Plan of decarbonisation of the domestic power industry through modernisation with the use of nuclear reactors

KM4.1 Preliminary feasibility studies for Generation III reactors – Dolna Odra

Contractor: **Energoprojekt Katowice S.A.**

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1. **Land use plan**
2. **Investment schedule.**
3. **List of professions in nuclear and coal-fired power plants**

1. Basic information about the project

The aim of the project is to develop a plan for decarbonising the Polish national energy sector through modernisation using Generation III/III+ and IV nuclear reactors.

The ongoing transformation of the Polish power system reinforces the need to develop a coherent structure that ensures stability and security. The decarbonisation plan is being developed through seven research tasks and is intended to serve as a roadmap for future investment processes in the area of Coal-to-Nuclear policy. The project plans to launch a national Energy Transformation Cluster (KTE), which will provide organisational support for activities in the process of transforming national power plants and combined heat and power plants.

The project is being implemented by a consortium of five entities: the Silesian University of Technology, the Ministry of Climate and Environment, Energoprojekt-Katowice SA, the Institute of Nuclear Chemistry and Technology, and the Sobieski Institute Foundation. Funding for the project was obtained as part of the 6th competition of the National Centre for Research and Development "Gospostrateg".

2. Market analysis of investment demand

The main objective of this project is to investigate the possibility of replacing coal-based sources of electricity generation with nuclear energy from Generation III/III+ reactors. This solution fits perfectly into the pan-European decarbonisation plan and the pursuit of a zero-emission European electricity system.

This chapter presents the current situation in the electricity generation sector in Poland and its projected development over the next few decades, taking into account other projects, including planned nuclear power plants and new renewable energy sources, based on published government plans, strategic documents and analyses by the transmission system operator.

2.1. Current characteristics of the electricity market in Poland

The Polish electricity market operates on the basis of the Energy Law Act of 10 April 1997, as amended. The institution regulating the legal aspects of the market's operation is the Energy Regulatory Office (*Urząd Regulacji Energetyki* - URE), the transmission system operator is Polskie Sieci Elektroenergetyczne (PSE SA), and electricity trading is possible through the Polish Power Exchange (*Towarową Giełdę Energii* - TGE).

In 2024, the Polish electricity market was characterised by the following figures:

Electricity production
- 166.99 TWh

Peak demand
- 28.66 GW

Total installed capacity
- 72.8 GW

Average wholesale energy price
- PLN 418/MWh

Data source: ARE, PSE, TGE.

Figure 1 Polish electricity market

2.1.1. Structure of energy demand and supply

The required level of electricity production results from the demand for electricity within a given power system. Over the last dozen or so years, there has been an upward trend in electricity consumption in Poland. However, at the turn of 2019 and 2020, as a result of the outbreak of the global COVID-19 pandemic, a significant drop in electricity consumption was observed. The lockdowns announced by the government in 2020-2021 resulted in reduced electricity consumption, mainly in the industrial and construction sectors and among small consumers. It was not until 2022 that electricity consumption returned to the level seen before the outbreak of the COVID-19 pandemic.

Detailed data on electricity consumption by individual sectors over the last dozen or so years is presented in the table and graph below. Data for 2024 has not yet been published and will only be available at the end of 2025.

Table 1 Electricity consumption in 2013-2023

Sectors, TWh	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Own consumption of power plants and professional combined heat and power plants[1]	14.1	13.5	13.4	14	14.3	14	13.8	12.5	14.20	13.88	12.24
Own consumption of professional heating plants	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.23	0.16	0.19
Mining and extraction	8.8	8.7	8.7	8.5	8.3	8.3	8.2	7.9	8.16	7.89	7.85
Industry and construction	47.9	48.2	50	52.1	55	57.8	57.2	55.8	58.86	57.62	54.14
Water supply; sewage and waste management waste management	2.6	2.7	2.7	2.9	3	3.1	3.1	3.1	3.32	3.28	3.27
Transport	4.1	4	4.3	4.6	5.2	5.6	5.6	5.3	5.72	5.92	6.40
Small business sector consumers	68.6	70.9	71	73.9	73.1	74	72.9	72.4	73.51	74.71	71.07
Total consumption[2]	**146.4**	**148.1**	**150.3**	**156.2**	**159.0**	**162.9**	**161.0**	**157.1**	**164.0**	**163.5**	**155.2**
Consumption of consumption	100.3	101.2	101.5	103.9	101.8	102.5%	98.8	97.6	104.4%	99.7%	94.9%
Average growth rate for the period	*100.6 %*										

