several years, which significantly reduces costs. The decommissioning of such an "extinguished" power station is then not much different from the decommissioning of a coal-fired power station.

Radiation and its impact on the environment

The impact of ionising radiation on living organisms takes place primarily at the cellular and subcellular level. We can distinguish three main phases:

Physical phase
– during this phase the absorption of radiation energy takes place. Ionisation and activation of atoms takes place, free electrons appear.

Chemical phase
– the previously formed products react with chemical molecules inside the cells. Free radicals and other active molecules are formed, which act as biological projectiles, damaging the intracellular structures they come into contact with.

Biological phase
– further biochemical processes.

With a small amount of damage, most can be repaired quickly. Once repair capacity is exceeded, further damage cascades, eventually resulting in the death of the cell. When the number of dying cells is significant, especially in vital organs, the death of the organism occurs. For this reason, it is not only the length of exposure to radiation that is very important, but above all the total dose received.

Occasionally, the hypothesis of radiation hormesis – the postulated beneficial effect of low doses of ionising radiation on living organisms – comes up in discussions. However, there is no conclusive evidence for the existence of such a phenomenon.

Radioactive material storage facilities and their environmental impact

Storing spent nuclear fuel without any safeguards as loose material would pose two main risks:

- **radiation** (ionising radiation) coming from uranium and some of its decay products
- **toxicity** due to the fact that spent nuclear fuel contains heavy metals that affect living organisms in a similar way to lead, for example.

For these reasons, nuclear fuel is stored in a specific way. It is secured in multiple layers to avoid release to the environment and to keep radiation emissions to a safe minimum. On the site of decommissioned power stations, spent nuclear fuel is sometimes stored, which was previously stored for several years in special pools until its activity level allowed for so-called dry storage. Such storage is temporary and does not involve any significant impact on the surroundings, and workers do not need to use special protection.

There are no plans for the storage of spent nuclear fuel outside power plants in Poland. Instead, a new repository for intermediate-level material and a final repository for spent fuel is to be built in the country. It will be similar to the one located in Różan, which has been storing such medical and industrial waste effectively and safely for years.

Nuclear reactors could have been created completely spontaneously in nature.

On Earth, this was possible some 2 billion years ago, because the isotopic composition of uranium then allowed the spontaneous fission of atomic nuclei in the presence of a moderator such as water. Near the village of Oklo in Gabon, traces of as many as 16 such “natural reactors” of just such a phenomenon were discovered and, when analysed, the negligible dispersion of decay products was found. Such a natural experiment confirms the experts’ belief in deep geological storage of nuclear waste as an appropriate solution. Such an installation is currently being commissioned in Finland, at Onkalo.

Disasters and accidents

National law and international agreements oblige Poland to prepare an environmental report for a nuclear facility. This applies equally to large power plants and smaller nuclear facilities including planned SMRs. As noted above, the Espoo Convention obliges project developers to carry out an international consultation process with all countries that may be affected by the facility. In the case of Poland, this also means consultations with anti-nuclear countries such as Germany and Austria.

Poland, as a potentially endangering party, is obliged to consider and reconcile the comments received during the cross-border consultations. This process lengthens the process of issuing the relevant administrative decisions, but also allows for an even greater increase in the safety of nuclear facilities.

As the effects of a potential accident could be transboundary, the design and construction of the power plant is reviewed in detail by international expert organisations such as the IAEA. With regard to the safety of the plant's operation and based on all previous failures of similar facilities, an approach of so-called defence-in-depth has been developed, i.e. a series of decisions, including design and construction, resulting in multi-layered, often redundant and complementary protection of the workers and the facility's surroundings from the effects of a potential worst-case disaster. As a result, a nuclear facility and its safety are never dependent on a single layer of safety that can fail due to human error or a random event.

Simulations of contamination in the event of a catastrophe at a nuclear facility are purely hypothetical and do not imply an actual risk. For example, modern PWR reactors are not capable of emitting all the nuclear fuel into the upper atmosphere in any realistic scenario because they have safety enclosures and other safeguards.

To contrast, the disaster at the Fukushima Daiichi nuclear power plant followed the tragic Tohoku tsunami, which killed more than 18,000 people. It should be noted that the triple core meltdown and hydrogen explosions are undoubtedly an example of the worst-case accident scenario that could theoretically happen in modern PWR units. The release of a significant amount of radionuclides resulted in the permanent displacement of local residents, and to this day some 300 km^2 of the zone is permanently excluded from use.

Despite the magnitude of the disaster, **no bystanders received a health-threatening dose of radiation, and the impact on the environment was relatively small,** including organisms living in the waters surrounding the power plant. Although trace amounts of radionuclides were initially detected in provincial food products, thanks to the Japanese government's swift action, the food there is safe for consumption today. Plans are being made to discharge treated water into the ocean, and although it contains trace amounts of tritium, the concentrations will eventually be lower than what is acceptable by many standards in drinking water.

SOCIAL CONDITIONS

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According to a CBOS survey, in May 2021, 45 per cent of Poles were opposed to the construction of nuclear power plants, while 39 per cent were in favour of such an investment. **By December 2022, however, the percentage of the former had fallen to 13 per cent, while those in favour had risen to 75 per cent**[85]. This is an unprecedented shift in opinion in terms of scale and speed – between 2011 and 2021, overall support for the atom remained in the 34-40 per cent range, with the second highest level (50 per cent) reached in 2009. This raises questions about whether this result can be used as a basis for assessing Poles' approval of nuclear power, whether a strategy for gaining support for nuclear power can be built on current enthusiasm, and whether the volatility of public opinion makes it possible to shape it.

The rise in support for nuclear power contrasts with data on Poles' support for the energy transition, particularly faster than the EU targets. The February 2023 CBOS survey shows that 38 per cent of respondents want to achieve climate neutrality by 2050, with 21 per cent saying it should happen sooner. This is a much worse result than in 2021, when the percentages were 48 and 27 per cent respectively. In contrast, the number of those who believe that Poland should pursue this goal at its own pace increased from 43 to 55 per cent, and the percentage of undecided declined from 9 to 7 per cent. Residents of the largest cities are 61 per cent in favour of neutrality in 2050, and 50 per cent of people under the age of 24. Only 29 per cent of the latter want it to be achieved earlier.

At the same time, **23 per cent of respondents believe that within 10-20 years, power generation should be based mainly on domestic hard coal resources** (up 4 percentage points from 2021). However, 70 per cent support a gradual shift away from this resource (down 4 percentage points). Significantly, for 63 per cent of respondents (up 12 percentage points), the price of energy is key in terms of the pace of the transition, for 48 per cent care for the environment (up 5 percentage points), and for 44 per cent independence from Russia. Only 11 per cent pointed to EU policy and Poland's international commitments.

Is nuclear enthusiasm to be believed?

The degree to which the public approves or rejects nuclear energy depends less on factors related to the nuclear power itself and more on external factors. At the root of the increase in support recorded in the surveys lies, first and foremost, a sense of threat to Poland's energy security caused by Russia's policy, particularly its aggression towards Ukraine. This means, firstly, that a wider context, not directly related to the energy sector itself, plays a role in assessing the degree of support for nuclear power. Secondly, nuclear power is seen not only through the prism of technology, but also through what the social aspects of decision-making are and who participates in them[86].

The rapid change in attitudes does not mean that they can be easily influenced. In the case of external factors not directly related to nuclear, the key question is to what extent they are controllable and shapeable by national policy, including information policy, and to what extent they are parameters to which one has to adapt. In the following section of the analysis, we identify the factors that may influence the support or rejection of plans to build nuclear power plants and the resulting recommendations. These will be:

- a general sense of threat and uncertainty (information sphere) and
- specific group and institutional interests/concerns (socio-political sphere).

How to deal with uncertainty?

The results of research to date have not encouraged politicians to accelerate the development of nuclear power in Poland. The number of nuclear opponents is decreasing, but since 2011 (i.e. since the Fukushima disaster) their number is still significant. Attitudes towards nuclear power are largely shaped by opinions on the advanced nature and safety of the available technologies and the competence of those who would operate them. As nuclear technology develops, the proportion of supporters should thus increase.

In November 2020, the Ministry of Climate and Environment noted 62.5 per cent in favour of building nuclear power plants in Poland. This is quite a lot more than in the aforementioned CBOS survey from May (39 per cent). These results cannot be directly compared with each other, as it is not known whether the sample for the ministry's survey was a fully random representation, as the CBOS's is. Nevertheless, it cannot be ruled out that there is a fluctuation of support in this case, which makes its prediction and monitoring even more difficult and limits the possibility of influencing its level. A legitimate conclusion, therefore, is that there is considerable uncertainty about attitudes towards nuclear power.

Such uncertainty is not a new phenomenon. It was present, for example, during the COViD-19 pandemic crisis, which was dealt with to varying degrees through information policy. Many analyses carried out at the time (e.g. by the Interdisciplinary Team for COVID-19 attached to the head of the Polish Academy of Sciences) indicated that a key factor in reducing uncertainty was the level of trust in state bodies. In Poland, trust both in them and in other people is relatively lower than in other EU countries and varies according to the type of institution. This, in turn, creates a difficult context also for nuclear energy policy and recommendations.

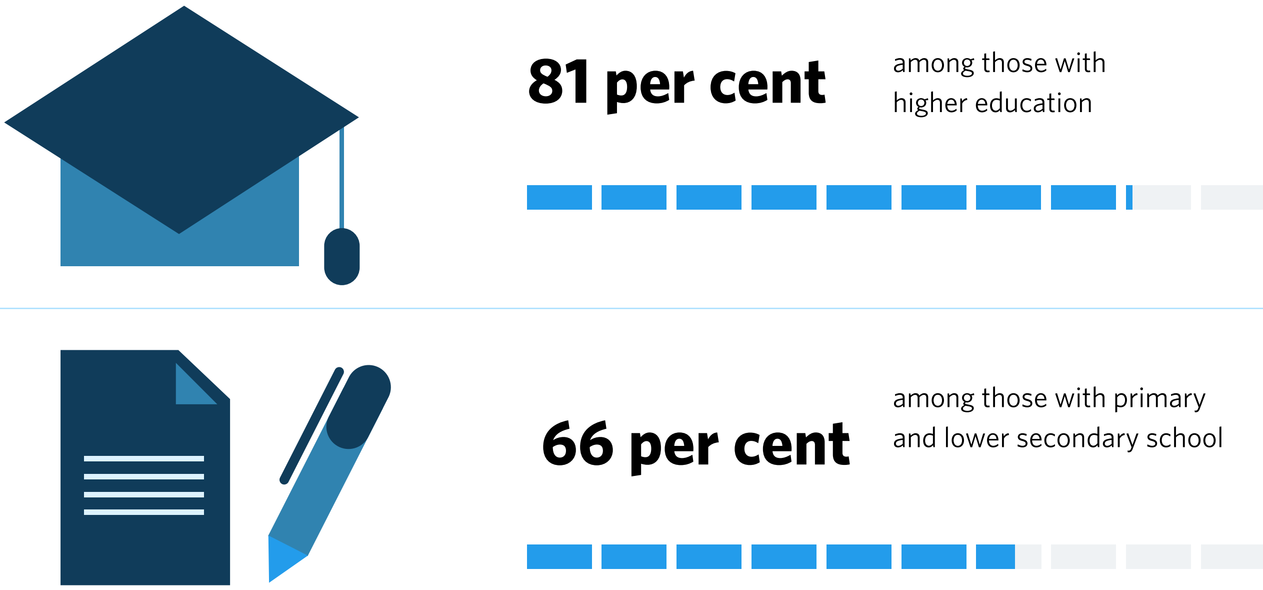
Nevertheless, there are factors that somewhat mitigate uncertainty in terms of support for nuclear power. A September 2022 CBOS poll showed that currently the main concerns for Poles are high prices, war and illnesses[87]. Although it was not possible to indicate nuclear power plants in the set of answers, one might think that in light of the increase in approval towards nuclear, it would not be one of the main concerns. **At the same time, climate change was cited by 15 per cent of respondents as one of the five main concerns.** This is only 1 percentage point less than the loss of a job and 2 points less than the lack of goods in stores. This means that many of the risks that were until recently distant and abstract (e.g. war, epidemics, climate) are becoming concrete and closer to everyday life. It cannot be ruled out that soon nuclear power will also be assessed through the prism of near-term threats. For the time being, however, it is not seen in these terms.

The potential uncertainty about the scale of support for nuclear power in Poland is also reduced by the approval recorded by CBOS for locating a nuclear power plant close to the respondent's place of residence. In November 2022, more than half of respondents

(54 per cent) supported such a solution. Although more people still support nuclear power "in the country" than close to home, the increase in approval for locating reactors even close to home is huge – in May 2021, it was as much as 30 percentage points lower. Hence, the phenomenon of the so-called NIMBY (Not In My Backyard), i.e. opposing an investment in the respondent's immediate neighbourhood, despite the lack of denial about the need for it at all, has been reduced.

At the same time, support for nuclear power increases with education: it stands at 81 per cent among those with a university degree and 66 per cent among respondents with primary or lower secondary education.

SUPPORT FOR NUCLEAR POWER



SOURCE: OWN COMPILATION BASED ON CBOS.

This is crucial for building support for nuclear power in Poland. Since various surveys show that local authorities are relatively more trusted than central ones, **it is worthwhile for them to become a potential ally of the idea of developing nuclear power plants in Poland, especially as public consent to the location of such a power plant close to where people live is growing.** These authorities should participate in community dialogue on the subject, talk about local conditions and the sources of possible fears and concerns, as well as the potential benefits for the community resulting from the nearby location of the power plant.

In addition to factors of an external and contextual nature, the uncertainty in question is also influenced by fears associated with nuclear power itself. These include general fears about disasters and environmental risks[88]. This directs public attention towards environmental issues where the position of important social actors is ambiguous. As a consequence, confidence in information policy is crucial for reducing uncertainty.

The effectiveness of efforts in this regard is influenced by factors such as:

- **Attitudes towards nuclear energy are characterised by considerable fluctuations in support and rejection, depending mainly on external factors (including threats).** These are mainly contextual, often independent of our influence. As a result, the impact of information policy is severely limited. However, this should not lead to information inactivity, but rather to a formulation that builds the message clearly and links external threats (e.g. war disrupting energy security) to the legitimacy of nuclear energy development.
- **Today we are experiencing a plurality of information policies.** "Centrally" undertaken measures in this area are only one source of communication and not necessarily the most effective. This assumption necessitates realistic planning of the funds allocated to them. It also stems from experience – for example, research conducted in 2020 during the COViD-19 pandemic showed that in Poland, the most reliable sources of information were not those of the government and specialists, but those closest to the respondent, i.e. family and friends. It is worth noting that out of the 26 countries surveyed around the world, Poland was the only country in which health system specialists were not considered the most trustworthy source of information. This also confirms the role of local factors in information policy and the potential of the network of closest contacts and potentially of local governments. The potential for trust is there, as well as in informal information structures and networks (e.g. social media), even if the media do not always promote rational positions.

To gain confidence in a process such as nuclear development, information policies must be sincere. They should not be based on monologue, labelling of opponents or one-way messaging[89]. They also require the acceptance of dissenting views (especially rational and legitimate ones). Subsequently, information policy must not include "pigeon-holing" people with differing views, but must involve an attempt to understand their genesis. The experience of pandemics shows that the latter are generally very simple and easy to apply answers that reduce uncertainty, e.g. that the pandemic threat is not there at all, so one should not protect oneself against it. There should always be a dialogue with opponents, the aim of which should be to understand them. Researchers point out the shortcomings of an indoctrinational information policy, which in fact pursues a soft power model at odds with democracy energy[90].

Nuclear power and politics. Who's in favour, who's against?

Effective information policies should take into account the diversity of actors and their interests, concerns, hopes. In public discourse, there is a tendency towards the typical soft power technique of co-opting by internalising values, imposing certain norms as "neutral"[91]. It is, in fact, a technocratic mechanism leading to the "depoliticisation" and "de-publicisation" of decision-making processes, which blurs the map of social interests and makes it difficult to identify the positions of individual actors in collective life. Meanwhile, the modern approach of technology assessment abandons the technocratic-expert paradigm in favour of a deliberative approach, with strong elements of citizen participation[92]. **This means that there should be a real debate and, second, that not only experts but also ordinary citizens should have a voice in it.** Such an approach, especially under conditions of considerable uncertainty, seems to be beyond doubt – interests and concerns need to be made known, rather than assuming that they do not exist and that the voice of experts is sufficient. However, there is a well-founded fear that the centralisation mechanisms gaining importance in Poland will promote a technocratic-expert approach, situating nuclear supporters as "rational" and its opponents as “irrational”. The authorities may therefore try to locate the dispute on the plane of knowledge and rationality rather than on the plane of legitimate differences of interest that have the right to be articulated.

The dispute over nuclear power may become hostage to the specifics of Polish politics, including its polarisation. The problem may not only be an attempt to depoliticise an inherently political decision-making process, such as the decision to develop nuclear power. In general, we often have to deal with the wrong positioning of politics: one depoliticises what is inherently political (e.g. disputes over investment priorities) and at the same time politicises what should remain outside politics, e.g. trying to control management of state companies or private life by criminalising abortion. The state and politics abdicate from where they are needed and often enter where they are unnecessary. At the same time, if an issue is already legitimately in the field of politics, it happens to be a particular kind of politics, based on a strong polarisation, which has increased dramatically in recent years. For it has long been pointed out (e.g. by Jadwiga Staniszkis) that there is an almost dichotomous, dualistic division underlying Polish politics, where the moral dimension dominates, making one choose between “good” and “bad” rather than identifying pluralistically diverse interests. And this is the kind of politics into which the nuclear dispute may fall. Meanwhile, the issues concerning it should in fact constitute an “apolitical politics”, the contradiction of which is to define its supporters as “good” and its opponents as “bad”.

The problem of the politicisation of the nuclear dispute is not made any easier by the fact that the decision to develop it and the related disputes are natural elements of politics in a deeper sense. At the same time, they should be “decoupled” from politics understood as a daily battle between factions. For the choice facing the Polish government is not strictly political, but civilisational, and its effects will be felt for years. Consequently, such decisions must be “transcendent” and not hindered by current electoral campaigns. In front of all actors potentially involved in the nuclear debates, this requires separating the debate from day-to-day party election politics and locating it within politics in a deeper sense, as a deliberation involving various stakeholders, not only formal politicians and experts.

Identifying the map of social divisions and actors with different degrees of support for nuclear is difficult. First, this is due to the considerable uncertainty that is a phenomenon that is not limited to the dozen or so percent of people who do not have an opinion on nuclear energy. Second, social opinions are characterised by a high degree of volatility, as people change their minds more under the influence of external factors than because they have become convinced of the rightness of certain solutions. In the process of identifying actors, it is useful to identify socially “visible” groups, named so that dedicated information policies can be targeted at them or that they themselves can co-create such policies. This is generally a complex process.

Information policy, or even just addressing public concerns, should not only concern opponents of nuclear energy development. Indeed, among nuclear supporters, there is a large group of people declaring concerns about nuclear power, with surveys indicating that their percentage is 51 per cent of those in favour[93]. So, in this case, there is no simple division between “for” and “against”, as a large proportion who are “for” nevertheless raise their own concerns, which need to be taken into account in information policy.

In terms of socio-demographic factors, nuclear supporters are more likely to be men (87 per cent) than women (64 per cent). Among them, most people are from large cities (more than 80 per cent) than from the rural areas (less than 70 per cent) and are more likely to have a higher education (81 per cent) than primary education (66 per cent). These and similar differences are noticeable, sometimes even considerable, but not dramatic. Rather, what is apparent is a general social acceptance across social groups rather than any fundamental division.

When building support for nuclear power, it is crucial how strong it is, and which, if any, groups in society are likely to be the first to change their attitude when general acceptance shifts. The scale of the latter phenomenon is admittedly difficult to predict, but must still be taken into account. The absence of significant social differences in the map of support for nuclear would indicate that it would be withdrawn fairly evenly. Anyway, generally this map coincides with support for the energy transition in Poland. Incidentally, support for this energy transition is conditional and withdrawn if it increases the risk of falling into energy poverty[94].