Source: own study based on: Fuel and energy carrier consumption (Central Statistical Office - GUS)

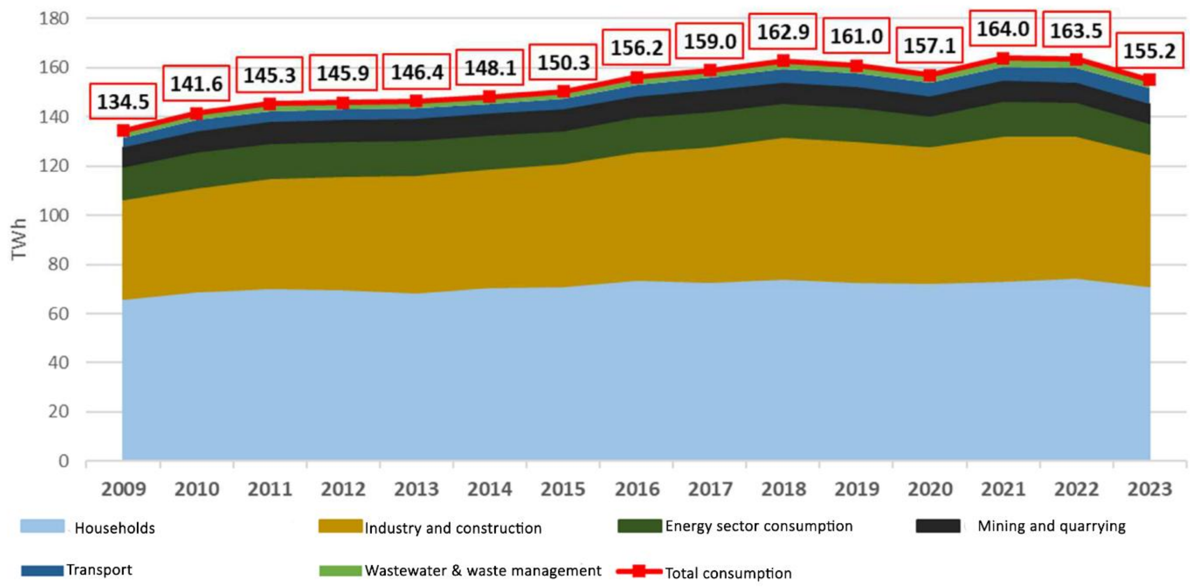

Figure 2 Electricity consumption in Poland in 2009-2023

Source: own study based on: FUEL AND ENERGY CONSUMPTION (Central Statistical Office - GUS)

[1] *including commercial heating boilers*

[2] *does not include direct consumption for heating and lighting in entities classified under section D (PKD2007)*

The progressive increase in electricity consumption is offset by energy efficiency measures, hence the decline in consumption in 2023 and the slowdown in growth observed since 2009.

Looking at the structure of energy consumption, the small consumer sector occupies a dominant position (45.8% in 2023). Industry and construction also consume large amounts of energy (34.9% in 2023). Approximately 7.9% of total consumption is accounted for by power plants and combined heat and power plants. The mining and quarrying sector consumes slightly more than 5% of energy. The least energy is consumed by the transport and water supply sector and waste management: 4.1% and 2% respectively.