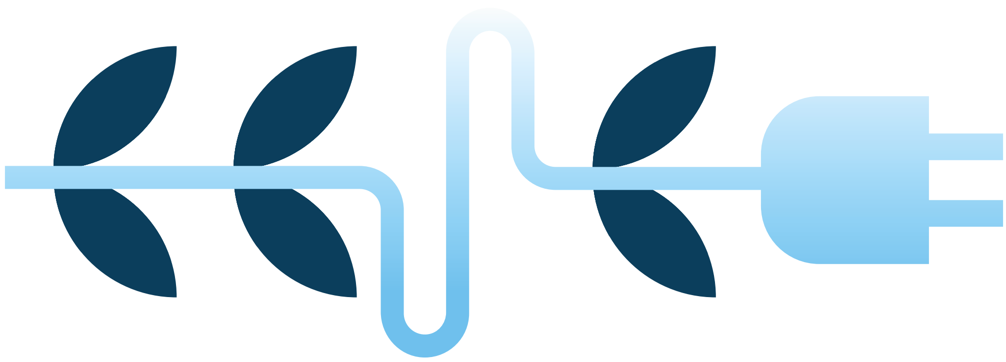
Ecological groups play a significant role. They are well institutionalised and active, making their voice heard. They clearly support the energy transition. However, this does not mean that these are groups that are explicitly supportive of nuclear energy development. On the contrary, surveys conducted in March 2021 in the Carpathian and Lublin voivodeships (snowball sampling, i.e. not random) indicated that respondents with a pro-ecological stance were more critical of nuclear energy[95]. A similar position is presented by Greenpeace, which has long opposed the construction of nuclear power plants in Poland. However, it seems that both pro-environmentalists and organisations active in this area can be – under certain conditions – potential allies in the development of nuclear power. Their acceptance of the energy transition (as long as it does not increase the risk of energy poverty) is important here. So, if their concerns in this area (e.g. regarding safety, environmental risks) could be minimised, nuclear power would have the potential to be perceived by these communities as a "lesser evil" than coal.[96]. Such acceptance would probably be fostered by the threat of limited access to energy generated by traditional sources (e.g. electricity shortages). This is, incidentally, a factor that could foster acceptance of nuclear energy not only in particularly pro-environmental circles, but among citizens in general. And such threats to energy access are not unrealistic, given the outdated state of Poland's energy infrastructure.

Support for the construction of nuclear power plants can also be sought from businesses, which, given the need to decarbonise their operations, could be key consumers of the electricity they generate.

Conclusion

Any outreach to the public and relevant actors should take into account the volatility of attitudes towards nuclear power, which is additionally quite dependent on factors independent of it. In the face of a changing information environment of diverging interests and scale of concerns, it is essential to accept an equal plurality of attitudes and behaviour. In view of the plethora of actors, it is also necessary to reckon with the potentially limited effectiveness of information policies, for the success of which the conditions of dialogue rather than a central monologue are important.

The current acceptance of nuclear is considerable, but its fate is uncertain. For the construction of effective information policies and recommendations, local actors such as local governments as well as third sector organisations are very important. There is also significant potential in pro-nuclear organisations and communities, despite their current reticence towards nuclear power.



03

Scenarios for nuclear power development in Poland up to 2040

Dominik Brodacki, Polityka Insight

In order to determine the prospects for nuclear power development in Poland, we developed three scenarios taking into account the different levels of domestic investment in this area. For each, we analysed the determinants discussed in Section Two, and based on these we identified the main factors that will determine the pace, scale and manner of reactor construction. We have also analysed the wider context – how the deployment of nuclear technology fits into the national energy transition. How, then, can nuclear power be deployed in Poland?

Scenario:

1. **Minimum:** Only the conventional nuclear projects envisaged in the PPEJ and the current PEP2040 will be implemented in Poland. Accordingly, there will be two nuclear power plants with a capacity of 6-9 GW. Three PWR units with a capacity of more than 1 GW will be installed in each of them. Construction of the first 1.1 GW reactor will start in 2026 and be completed in 2033. Two additional NPP1 reactors will be built at the same time and, according to the government's current plans, will start in 2035 and 2037. In 2032, construction of NPP2 will start, with the first reactor starting in 2039, the second in 2041 and the third in 2043. The idea of using SMRs will be abandoned over time.

2. **Balanced:** Three conventional nuclear projects – those listed in the minimum scenario and the Pątnów nuclear power plant – and some SMR projects will be implemented in Poland. Only the largest national groups (including the joint venture Orlen Synthos Green Energy) will afford investments in the latter, with the remaining companies abandoning their intention to build them mainly due to high costs and administrative difficulties.

3. **Nuclearisation of Poland:** All currently planned conventional projects will be implemented in Poland, i.e. the three conventional power plants mentioned above, as well as dozens of SMRs, which will be built both by large capital groups and by smaller Polish and foreign investors.

Each scenario is based on unchanging assumptions, whose occurrence determines any investment in Polish nuclear power. The key one is at least a partial continuation of energy policy over the years, including successive governments maintaining a favourable attitude towards nuclear power and its development path. The second condition is the maintenance of a relatively favourable EU policy towards nuclear power, which is important from the point of view of being able to obtain funding for such projects. The third is the emergence of a supply gap in the Polish energy sector in the 2030s, i.e. an increase in electricity consumption with a decrease in supply from domestic sources. It will increase Poland's dependence on electricity imports from other countries, and hence the cost of its purchase by end users. Such a prospect will put the government in a position of having to invest massively in the domestic generation pool. The fourth assumption is the full implementation of the Fit for 55 and REPowerEU packages, which will accelerate the energy transition across the EU. CO2 emissions will become increasingly expensive and the use of green energy will become increasingly cost-effective. For Poland, this will mean that it will have to move more quickly away from coal in the energy sector, and this in the context of the increasingly limited possibility of using gas as a transitional energy source.

1 Minimum scenario

Financial aspect

The full costs of building a nuclear power plant cannot be estimated. This is due to trade secrets of the owners of the technology and its contractors and subcontractors, as well as many variables (e.g. inflation, exchange rates) whose impact on the long-term value of the project is unknown. Because of these, it is also very often subject to large changes throughout the life of a project, as exemplified by nuclear investments in other countries. The caveat here is that any estimates in this regard are at least partly inaccurate and should be treated as "scale of magnitude". This also applies to the other scenarios analysed in this section.

The construction of a nuclear power plant involves a huge financial outlay and high investment, regulatory and political risks. They also result from high so-called sunk costs and a long period of cost amortisation and return on investment. According to data collected in 2022 by the Polish Economic Institute, the average **cost of building two nuclear power plants in Poland will be at least PLN 184 billion** (assuming six reactors with the same technology). These calculations are based on the costs of the already completed projects of Westinghouse, EDF and KHNP, assuming the transfer to Poland of exactly the same technology and ignoring, for example, the changing regulatory and political environment and the technological aspect. Declarations by representatives of the Polish government, however, allow us to estimate that the actual expenditure in this respect may be quite different and amount to around PLN 39 billion for one EPR reactor (EDF), PLN 33.5 billion for APR1400 (KHNP) and just under PLN 32 billion for AP1000 (Westinghouse). The former could cost PLN 22.2 million/MW, the latter PLN 23.9 million/MW and the third PLN 25.3 million/MW.

This notwithstanding, **it should be noted that the actual cost of purchasing and implementing each of these technologies is likely to be higher**. The construction of the first and possibly the second nuclear power plant in Poland would be a so-called FOAK (First of a Kind) project, which will translate into significantly higher investment expenditure compared to similar investments in other countries. It involves the necessity to implement for the first time a number of solutions and actions necessary for the implementation of nuclear power, e.g. in terms of logistics, or adaptation of the administration to new tasks.

The way in which these costs are covered and their impact on the various stakeholders depends on both the duration of the investment and the financing model adopted. The longer the former, the higher the expenses, if only because of the increase in the value of the project (longer implementation time means, among other things, higher costs of maintaining managers) and inflationary effects (i.e. steadily increasing costs of salaries, goods and services).

As far as the financing model is concerned, it should be pointed out that market failure makes public support for nuclear power plants essential – in Europe, practically no investor is able to bear the costs and, above all, the risk of their construction alone.

For Poland, the point of reference is the solutions adopted in other countries, including:

- **long-term agreements** (PPAs), e.g. in the US, United Arab Emirates, Turkey
- **contracts for difference** (CfD), e.g. in the UK
- **tariff model (RAB)**, e.g. in the US, planned in the UK
- **cooperative models,** e.g. Mankala in Finland and the Polish SaHo Model.

In the past, the solution most seriously considered by the government was a contract for difference, guaranteeing the sale of electricity from power plants at a fixed price – the price of energy on the market would fall below the guaranteed one, the government covers the difference. However, from the perspective of investment financing, the downside of this solution is the need to obtain EC approval for it, potentially huge costs on the side of the state budget, but also the risk of electricity market prices rising above the guaranteed level – then the costs fall on the investor, who is obliged to pay the difference in favour of contractors. At the same time, the EC's already issued decisions on the matter create a theoretical space for the government to guarantee the profits of the bonds issued by the investor and provide a kind of interpretation of the investor-state profit-sharing mechanism accepted by the government for the entire duration of the subsidised investment.

! In the explanatory memorandum of the decision accepting state aid for the Hinkley Point C nuclear power station, published in 2015, the EC agreed that the guarantees should cover the investor's return on the bonds (their cost was to be based on the estimated risk of the securities and the investment), and that they could be provided by a special unit of the UK Treasury. In return, the investor was to share part of the profits with the state. In this respect, the UK government and investor estimated a nominal return on capital of 11.4 per cent. Above this level, the state was to receive 30 per cent of the profits and the investor 70 per cent. The Commission committed the UK to a second threshold, above 13.5 per cent nominal return on investment. Profits above this threshold would be shared 60:40 in favour of the state. In addition, the EC recognised that profits would be shared over the entire planned investment period (60 years), not just the duration of the contracts for difference (35 years).

The SaHo model can be very attractive in terms of financing the development of Polish nuclear power. It requires the establishment of a state company to build the power plant and produce electricity. From the moment of its creation, this company will be able to gradually sell shares to consumers, and their price – due to the decreasing investment risk – will vary depending on the stage of construction. State involvement, in turn, can make it possible to guarantee access to low-cost capital, but also to effectively manage the initial political and regulatory risks to the investment. Although it will require a large involvement of the State Treasury, it will enable smaller entities and individual consumers to participate in the investment, for whom it will ensure stable and low electricity prices, while reducing the burden on the state budget. Importantly, these measures are likely to comply with EU state aid rules – all of the funds received are divided into the number of shares issued and, in effect, repaid. This represents a significant advantage over contracts for difference.

The tariff model involves at least partially charging consumers for the construction of the nuclear power plant. In November 2022, the Ministry of Climate and Environment and the Ministry of Finance announced that no work was underway to implement it for Polish nuclear power plants[97], although in February 2023 the government plenipotentiary for strategic energy infrastructure, Mateusz Berger, did not rule out that an additional charge would appear on all consumers' bills within a few years. Although this would be a solution that would make it much easier for an investor to raise capital for an investment, it would carry significant economic risks (e.g. increased electricity charges and inflationary pressures) on the one hand, and social risks on the other. Under the conditions of already high energy tariffs and the prospect of their further increase (related to the domestic energy sector's dependence on coal and the supply gap in the sector), this could be associated with a potential drop in support for the construction of nuclear reactors in Poland.