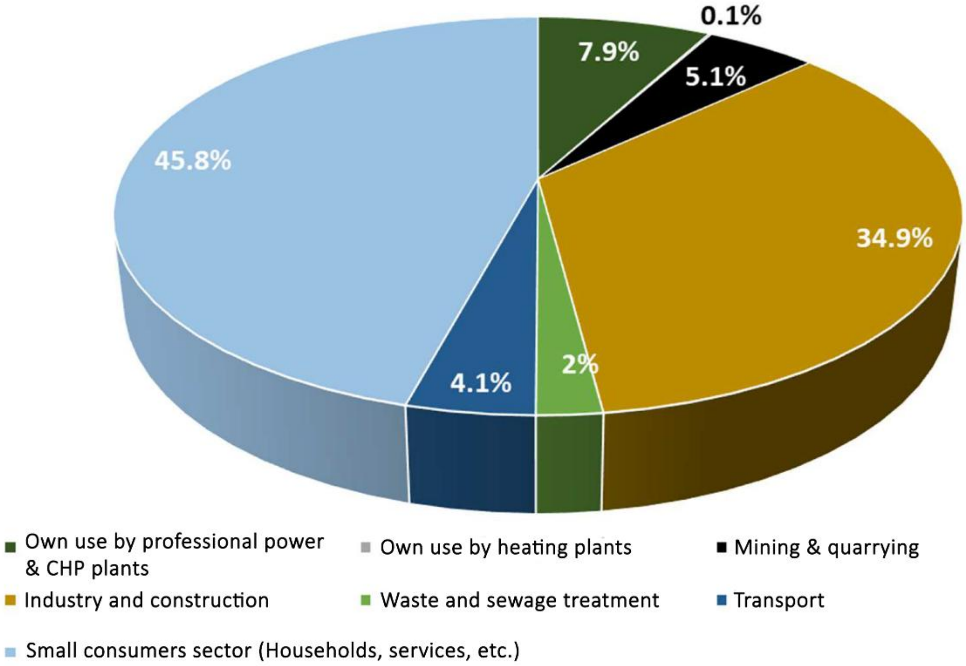

Figure 3 Structure of electricity consumption in Poland in 2023

Source: own study based on: Fuel and energy carrier consumption in 2023 (Central Statistical Office - GUS)

The decline in electricity consumption in 2019–2021 also translated into lower electricity production from domestic generation sources. Over the last dozen or so years, electricity production in Poland has shown a slight upward trend despite global events. Depending on the length of the analysed time period, it takes the following average annual values:

- 2022–2024 (last 3 years) – average increase of 2.8%
- 2019–2023 (5 years) – average increase of 0.1%
- 2014–2023 (10 years) – average growth of 0.2%

Domestic electricity production in 2024 amounted to 166.99 TWh and was over 2% higher than in 2023, while consumption increased by 0.9%. Thus, the interconnection balance amounted to approximately 2 TWh of imports. The chart below shows the changes in electricity demand and production in Poland since 2012, according to data from the transmission system operator PSE. The electricity consumption presented by PSE is higher than the consumption reported by the Central Statistical Office (GUS), which may be due, among other things, to the fact that some electricity consumers do not report to GUS.