The Polish government may also opt for the "Hungarian" model, involving direct financing of the nuclear power plant from the state budget, which is supplemented by a loan from another country (in the case of Hungary from Russia). However, in addition to the large public outlay in this regard, there is a significant risk arising from the so-called "private investor test", which may show that the state's involvement in the project is not on market terms and constitutes state aid, and thus contradicts EU regulations. In Poland's favour in this regard, the fact that the EC has agreed to apply this model in the case of the construction of units 5 and 6 at the Hungarian Paks II power plant may potentially speak in favour of Poland.

Each of these financial models is theoretically feasible in Poland for the minimum scenario. However, the Contracts for Difference (due to its costs and high risks) may not be very promising in this respect, although it is relatively simple to apply and proven worldwide. However, some of the challenges faced by the Polish nuclear power sector may be addressed by the SaHo and Tariff Model, or a model that is a combination of the two. The former is strongly disadvantaged by the lack of experience in its application.

In addition to government support, external financing of the investment will also be needed. **It should be assumed that, contrary to the provisions of the PPEJ, the share of the technology provider in the SPV established by PEJ will not reach a level even close to 49 per cent and will amount to no more than a dozen or so per cent.** In the minimum scenario, this means that at least 30 per cent of the funds for the construction of the power plant will have to be provided by the investor, and 70 per cent will be covered by debt financing, which, however, will involve adding interest to the cost of the project. This financing will in part be able to be provided by the technology provider itself or by the government of its country of origin, but may also be provided by government institutions or provided by loans, taken under the terms discussed in section two.

To a large extent, it makes sense to introduce debt incurred only by the SPV (PEJ or its subsidiary) into the financing structure. Such a solution may reduce the direct nuclear expenditure of the State Treasury, but also the willingness of financial institutions to support the investment. The latter means that the construction of the power plant will still generate costs on the part of the State Treasury, associated with the need to provide support in another form, especially as at the investment stage the SPV is unlikely to have sufficient capital to service the debt. This support can take the form of guarantees to secure this capital during construction, as well as the ability to service the debt during the operational phase of the plant. Also in its favour is the prospect of debt service costs, which in this case are borne more at the level of the nuclear project itself rather than the state as a whole. The downside, however, is the costliness of this option over the long life of the project, which will also partly result from higher interest being added to the capital. This is because it implies that financial institutions will most likely have to agree to start repayments only after the plant starts operating.

In this situation, in the long term, the cheapest and least economically risky solution is to include in this model at least a partial participation of end users in the construction costs of nuclear power plants. Regardless of the financing model adopted, it is crucial to create a transparent mechanism for sharing the costs and benefits of the project. This is both because of the almost certain need to involve many stakeholders and to build and maintain public support, and because of the need to make it compliant with EU state aid rules.

Staffing aspect

The implementation of the minimum scenario will require the urgent construction of a cadre in Poland for the development of nuclear power. They will need to be specialised in every element of its value chain – from the execution of contracts to the design, construction and operation phases of the power plant.

The Polish government's 2017 estimates anticipated that **in Poland, the construction of two nuclear reactors in a single power plant would entail at least 5,000 direct jobs and 11,800 in external companies, with the structure and productivity of the domestic economy likely to force this number to be even several times higher.** However, later calculations by the Ministry of Climate and Environment (based on US Department of Energy data) assumed that the construction of one reactor employs about 2 400 people, of whom 1 600 are construction workers and the remainder are project management and supervision staff. The subsequent operation of one unit, on the other hand, requires about 600 people[98]. Meanwhile, the 2020 PPEJ assumes that the construction of the nuclear power unit itself means employing a total of 3-4 thousand workers for construction and assembly work, 80-90 per cent of whom have technical and vocational training and are further educated to perform the aforementioned work. Employees of inspection, regulatory and coordinating bodies should be added to these calculations.

The possibility of meeting the staffing needs associated with the development of nuclear energy is well beyond the perspective of a few years. In the Polish case, this is due not only to the need to educate specialists, but also to the construction of an almost entire system for their education. This, in turn, must be tailored to the needs of the investment itself, as well as those of the administration (including nuclear supervision), industry, R&D organisations and educational institutions themselves.

In the initial phase of nuclear power development in Poland, a large part of the workforce is likely to be made up of people from other countries, working with suppliers of particular products and services on a daily basis. However, building and maximising Poland's potential in this area requires a gradual increase in the role of domestic specialists in the sector, who need to be educated. This is because the current workforce consists mainly of people from research and development centres and those who have previously worked in related industries, such as coal and renewable energy, or on nuclear power plant construction sites in other countries. It is worth noting that in the past there were universities and departments in Poland that educated many nuclear specialists. However, the current supply gap is due to both the abandonment of the Żarnowiec project in the 1990s and the lack of real government action to actually implement nuclear power in Poland. As a result, many people educated in this field have decided to change careers or join the workforce supporting investments in other countries.

For this reason, **at least in the initial phase of this scenario, the participation of Polish workers in the construction phase of the power plant may be severely limited and confined to carrying out individual tasks.** In the longer term (e.g. during the construction of the second nuclear power plant), a systematic increase in their role in the construction process is possible. With respect to the power plant operation stage, on the other hand, it can be assumed that Poland's potential fluctuates around at least a few dozen percent participation of domestic specialists.

Already at the minimum scenario stage, it is crucial to finalise the Nuclear Power Human Resources Development Plan as soon as possible. It is currently assumed that its adoption will take place in 2023 and the framework document adopted in 2016 by the then Ministry of Energy, setting out the general directions of the various stakeholders, is the basis for its development. The plan is intended to be a roadmap for building cadres for the nuclear power industry, also setting out the premises for a recruitment system for future employees and career paths. On this basis, each public entity implementing a nuclear programme is to prepare its own human resources development plan. Their implementation, on the other hand, should be done in close coordination with the IAEA, which has modelling programmes for human resource development for nuclear power.

These measures are necessary first and foremost because of the still large staff shortage in the administration itself and the need to strengthen the PAA's staff responsible for regulatory oversight of the implementation of investments. This, in turn, entails the task of broadening the Agency's current remit to include technical staff, e.g. power engineers, electrical engineers and automation, mechanical or construction specialists, who can deal with nuclear supervision inspection and analysis. This requires close cooperation between the PAA and the nuclear supervisors of other countries. It is worth noting that these challenges are indicated in the PPEJ itself, in which the government has assumed that it is necessary to recruit 80-90 per cent of the postulated staff at least three years before receiving the licence application to build the first nuclear power plant.

Rebuilding Poland's potential in this area will require the **creation of faculties and specialisations at at least a dozen of the largest universities that are directly related to nuclear energy** (as is the case in the RES sector). It is also particularly important to build a good educational offer, especially in the technical aspect, e.g. mechanics, mechanical engineering and operation, thermal circuits and diagnostics. It is also necessary to launch government support for research staff and doctoral students for research and scientific projects in the field of nuclear energy, as well as to support universities with staff from research institutes and foreign experts. In this regard, there is also a need for an attractive offer of further education of personnel and specialised training provided by industry and companies directly involved in nuclear projects. In all these activities, close cooperation of the PEJ with scientific centres and foreign universities is crucial, so that the educational offer meets the needs of the market to the greatest possible extent.

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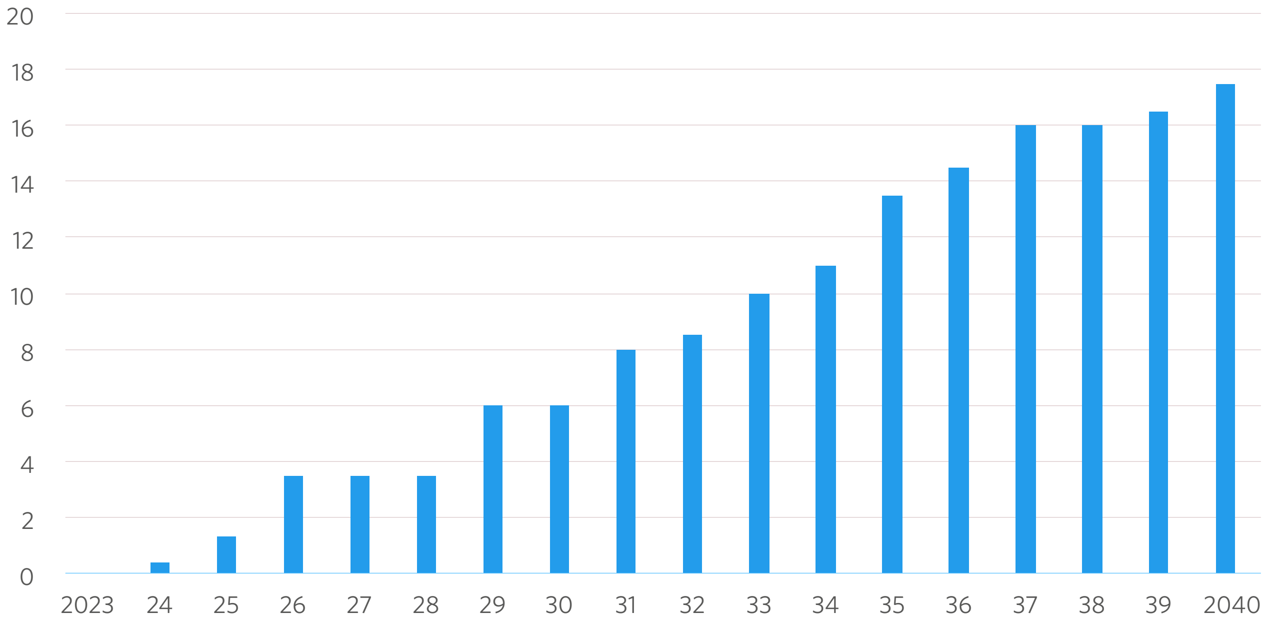
A positive development in this respect is the signing of a letter of intent on January 31, 2021 by the Minister of Education and Science, the CEO of PKN ORLEN and the rectors of the Poznań, Śląsk, Gdańsk, Warsaw and Wrocław Universities of Technology and the AGH University of Science and Technology in Kraków, which provides for the development of an educational programme in nuclear power engineering. As part of the programme, first – and second-cycle studies of a general academic profile are to be launched from the 2023/2024 academic year. Similar measures should be taken at centres located in the vicinity of the planned nuclear power plants, e.g. at the Koszalin University of Technology, the Słupsk Maritime University or the Szczecin University of Technology. The latter has great potential in terms of building human resources for new sectors of the economy, thanks to the development of a programme to educate employees in the offshore wind energy sector.