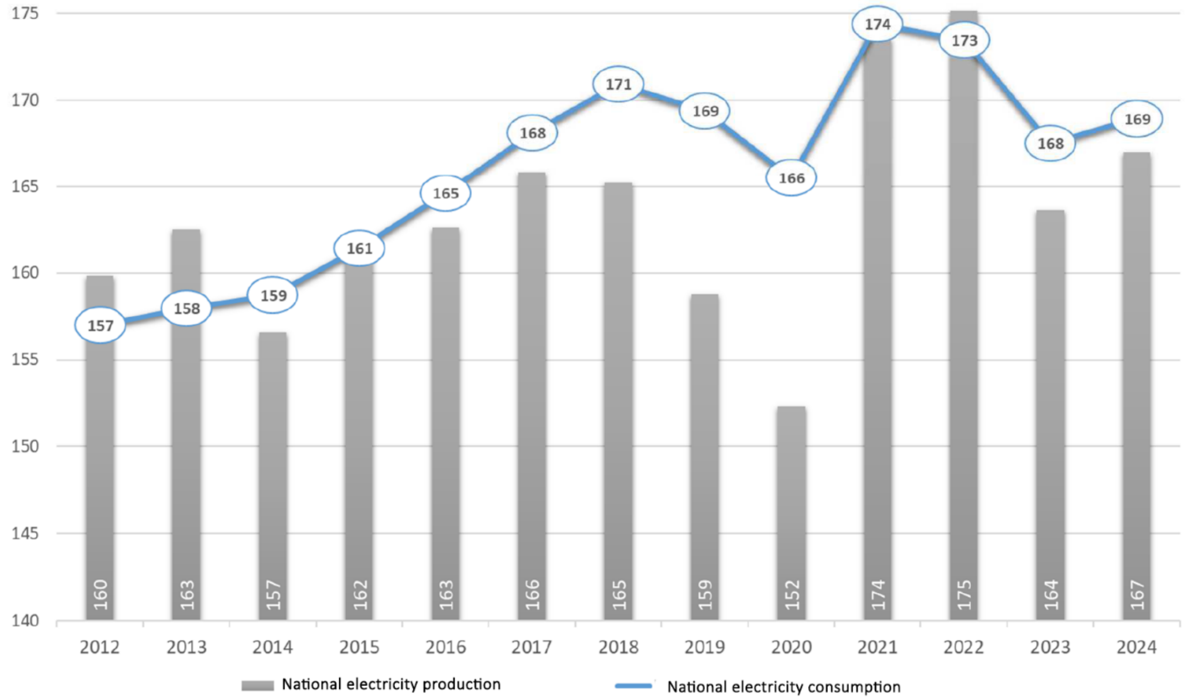

Figure 4 Electricity production and consumption in Poland since 2012

Source: own study based on PSE data

The table below presents the dynamics of changes in three time intervals, which shows that energy production in the long term has been growing with considerable fluctuation in recent years. Historical energy consumption grew until the pandemic, and after a large increase and decrease in recent years, it is now showing an upward trend again.

Table 2 Average rate of change for energy production and consumption in selected periods for the period 2013–2024

PSE data	Last 3 years	Last 5 years	10 years
Energy production	-1.2 %	+1.3 %	+0.8 %
Energy consumption	-1.0 %	+/-0 %	+0.7 %

Hard coal and lignite combustion sources account for the largest share of electricity production in Poland. However, year on year, there has been a noticeable decline in the share of these sources due to increased production from renewable energy sources. In addition, new natural gas-fired units, replacing coal-fired sources, have also increased their share in electricity production in recent years. Hydroelectric power plants have a stable share of electricity generation, similar to industrial combined heat and power plants.

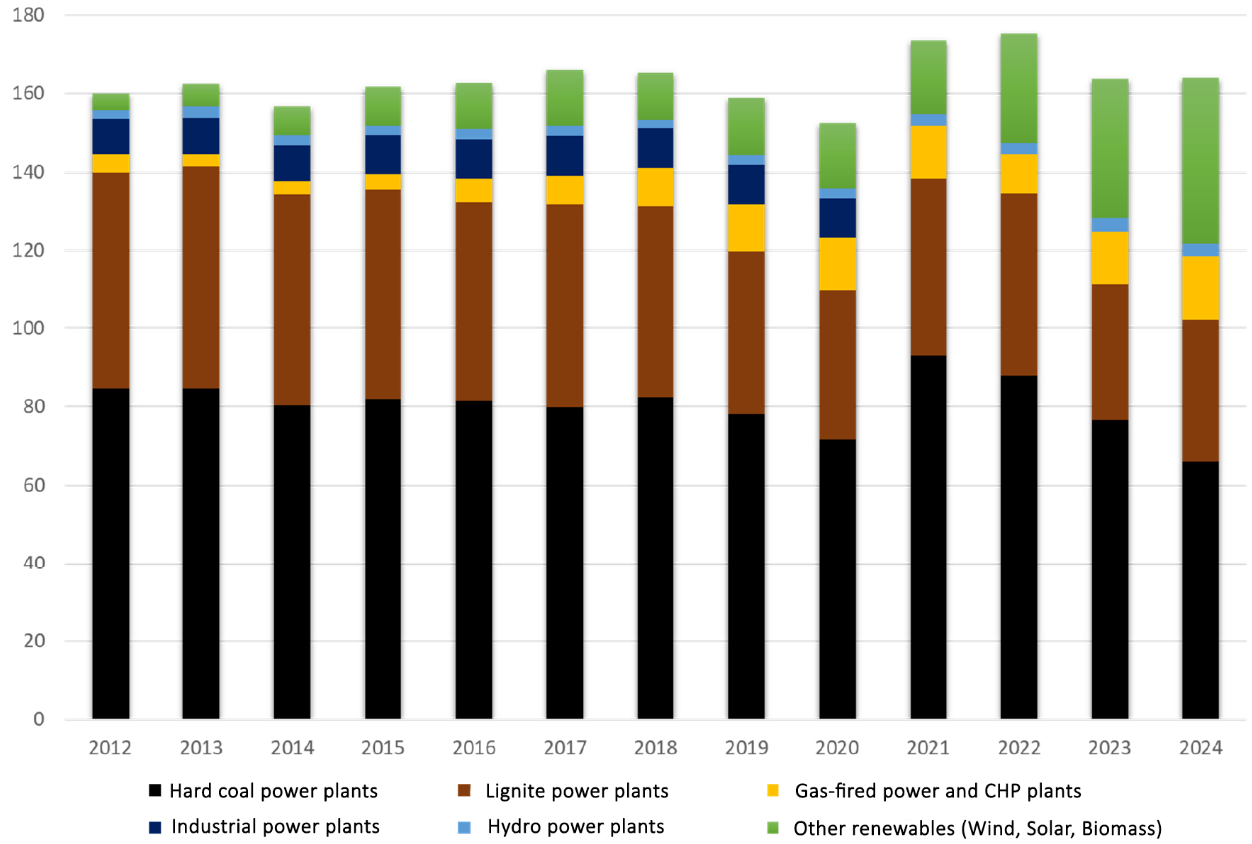

Figure 5 Structure of electricity production in Poland since 2012

Source: own study based on data from PSE and ARE (since 2019)

2.1.2. Structure of installed capacity in the National Power System

Currently, the Polish energy mix is based predominantly on coal, both hard coal and lignite. Coal fuel is burned primarily in system condensing units, as well as in industrial and municipal combined heat and power plants (cogeneration sources). Changes in installed capacity in recent years are mainly related to the growth of Renewable Energy Sources. The chart below shows changes in installed capacity in the National Power System in recent years.

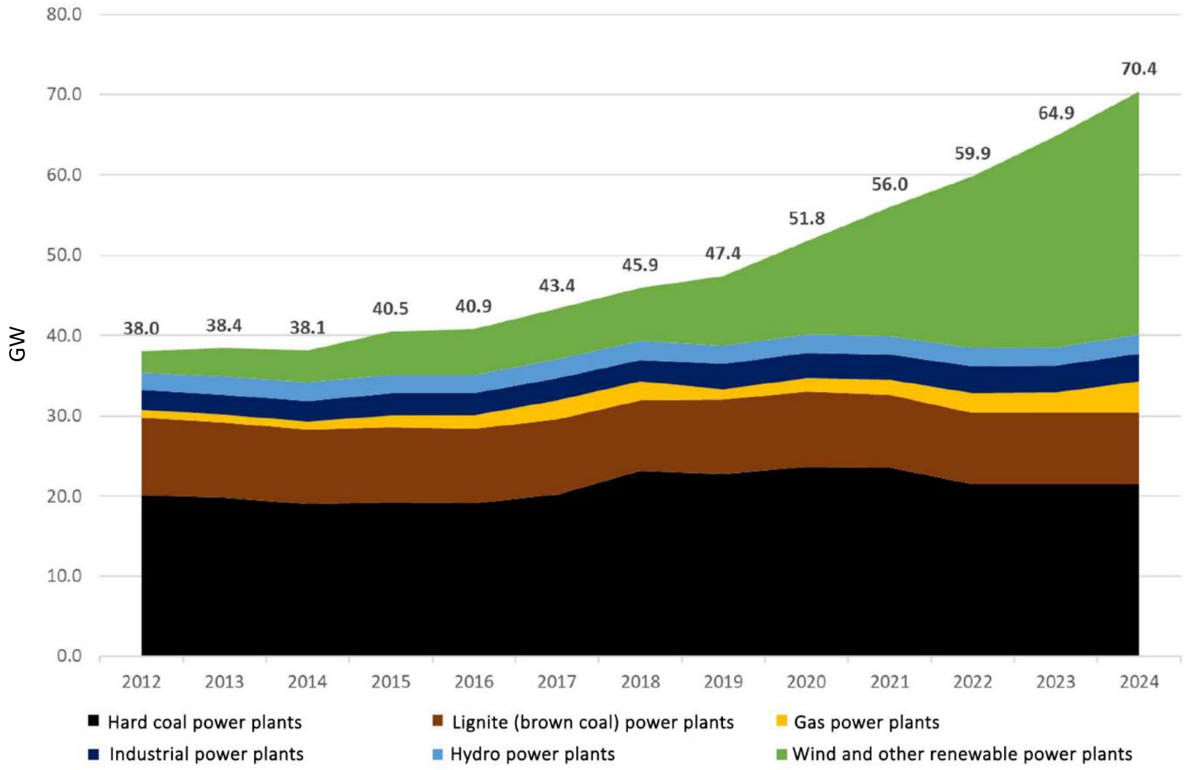

Figure 6 Installed capacity in the National Power System in recent years

Source: Own study based on data from PSE and ARE (since 2019)

In the case of new conventional generation sources, new gas-and-steam units have been connected to the system in recent years: in Włocławek – 485 MW (2017), Płock – 630 MW (2018), Stalowa Wola – 467 MW (2019) and EC Żerań – 497 MW (2021). In addition, in 2024, units in Dolna Odra with a total capacity of 1,400 MW were put into operation.