Meanwhile, on March 17, 2023, the Ministry of Climate and Environment and the Economic Chamber of Energy and Environmental Protection concluded a contract to provide advanced training for the Polish electricity, construction and mechanical-welding industries. Their aim is to familiarise participants with the technical requirements in the nuclear power industry, in terms of quality assurance and control, and in the business area, e.g. how to become a qualified supplier to major nuclear companies. It is also worth noting that the exchange of good practices in the field of human resources acquisition is one of the tasks of the team for the development of nuclear energy in Poland, established in the Ministry of Climate and Environment in February 2023. In addition to representatives of the ministry, it includes the government plenipotentiary for strategic energy infrastructure, as well as representatives of PEJ, PGE, KGHM and ORLEN Synthos Green Energy.

Technological and environmental aspects

The construction of two 6-9 GW nuclear power plants would go a long way to addressing the current challenges facing the Polish energy system. This is one of the largest in Europe, but the country's generation capacity is still largely based on burning coal and a large part of it will have to be shut down within the current decade.

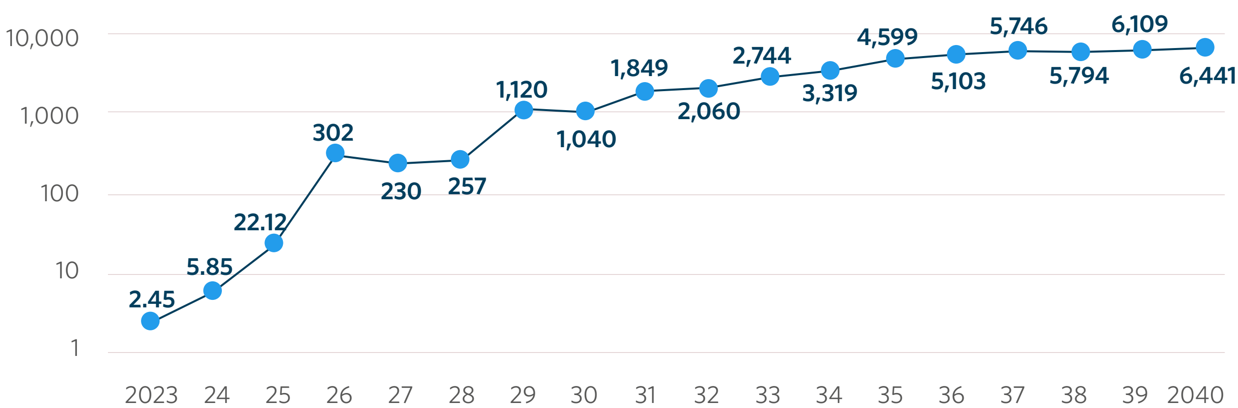
NET ADDITIONAL AVAILABLE CAPACITY REQUIRED IN CSE 2034-2040 (GW)



SOURCE: OWN COMPILATION BASED ON PSE.

PSE's 2022 data on the future sufficiency of power generation in the NPS indicates that the system will require up to 17.5 GW of additional dispatchable capacity in 2040. Estimates in this regard are based on the so-called Loss of Load Expectation (LOLE) indicator, which corresponds to the total duration of a power deficit over a 12-month period. The LOLE safety standard is 3 hours per year (8760 hours). Meanwhile, while in 2023 the deficit will be 2.45 hours, two years later it will already be 22 hours, and in 2030, 1.04 thousand, in 2032, 2.06 thousand and in 2040 6.44 thousand.

AVERAGE VALUES OF LOLE INDEX [H/YEAR] IN 2023-2040



SOURCE: OWN COMPILATION BASED ON PSE.

The resulting system needs over the next decade will be covered by RES sources, whose share in the generation mix could reach close to 50 per cent in 2040. In this context, nuclear power plants will represent a stable, available source that can also be used for regulating operations. This will be due to their high availability (which, according to the Ministry of Climate and Environment's methodology, is 97 per cent, compared to 93 per cent for gas-fired units and 20 per cent for offshore wind farms), zero CO2 emissions and no associated costs, and relatively low system expenses arising from, for example, the need to expand the electricity grid, energy storage systems or balancing costs.

Implementation of the minimum scenario assumes that 2.2 GW of nuclear reactors will be in operation in Poland in 2035 and 4.4 GW in 2040, capable of producing 16.7 and 33.4 TWh of electricity respectively. This will give them an estimated 11.9 and 20.7 per cent share in the mix. Such an increase in capacity in view of the prospect of rapid development of non-controllable RES will force a relatively slow pace of conventional units' withdrawal. This is because it will, to a very limited extent, offset the decline in available capacity in the system by 2036 forecast by the ERO from 33.95 to 27.55 GW or fill the supply gap forecast by PSE for 2040.

Building two nuclear power plants with different technology will generate additional costs due to the lack of so-called economies of scale. These will be related both to the need to contract two different suppliers and contractors and to the need to adapt the entire nuclear system architecture, e.g. in terms of staff expertise, to the different reactor types. Moreover, negotiating the purchase of a larger number of units from a single entity at least theoretically puts the buyer in a better negotiating position and allows them to lower their price. This perspective is in line with the approach included in the PPEJ.

Each of the nuclear technologies offered to Poland includes sufficient operational and safety parameters, while fully complying with international standards. It is worth noting, however, that a potential impediment to the use of APR1400 reactors in Poland (e.g. for the second NPP under the PPEJ) could be the fact that they are based on technology developed by the US company Combustion Engineering. In 2000, the nuclear branch of this company was taken over by Westinghouse; KHNP therefore uses technology now owned by the manufacturer of the AP1000. In October 2022, the US company took KHNP to court, claiming that their use outside South Korea is subject to US export laws and requires US approval. KHNP argues that it has full intellectual property rights to the APR1400 technology, so it can export it at will. Regardless of the resolution of the dispute between the companies, the very fact of their litigation could theoretically make it more difficult for Poland to select the AP1400 technology and create risks associated with its purchase. These, in turn, could, for example, make it difficult to obtain external funding for the project or to contract some of the subcontractors.

It remains the government's task to secure uranium supplies. In this respect, cooperation with Westinghouse, which already supplies uranium, to nuclear power plants in Ukraine, is promising. Under these circumstances, cooperation with Poland could potentially fit into its local supply chain. Nor will the fluctuation of uranium prices on international markets be a major challenge. Indeed, the cost of purchasing fuel represents only around 20 per cent of the operating costs of nuclear power plants, compared to 80-90 per cent for conventional power plants. Moreover, Polish power plants will be able to buy uranium through the Euratom Supply Agency, which supplies other EU reactors. This will give Poland access to much more attractive prices.

Legal aspect

The current regulatory landscape is largely in line with the needs arising from the minimum scenario investments.

The Special Act contains a number of solutions to streamline the investment process. It sets out time limits for issuing administrative decisions of key importance to the investor (e.g. building permit, location decision) and introduces an accelerated appeal procedure against certain decisions and procedural improvements at the stage of potential administrative court proceedings. Particularly noteworthy are the changes stipulated in the amendment to the Act, primarily with respect to changing the sequence of obtaining certain administrative decisions (including the fundamental decision) and the changes concerning accompanying investments made at the consultation stage of its draft. Originally, it was stipulated that the list of associated investments would only be extended to include the construction of transmission networks and projects for environmental and location studies, but it was eventually extended to include the construction and expansion of distribution, heating and cooling networks, as well as water supply, sewerage, telecommunications and ICT networks. In addition, the list included the construction of gas grid facilities and investments in energy storage and hydrogen production, distribution and storage facilities. In addition, a significant relief is the exemption of the provisions of the Nature Conservation Act concerning obtaining permits for the removal of trees or shrubs when implementing investments in the construction of nuclear power facilities.

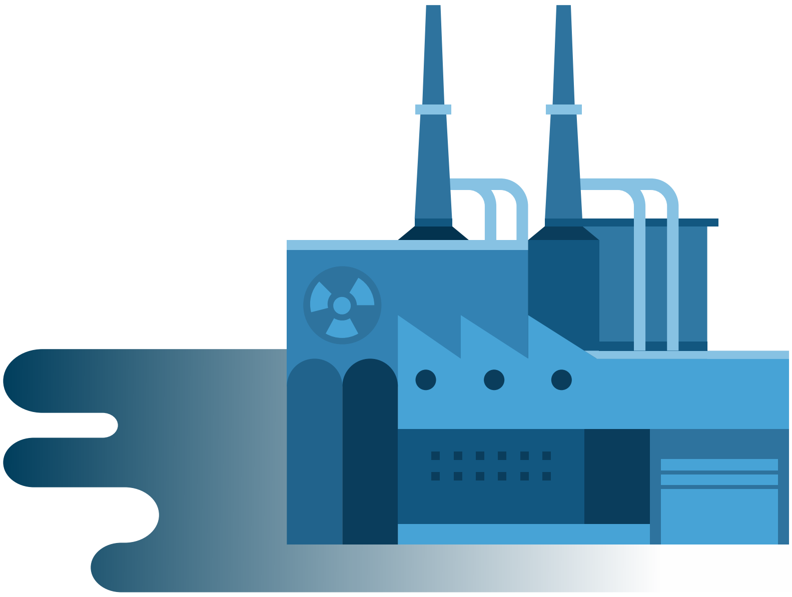
Social aspect

The construction of two nuclear power plants in Poland will require at least continued support for this technology. The public is increasingly in favour of them, but a risk factor is the stability of this approval and the occurrence of the so-called NIMBY phenomenon mentioned above. In the former respect, the activities of the authorities should focus on continuous dialogue with Poles and educating them about the necessity and safety of nuclear investments, as well as their benefits.

Overcoming the so-called NIMBY effect is key to avoiding conflict between the common good and the good of the local community. In order to achieve this, it is necessary to genuinely activate the voice of the "silent majority" in favour of the investment or having at least a neutral attitude towards it. Actions in this respect should not be limited to education, but should also consist in presenting to the public all information about the project and its (mainly local) benefits in an understandable way. These should be undertaken in the form of direct contact with the residents, e.g. through face-to-face meetings (at meetings or sessions of the municipal council), the involvement of local community organisations or promotional campaigns in social media and local newspapers.

It is also necessary to systematically build trust in public institutions, which is at a low level in Poland. In this respect, it is advisable to conclude cross-party consensus for the construction of reactors and to involve representatives of various political groups in their promotion.