The most recent non-gas conventional investments include two units in Opole with a total capacity of 1,800 MW, commissioned in 2019, and a 900 MW unit in Jaworzno, commissioned a few years later.

Despite the appearance of the above-mentioned new units in the system, due to the age of the remaining units operating in the National Power System, the Polish power industry is not among the youngest. The majority of them are between 40 and 50 years old, and several units are already over 50 years old. The average age of generating units in Poland is over 37 years.

In terms of renewable energy sources in Poland, electricity is obtained from wind, water resources, solid biomass, biogas and liquid biofuels, as well as solar radiation. Geothermal resources are mainly used in heating installations (heating sector).

In recent years, there has been rapid development in solar energy sources, particularly in the prosumer sector – domestic photovoltaic installations.

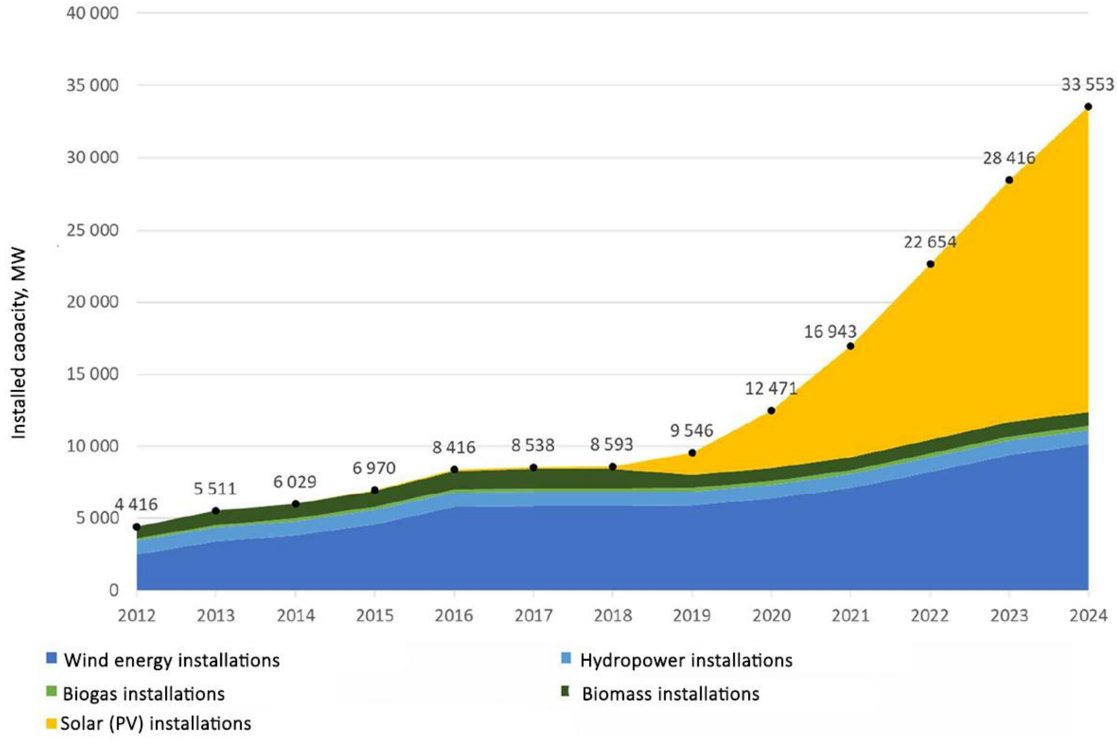

Figure 7 Installed electrical capacity in Renewable Energy Sources

Source: Own study based on data from the Energy Regulatory Office (URE) and the Energy Market Authority (ARE) (since 2019)

The installed electrical capacity of renewable energy sources in Poland at the end of 2024 exceeded 32.5 GW (according to ARE). Solar sources accounted for the largest share of installed capacity – over 19 GW. Wind installations are the next largest, with over 10 GW.

2.2. Forecast for the development of the electricity market in Poland

The following market development forecast has been prepared on the basis of the Development Plan for Meeting Current and Future Electricity Demand[3] by PSE and other publicly available reports on the functioning of the electricity market, as well as EPK's knowledge gained from many years of activity on the electricity market.

The forecasts presented are intended to indicate the conditions under which the project in question can be implemented and how the energy transition process in Poland may proceed.