In order to build sustained public support for nuclear power, an unequivocal government position on the implementation of the investment is crucial. This requires a real transition from the phase of political declarations to the phase of making binding decisions. This will make the actions of the various institutions more understandable and predictable for the public. It will also be important to constantly monitor approval in the long term, as the fear of it falling – even due to a lack of awareness on the part of the authorities – may be a deterrent to their smooth implementation of nuclear investments.



2 Balanced scenario

Financial aspect

Building more nuclear power plants in Poland will have a different cost than a simple calculation based on the price of individual reactors. The amount of outlays in this regard will partly be influenced by the so-called economies of scale. Investments in the third power plant (to be carried out by PGE, ZE PAK and KHNP) and the first SMRs will be able to rely to a large extent on the experience and market architecture developed with earlier projects.

Investor estimates indicate that the cost of each of the two-four reactors at Pątnów will be around USD 24 billion, or well over PLN 100 billion. Their point of reference in this regard is the outlay for KHNP's APR1400 at the Barakah power plant in the United Arab Emirates. In practice, this cost will be significantly different. A factor reducing it will be the fact that the investment in Barakah was carried out entirely and from the ground up as a so-called greenfield, but also the fact that Poland has a relatively stronger negotiating position in talks with the Korean side. For this reason, the media there (e.g. the Korea Times) estimate that the value of KHNP's order for the construction of the two APR1400 units at Pątnów may be around USD 14.1 billion.

Tania Arora, Baker McKenzie, London

The construction of the Barakah power plant was a unique nuclear project in which our law firm advised. The plant was built in a country where nuclear power had not previously been in operation, which was associated with the lack of a comprehensive regulatory environment for nuclear power. It was critical for all stakeholders, including lenders, to obtain certainty on the allocation of regulatory risks at a time when the local Nuclear Act was still under development (including third-party liability regulations). Addressing regulatory risks required a commercial and proactive approach by all parties and their advisors who understood the key regulatory uncertainties and their potential impact on project economics, timelines and overall investment viability. It was the collaboration of business partners and administrations that contributed to the success of the project.

An additional factor in reducing the investment cost may be the use by PGE and ZE PAK of a smaller version of the KHNP reactor, the APR1400. In March 2023, the unit was certified by the EU's Organisation for European Energy Company Requirements, confirming that it complies with European performance requirements and can be marketed. The reactor is expected to be KHNP's main export product to Europe – the company plans to bid for a contract to supply it to nuclear power plants in the Czech Republic. Its cost is not yet known, but it is safe to assume that it will be lower than the larger version of this unit.

At the same time, it is important to note that the reactor offered to Poland by KHNP (formally: EU-APR1400) is not a complete copy of the reactors being built in South Korea and the UAE. European requirements necessitated major modifications to its safety features. This included doubling the concrete casing of the reactor building, reinforcing the structure of the auxiliary systems building and adding redundancy to the safety and electrical systems, so that EU-APR1400 now has four such systems. Based on this, it should be expected that its construction at Pątnów (which may in fact be the world's first installation of a new version of the reactor) will in practice also be a FOAK project, which may increase project costs. In Poland, staff or administrative costs are also likely to be higher than at Barakah.

The way in which PGE and ZE PAK will cover the costs of the investment is not yet known. However, its nature, but also the parallel implementation of projects under the PPEJ, will significantly limit the possibility of the State Treasury becoming involved. It is planned that **at least 51 per cent of the shares in the SPV will be held by PGE and ZE PAK and that it will not be supported by budgetary funds.** In practice, however, this is unrealistic not just because of the sheer amount of the expenditure, but mainly because of the need to create acceptable and safe conditions for investors to obtain it. This means that it may not be possible to implement the project without government support in the form of, for example, financial guarantees or even direct financing. This, in turn, creates the already discussed budgetary risks and issues resulting from EU regulations on state aid – adjusting the project to their requirements may additionally increase the costs of its implementation and the burden on investors.

The costs of building and operating SMRs are unknown today and it is not possible to estimate them reliably. Any declarations and forecasts in this regard should be assessed as hypotheses.

This is shown by the rapidly changing investment in the construction of experimental units, as well as by the diverging estimates of their so-called LCOE (Levelised Cost of Electricity), or cost-effectiveness ratio. For example, in 2022, the Kearney consultancy estimated it at USD 36/MWh for SMRs, compared to USD 92/MWh for a conventional power plant. A year earlier, by contrast, NuScale itself indicated that it was around USD 55/MWh for the former. Similarly, the cost of electricity and heat from SMRs is unknown, although by extrapolation it cannot be ruled out that it will be proportional to the expected high unit cost of installed capacity.

It is possible that the construction costs of SMRs in general will not differ significantly from those of conventional units, since in nuclear projects it is not the power of the reactor itself, but its physical size, the quality of the materials and the labour costs, which in this case may be comparable, that have the greatest impact. Only in the longer term, with the start of mass production of SMRs, can their unit cost be expected to fall, which will also be lowered by shorter construction time (multiplicity effect). In the initial phase, this may also make it more difficult to raise external capital for the purchase and construction of small reactors – **financial institutions will probably price the associated risks higher than in the case of a traditional nuclear investment, which will raise the cost of borrowing.**

Even this aside, it is almost certain that **the implementation of the balanced scenario will require a strong state commitment to funding SMRs**. In this regard, some initial declarations from investors indicate the possibility of supporting their investments with contracts for difference. From an economic point of view, this is to some extent justified – Poland has a lot of experience in using this mechanism, although its implementation will constitute a significant budget burden and will require the EC's consent each time. For the former reason, in the longer term a large participation of end users in the investment costs may also be necessary.

At least in the initial phase, investment in SMRs is unlikely to involve a large participation of Polish so-called local content. This is due to their modularity, which means that already-finished components manufactured in other countries will be delivered to the site. At the same time, this will probably translate into a lower time for the assembly itself, which is expected to be only about two years (not counting several years of component production).

Staffing aspect

In this respect, the construction of the Pątnów nuclear power plant can be expected to partly benefit from so-called economies of scale. Personnel educated and experienced in PPEJ projects should be able to commit to the next project with relative ease – all the more so since supplying the next wave of needed workers to the market will be much easier than if the first specialists were educated for "government" investments. Moreover, concretisation of plans in this regard would certainly also make it easier to recruit many specialists from other countries that will have completed ongoing reactor construction or shut down existing units by then.

The large number of nuclear projects underway at the same time will result in strong competition among investors for workers. This could make their implementation much more difficult and slower. A powerful challenge will also be the already visible exodus of staff from the public sector to the SPVs set up to implement projects, caused mainly by much higher salaries in the latter. As a result, the regulatory, inspection and coordination institutions are already facing a massive staff gap in the coming years, which will have to be partly filled with experts from other countries (which will be very costly).

However, there is currently no estimate of the number of staff needed to build and operate SMRs. Only Orlen estimates that one reactor will need more than 100 specialists and that, in view of its plans, their number will have to be around 2,500 by 2040. However, it can be assumed that obtaining human resources will not be a significant barrier to the implementation of investments, especially as most of them will probably be implemented in the mid-2030s at the earliest. In this aspect, however, the lack of experience of the relevant bodies in managing the new technology may be a risk.

Technological aspect

Increasing the capacity of Polish nuclear power plants beyond the projects envisaged in the PPEJ is definitely justified. This is primarily due to the needs of the energy system. The construction of the first of two planned reactors (in the first phase of the project) at Pątnów by 2035 alone would increase the capacity of three such units in Poland to 3.55 GW. In 2040 – taking into account all conventional projects – their number could in turn be six and their capacity 7.1-7.65 GW. On the other hand, the update of Poland's Energy Policy up to 2040, prepared in 2023, assumes that in the most optimistic scenario in 2040, the capacity of Polish nuclear power plants will reach 7.8 GW, of which 2.1 GW will be covered by SMRs.

This would make it possible to cover the aforementioned supply gap in the NPS to a large extent and allow for a more rapid shutdown of gas sources. This, in turn, is important, as the latter projects already carry a high degree of risk, not least because of climate policy and the increasingly less favourable attitude towards them on the part of financial institutions. The latter in favour of nuclear power contrasts with the inclusion of nuclear energy in the EU taxonomy, as a result of which the nuclear power industry will be able to obtain financing from the market.

In the case of the Pątnów nuclear power plant, a greater challenge may be securing the supply of nuclear fuel. The reason may be the need to import it from South Korea – KHNP is expected to offer the possibility of such a transaction through its company KEPCO Nuclear Fuel (KNF). In the longer term, the operation of as many as three conventional power plants in Poland will already require technology transfer and the construction of a domestic production facility. This is driven by logistical and economic factors as well as safety considerations.

SMRs could be a future supplement to the Polish energy system. Given the risks and uncertainties associated with the deployment of this technology discussed here, it can be assumed that before 2040 such units will become a partial alternative to the current 200 and 300 MW class coal-fired units. The scenario assumes that, to this end, around 2035 the total capacity of the country's two-six SMRs should be 600-1.06 MW (two BWRX-300 reactors from Orlen of 300 MW each and possibly six KGHM units from NuScale of 77 MW each). In the following years, their number should steadily increase, so that around 2040 at least part of Orlen's planned pool of such facilities will be operational.

An important advantage of SMRs may be their location closer to the potential consumers of the electricity and heat generated by them (including human settlements and industrial plants). This is supported by their modularity passive safety systems, which reduce the risk of LOCA (i.e. loss of coolant), or smaller power, which translates into lesser post-load energy. This means that, unlike in the case of large units, in the case of small reactors a much smaller area can be excluded from investment due to so-called exclusionary conditions. It can be estimated that there are up to several hundred potential locations for such units in the country, which will not only make their construction much easier, but also – combined with their smaller capacity – enable them to better match local demand. In this respect, SMRs will also have the advantage of being more flexible – it is estimated that a power change rate of up to 10 per cent per minute is to be possible, which would be at least twice as good as for conventional units (although still significantly worse than for gas-fired units).

Small reactors are an attractive prospect in the context of the transformation of Polish industry and the heating sector, especially working in cogeneration and in cooperation with RES sources. The increasingly real need to reduce investment in gas is forcing large companies to look for zero-carbon, stable sources of generation – not only electricity, but also process heat and technological steam.

However, the technological factor acting against SMRs is time – European industry is already having to decide how to decarbonise its business, while small reactors will not be available on the market until next decade at the earliest. Moreover, their exact lifetime is still unknown (it may be lower than expected). Nevertheless, it is not impossible that in the longer term they will become the first choice for companies planning to continue operations in Europe.