2.2.1. Forecast of installed capacity

Over the years, Poland's energy mix will change as the energy generation sector undergoes decarbonisation, accompanied by significant development of renewable energy sources. Most coal-fired power units in Poland are ageing, and their modernisation does not make economic sense given the declining use of coal in the energy mix. Furthermore, coal-fired power stations have the highest carbon emissions per unit of energy (kgCO2/kWh), which means they cannot be financed through, for example, the capacity market (at present, coal-fired power stations were only eligible to participate in capacity market auctions until 2025) or the financial market (investment loans), and they also incur high CO_2 emission costs. The broadly defined taxonomy also excludes investments in this type of energy source.

[3] *Development plan for meeting current and future electricity demand for the years 2025–2034; PSE; December 2024.*
https://www.pse.pl/-/projekt-nowego-planu-rozwoju-sieci-przesylowej-na-lata-2025-2034-uzgodniony

The schedule of coal-fired unit decommissioning based on the PSE report[4] is presented below (broken down into hard coal and lignite) – these capacities will need to be replaced in the future in order to maintain an adequate level of available capacity in the system.

The diagram shows the blocks of the Dolna Odra power plant, which is considered in this report in terms of its use for the installation of Generation III/III+ reactors. It was assumed that the planned shutdown date for units 5-8 at the Dolna Odra power plant could be no later than the end of 2036, as reported by PSE in its analyses, which present possible shutdown dates for JWCD units in Poland in two scenarios, based on surveys conducted at the turn of 2020 and 2021[5].

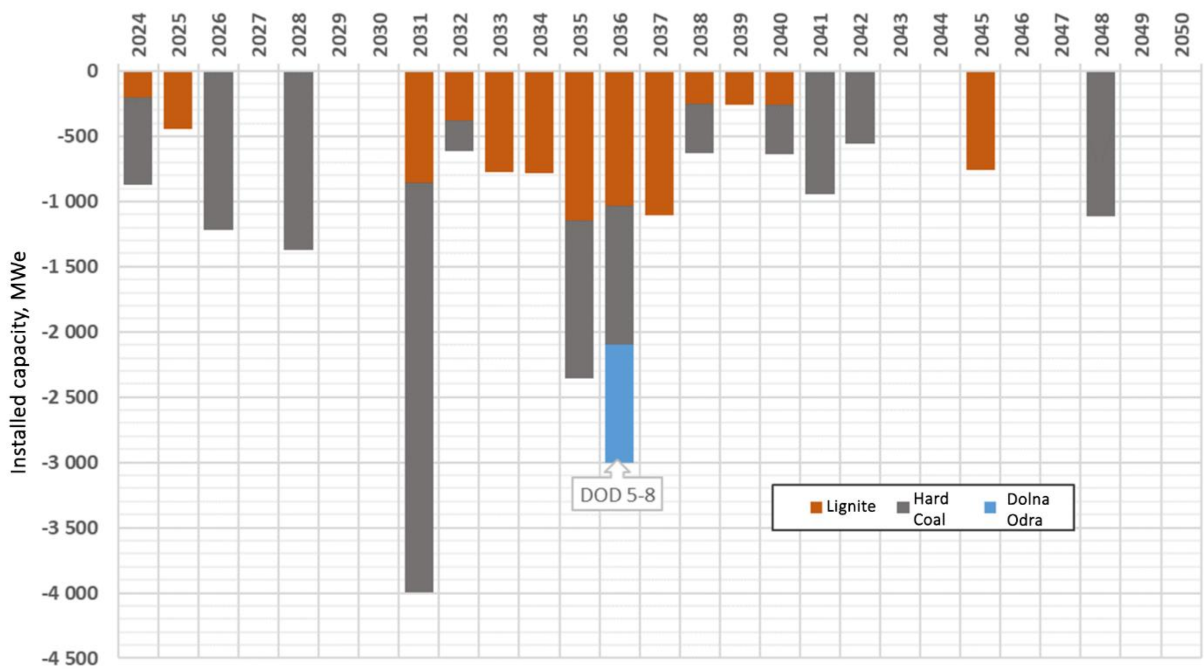

Figure 8 Schedule of shutdowns of coal-fired units participating in the central balancing mechanism. Status at the end of the year.

Source: Own study based on PSE data.

In terms of new capacity, the plan includes the construction of new combined cycle gas turbines, which were submitted for **auctions** on **the Capacity Market**. The last auction took place in December 2024 for the 2029 delivery year. The table below lists the new gas-fired combined cycle units that won the RM auctions, some of which are currently at an advanced stage of construction.