Legal aspect

Small nuclear reactors can be deployed in the domestic power industry at a faster pace than conventional units. The entry threshold for such investment has the potential to be lower and, as a consequence, SMRs may be erected in many places simultaneously. However, this requires the creation of an appropriate regulatory framework tailored to this technology. **The current regulatory environment, while in theory allowing the construction of a small reactor, is designed with large power plants in mind and requires an investor building an SMR to go through the same complex permitting process as for a standard plant.** This offsets many of the advantages of small reactors, as the investment process is significantly lengthened and its costs grow.

In a balanced scenario, it would be advisable to distinguish in legislation between large-scale nuclear reactors and SMRs, so that the latter can be exempted, for example, from the obligation to obtain a fundamental decision (after state certification or recognition of foreign certification, e.g. from the US or Canada) or to carry out a multiple project impact assessments.

Social aspect

The balanced scenario requires identical measures to the minimum scenario. However, it will be necessary to overcome the so-called NIMBY effect also in the area of Pątnów and neighbouring areas (or even in the whole Wielkopolska region). In this case, activities building public support for the construction of the nuclear power plant will potentially be able to benefit from a kind of "bonus" obtained with a similar investment in Choczew. On the one hand, the relevant central and local authorities will be able to build on the experience gained from it. On the other hand, there will be greater awareness among the local community, which will probably already be well informed about the benefits of reactor construction and the details of its implementation.

It can be a major challenge to convince the public to build SMRs – both the general Polish public and residents of a particular region. As a new technology on the market, they may be perceived as an untested solution and thus generate a number of risks (e.g. in terms of economics and safety). This is why investors as well as central and local authorities should build public support for small reactors with actions at three levels: by providing support to residents inside and outside the local community, by taking actions of a substantive nature (e.g. by providing reliable information) and by providing them with the opportunity to actively participate in the decision-making process.

In any case, the local community should have the knowledge and guarantee of achieving tangible benefits related to the construction of SMRs, both directly resulting from the implementation of the investment and indirectly (e.g. in the form of promotion of the region).

Financial aspect

This scenario is based on the timely construction of all conventional nuclear power plants. As a result, four reactors would have to be operating in the country in 2035 (two each at Lubiatów-Kopalin and Pątnów), five in 2037 (of which three under the PPEJ), six in 2039 (of which four under the PPEJ), and seven in 2041 (of which five under the PPEJ). At the same time, the construction of two additional units at Pątnów will be under consideration. In the meantime, more SMRs will be commissioned and by the end of the 2030s most of the planned facilities will be in operation, including those belonging to smaller market players. As a result, their number in 2040 will range from a dozen to more than 20 units.

The cost of this scenario is impossible to determine, but it will significantly exceed PLN 500 billion (excluding the cost of debt). Taking into account the current conditions, such large funding in the perspective of several years (or even sooner, if the majority of investments would have to start in this decade) will not be possible to obtain without:

- a substantial involvement of the State Treasury and its subordinate institutions and companies,
- extensive support from external entities,
- a significant cost participation of electricity (and partly heat) end users in the costs of their implementation.

On this basis, it can be assumed that at least differential contracts financed by a broad-based tariff model should be among the support schemes considered.
The scenario of nuclearisation of Poland requires a systemic change in the approach to state aid, so that the development of nuclear power, and therefore the energy transition, can be covered by structural support from government agencies. Without this – to a much greater extent than in the other scenarios – the market will not be able to provide sufficient capital, especially in view of the still limited business credibility of at least some of the nuclear projects under consideration.

An additional challenge will be the increase in the price of essential goods and services due to the insufficient number of subcontractors for nuclear projects. At the same time, subsequent projects will not necessarily involve as much associated investment, which may allow their unit cost to be reduced. However, a risk factor in this respect is the timing of the technological maturity of the SMRs and the commercial maturity of the European version of the KHNP reactor, as well as the need for massive expansion of distribution networks, including heating.

Staffing aspect

The more nuclear projects there are in the country, the harder it will be to provide them with the necessary human resources. The reason for this will be both the current deep shortage of human resources on the market and the expected radical increase in wage pressure in the sector, especially among highly qualified and experienced people. This will increase investment costs, but may also delay implementation, not least as a result of the very high risk of a staffing gap on the part of the administration, which will not be able to "handle" the massive construction of reactors in kind. As a result, it will most likely have to rely on even more support from foreign experts, which will be very costly.

In this scenario, there will be an immediate need to increase investment in education of nuclear power personnel and employment in the sector, especially in the R&D and operation of future reactors. Increasing the skills of the public sector (especially in regulatory and inspection institutions) will also be key.

In any case, the key to the success of the measures taken is their consistency over the long term and the predictability of the actions of all stakeholders, especially public ones. For the latter purpose, it is worth considering the conclusion of a sectoral agreement defining precisely the objectives of building human resources for nuclear power. The parties to the agreement should include central and local authorities, representatives of academia, companies interested in participating in nuclear investments, and non-governmental organisations. The actions indicated therein could consist, among other things, of:

- Set precise, measurable milestones for the training of professionals.
- Creating a point of contact for companies interested in participating in nuclear investments. It would be a source of information on the criteria involved, the actions to be taken, detailed certification and technical requirements or possible support mechanisms (including sources of funding for the activity).
- Create clear guidelines and a "road map" for companies to align their operations with the requirements of the nuclear power sector.
- Develop and implement a schedule of regular training for the business on expanding HR expertise.
- Implement a mechanism to promote companies investing in building human resources for nuclear power (e.g. through a system of special certificates or easier access to government programmes).
- Establish nuclear task forces in academic centres. These should work closely with business, administration (central and local), representatives of all stages of the nuclear value chain, and coordinate actions taken at universities.
- Develop and implement possible legal changes to remove "bottlenecks" in the process of developing human resources for the sector.

Technological aspect

The atomisation of Poland would make nuclear reactors of various scales the dominant source of generation in the Polish energy system around 2040, alongside RES and gas. Their share in the mix could exceed 40 per cent, which would allow for the rapid shutdown of gas-fired units, many of which may become unprofitable in the next decade. In this variant, only a few of the most efficient coal-fired units will be in operation in the country, but their share in the generation structure will be less than 10 per cent, compared to the dozen or so per cent envisaged in the current version of Poland's Energy Policy until 2040.

The nuclearisation of Poland will make it possible to make up for the expected loss of capacity in the Polish energy system and fill the projected supply gap in it. Nuclear reactors could also become an important source of zero-emission electricity for industry, which will also have the opportunity to reduce its dependence on hard-to-control RES.

A prerequisite for the development of a large number of small nuclear reactors will be the rapid development and improvement of the technical condition of the national transmission and distribution network. Currently, in many places, the latter may not allow the reception of electricity from these installations, which raises the risk of refusals to connect them. The Charter for the Effective Transformation of the Distribution Networks of the Polish Power Sector, signed in November 2022 by the head of the URE and the largest Polish DSOs, assumes that by 2030, investments in the transformation of the sector should amount to around PLN 130 billion.

With a number of nuclear reactors of different technologies operating in the country, the challenge will be to secure the supply of nuclear fuel. These will largely have to come from multiple markets (e.g. the US), which will increase their price and make the contracting process more difficult. An additional problem may be the growing amount of nuclear waste. The nuclearisation of Poland will require an accelerated decision on the construction of a new nuclear waste repository.

Legal aspect

The nuclearisation of Poland will unconditionally require the inclusion of both large and small nuclear reactors in EU decarbonisation plans. **The need for simultaneous implementation of multiple projects of different scales may require differentiation of their nature in the current legislation.** Extensive procedural improvements for SMRs and acceleration of their licensing process (including an exemption from the need to obtain certain administrative decisions) will potentially be needed so that they can be built much faster than conventional nuclear units. With far-reaching respect for the rights of local communities, in the case of SMRs, regulations should also allow for a shortened public consultation process. Similarly, projects accompanying their construction should be able to benefit from an accelerated procedure.

For this scenario, it makes sense to develop a separate special act for SMRs in the longer term. This should be done as soon as the specification of this technology, its design conditions and requirements regarding safety, the scope of the siting and environmental report or the assessment of the site to be developed are fully known.

It would also be potentially worthwhile to consider measures to simplify the connection of small reactors to electricity and heat networks, or at least to limit the scope of the preliminary location report to those data on the location of the SMR that are already in the resources of the relevant institutions. The report could contain only a preliminary assessment of the area intended for the investment (covering several locations) and refer only to the key risks associated with its implementation, such as seismic or geological ones. There would also be an opportunity to speed up investment by exempting investment in SMRs from the obligation to obtain a fundamental decision, or making it non-discretionary. As a result, the energy minister would not be able to refuse to issue it.

It is possible that, over time, it may also be advisable to differentiate the fees incurred in the administrative phase of the investment for different reactor sizes. A prerequisite for this is that the construction of SMRs results in a lesser amount of work for the PAA, which may happen after the first FOAK projects have rolled out.

From the point of view of industry, the regulation of direct lines, which connect industrial plants to generation sources without the intermediation of the relevant electricity grid operator, will also require further changes. One solution could be to exempt owners of direct lines from a solidarity charge incurred for the electricity grid operator's "readiness" to supply electricity.

Social aspect

The nuclearisation of Poland will require widespread, very high and sustained public acceptance for the construction of nuclear reactors. The biggest challenge in this respect will be to overcome the so-called NIMBY effect.

It is likely that a sense of threat to the planned investment will prevail in many SMR construction regions, particularly reinforced by declared opponents of nuclear power, characterised by a strong degree of attachment to their place of residence. The more of the latter, the easier it will be for them to construct a narrative that the investment poses a threat to the identity and values, and even the existence, of the entire local community. Often, such people organise themselves into formal (e.g. associations) or informal structures in an attempt to block changes to planning documents or limit the scale of investment.

At the same time, following the experience of projects in other sectors of the economy, it cannot be ruled out that a large proportion of those averse to nuclear power will remain moderately active or even passive in their opposition, with their actions being limited to, for example, signing petitions. Identifying such people at a sufficiently early stage of the investment and making attempts to convince them are key to avoiding an increase in the number of opponents of reactor construction at the expense of their supporters.

The actions of authorities and investors should aim to avoid the concentration of NIMBY conflicts. In some regions, this may require investments to be carried out at an appropriate distance from each other, and in others to carry out several projects, e.g. where there will be high public approval for this.

In any case, the selection of the location of future SMRs should not be done in a "pointing-convincing" mode (for development on the site), but the reverse. It is crucial that surveys of support for nuclear power in the area of the planned development are conducted well in advance and over a long period of time. These should cover the structure of the given community and its diversity in as much detail as possible. Their effect should not only be to examine the chances of a smooth construction of SMRs, but also to avoid generalising and stereotyping in terms of conclusions regarding the general approval of Poles in this area.

Authorities and investors should avoid acting according to the so-called DAD (Decide Announce Defend) mechanism. This is because it usually assumes in advance the impossibility of opting out of a planned action, public resistance to it, a dichotomy between the authority and the local community, and a conflict of their interests. Such an approach should be replaced by a participatory, dialogue-based and deliberative approach, in which the public will not be a passive recipient of decisions, but a subject of multidirectional communication between equal parties.

Conclusion

Presently, the construction of only two conventional nuclear power plants in Poland, as foreseen in the current version of the PPEJ, is currently the most likely scenario. Its implementation is necessary in the context of Poland's strategic interest, including the economic and political challenges it faces, and possible in the context of economic, technological, legal, environmental and social conditions.

The other planned nuclear projects are at a very early stage of implementation and are currently mainly expressed in stakeholder declarations. However, the actions taken and planned so far are aimed at implementing at least the balanced scenario. Nevertheless, the nuclearisation of Poland is still a feasible scenario and at a minimum the most desirable from the point of view of the needs of the national economy. Its implementation would require the generation of a "snowball" effect – the implementation of further investments would fuel additional investments, which would increasingly benefit from economies of scale. In this way, within a twenty year time horizon, Poland would have a chance to have one of the best developed and most modern nuclear energy sectors.

The construction of each planned power plant wil require state support – largely direct (consisting of a capital commitment to the project), but also indirect, such as the provision of guarantees. Its financing model may be based on a contract for difference, supported by extensive experience in its use and financial security on the part of the investor. Its downside, however, will be high costs on the part of the State Treasury and the need to notify the EC of each measure, which will involve complicated negotiations. The SaHo Model may also be promising, mainly due to the prospect of reducing the state's capital share in the project. However, there are many indications that at a further stage of construction of nuclear power plants in Poland, end-user participation in their costs will be inevitable.

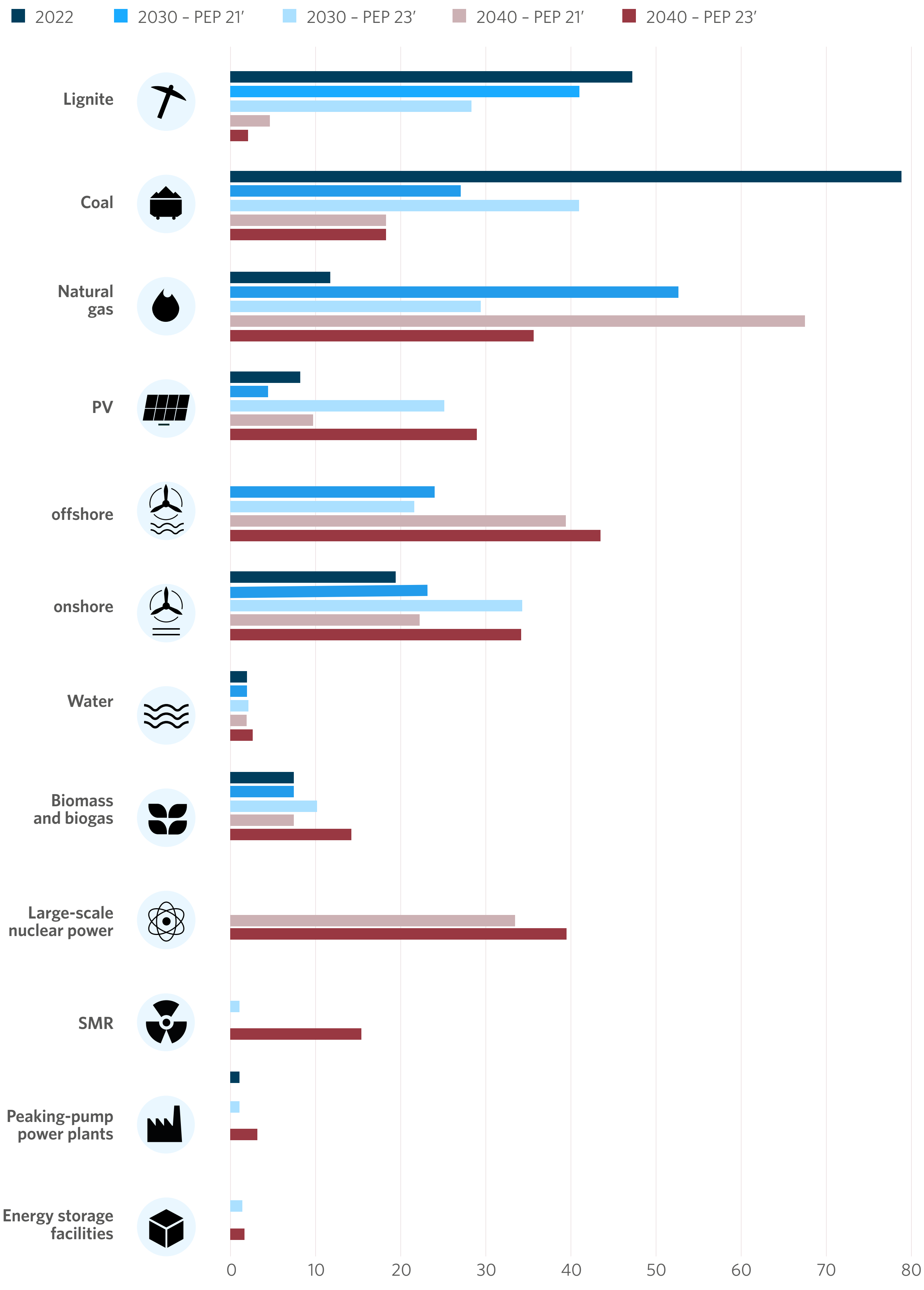
The construction of nuclear reactors will be in Poland requires sustained and high public support. The starting point for action in this regard is the current level of approval for nuclear power, which, however, depends mainly on external factors and may therefore fluctuate. The starting point should be to increase trust in public institutions and to agree on a cross-party consensus on the legitimacy of reactor construction. Concrete actions should be as much dedicated to the "general" public as to communities in those regions where nuclear investments will be made.

In any scenario, a formidable challenge will be the supply of human resources for reactor construction and operation. An immediate increase in investment in their training and a halt to the outflow of staff from R&D institutions and public administrative bodies is essential. In the medium term, however, their human resources should be significantly expanded.

At the very least, it is necessary to ensure that regulatory needs are monitored and their improvements are implemented on an ongoing basis in the application of the Nuclear Act and the nuclear Special Act amended in 2023. The measures provided for in them largely meet the needs arising from the investments foreseen in the Polish Nuclear Power Programme, but the construction of SMRs in the longer term will probably require adaptation of regulations to the specifics of this technology.

Regardless of the scenario, the priority should be to take real steps towards the development of nuclear power plant in Poland as soon as possible and for successive governments to continue to do so. Among the most urgent measures are: choosing a financial model for investments and defining a strategy for raising capital for their implementation, finalising and formalising talks on the rules for the construction of the power plant in Lubiatów-Kopalin, using the provisions of the Nuclear Act and the Special Act to streamline the investment process and taking structural measures to build a workforce for the sector. In the medium term, however, it is advisable to develop a comprehensive strategy to involve Polish companies in the implementation of the investment, while in the perspective of the end of the decade, it is necessary to prepare Polish companies and administrations for a possible boom in the SMR market, so that the technology can be quickly implemented.

NET ELECTRICITY GENERATION FORECAST TO 2030 AND 2040 ACCORDING TO THE 2021 AND 2023 PEP (TWH)



SOURCE: OWN COMPILATION BASED ON THE DATA OF MINISTRY OF CLIMATE AND ENVIRONMENT.

SUMMARY OF THE SCENARIOS

Scenario	Assumptions	Perspectives	Actions
MINIMUM	Timely construction of two 6-9 GW nuclear power plants (PPEJ)	High costs, staff shortage, favourable regulatory environment, high public support, stable technological and environmental conditions, significant reduction in the share of coal in the energy mix	Selecting a financial model, urgently contracting a technology supplier and contractor for the first NPP, taking structural steps towards building a human resources base, ensuring the application of the Nuclear Special Act
BALANCED	Timely construction of two 6-9 GW nuclear power plants (PPEJ) and two reactors at Pątnów, as well as the roll-out of the first few SMRs	High costs, risk of no/delayed commercialisation of SMRs, staffing shortage, technology "neutral" regulations, high public support, large environmental benefits, rapid shift away from coal in power generation and partly away from gas	Development of a strategy for the construction of Polish local content and a policy of support for companies, formalising plans for the construction of the Pątnów NPP (financial model, cost cover, technology supplier and contractor)
NUCLEARISATION OF POLAND	Timely construction of two 6-9 GW nuclear power plants (PPEJ) and at least two reactors at Pątnów, as well as the launch of more than 15 SMRs	Huge costs (snowball effect required), massive staffing gap, no Special Act for SMRs, risk of lack of local community support, not sufficiently developed infrastructure, rapid shift away from coal in power generation and partly away from gas	Development of a Special Act for SMRs, building public support, development of infrastructure (especially network)

FACTORS IMPACTING SCENARIO IMPLEMENTATION

	PERSPECTIVE		
Aspect	Short-term	Short-term	Long-term
Financial	Medium	Negative	Negative
Staffing	Negative	Negative	Negative
Legal	Positive	Positive	Medium
Technological	Medium	Positive	Positive
Social	Positive	Medium	Negative
Environmental	Positive	Positive	Positive

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BAKER MCKENZIE has been advising key players in global energy and natural resources markets for more than 70 years. The firm is engaged regularly in both global and regional projects as a leading legal and tax advisor. Experience in the nuclear energy sector includes advising on projects for the construction of new nuclear power plants in the United Kingdom, United Arab Emirates, Egypt, South Africa and Hungary, among others. The firm has advised on nuclear liability, related insurance, export control of nuclear materials and technology, nuclear fuels, and other key aspects in the development and operation of both large-scale nuclear power plants and SMRs. The firm counts EDF, Hitachi Energy, Energoatom, KHNP, Nuclear Mutual Limited, Urenco, and Westinghouse among its global clients. A flagship matter on which the firm recently advised is the Barakah project, involving the construction and financing of the first nuclear power plant in the United Arab Emirates. The project which has now been completed consists of four APR1400 units generating a total of 5380 MW, at a cost of more than USD 25 billion.

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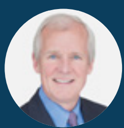

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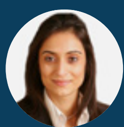

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