[4] *Development plan for meeting current and future electricity demand for the years 2025–2034; PSE; December 2024.* *https://www.pse.pl/-/projekt-nowego-planu-rozwoju-sieci-przesylowej-na-lata-2025-2034-uzgodniony*

[5] *https://wysokienapiecie.pl/88275-polska-ma-szanse-na-utrzymanie-starych-weglowek-do-2028-r/ 25 March.*

Table 3 Combined cycle gas turbines in Capacity Market auctions

No.	Name of power supplier	Location	Year of supply	Capacity of power obligation [MW]	Duration of capacity obligation [years]
1	PGE Polska Grupa Energetyczna S.A.	Dolna Odra	2024	667.6	17
2	PGE Polska Grupa Energetyczna S.A.	Dolna Odra	2024	667.6	17
3	CCGT Grudziądz sp. z o.o.	Grudziądz	2026	518.4	17
4	PAK CCGT Ltd.	Adamów	2026	493.0	17
5	CCGT Ostrołęka sp. z o.o.	Ostrołęka	2026	696.0	17
6	PGE Polska Grupa Energetyczna S.A.	Rybnik	2027	794.6	17

Another source that could replace coal in the energy mix is nuclear power plants. The current strategy for the development of nuclear energy in Poland is described in **the Polish Nuclear Power Programme** published in October 2020. It envisages the construction of six nuclear units every two years, starting in 2033. In total, two nuclear power plants will be built in two locations, each with three units. Currently, it is assumed that the first power plant will be built in Lubiatowo-Kopalin on the Baltic Sea and will use Westinghouse AP-1000 reactors. The location of the second power plant is not yet known, but various locations are being considered, including Konin, Bełchatów, Połaniec and Kozienice.

The Development Plan for Meeting Current and Future Electricity Demand for 2025-2034, prepared by PSE, also provides for smaller nuclear units using SMR (small modular reactor) technology. According to the PSE report, information obtained from professional electricity producers through a survey was taken into account when determining the future generation structure. Plans for the development of offshore wind farms and nuclear energy, as specified in strategic documents, were also taken into account. Information on the results of RES auctions, as well as major national support programmes dedicated to prosumer sources and the results of concluded capacity auctions, was taken into account.

PSE has prepared a projected electricity generation structure in two scenarios, the SST (Free Transformation Scenario) and SDT (Dynamic Transformation Scenario), which differ mainly in terms of the installed capacity of renewable energy sources and energy storage facilities. The table below presents the results of PSE's analyses.

Table 4 Structure of electricity generation resources in 2034

Type of power resource	SST scenario Net capacity [MW]	SDT scenario Net capacity [MW]
Lignite	4,401	
Hard coal	6,317	
Hard coal - peak sources	2,277	
Natural gas	10,772	
Biomass and biogas	2,830	
Large nuclear power plants	1,146	2,292
SMR	560	840
Hydroelectric power	1,250	
Pumped storage power plants	2,462	
Photovoltaics	36,000	45,000
Onshore wind farms	16,940	19,362
Offshore wind farms	10,900	11,885
Energy storage facilities	3,750	15,207
Combined heat and power plants	5,217	

Source: Transmission network development plan for 2025–2034, PSE

2.2.2. Forecast for electricity demand

The long-term forecast of energy demand in the National Power System presented in this section was prepared by PSE[6] taking into account:

- historical trends and the forecast for final energy consumption.
- macro factors affecting the structure of energy consumption in the household, transport, industry and services sectors,
- changes in the area of energy efficiency,
- forecasts of Gross Domestic Product growth in individual sectors,
- technological and consumer changes, as well as changes resulting from EU directives regarding Poland's achievement of the required RES target in final energy consumption,
- anticipated structural changes in final energy consumption, i.e., an increase in the number of electric vehicles, heat pumps and fuel cells, among other things.

The prepared forecast assumes two scenarios that address the adopted path of development of the KSE environment. The first is a scenario of gradual transformation, and the second is one of dynamic transformation, which assumes a significant increase in energy demand. These scenarios are illustrated in the charts below. Both scenarios assume an increase in electricity demand in the future.

[6] *Development plan for meeting current and future electricity demand for 2025-2034; PSE; December 2024.* *https://www.pse.pl/-/projekt-nowego-planu-rozwoju-sieci-przesylowej-na-lata-2025-2034-uzgodniony*

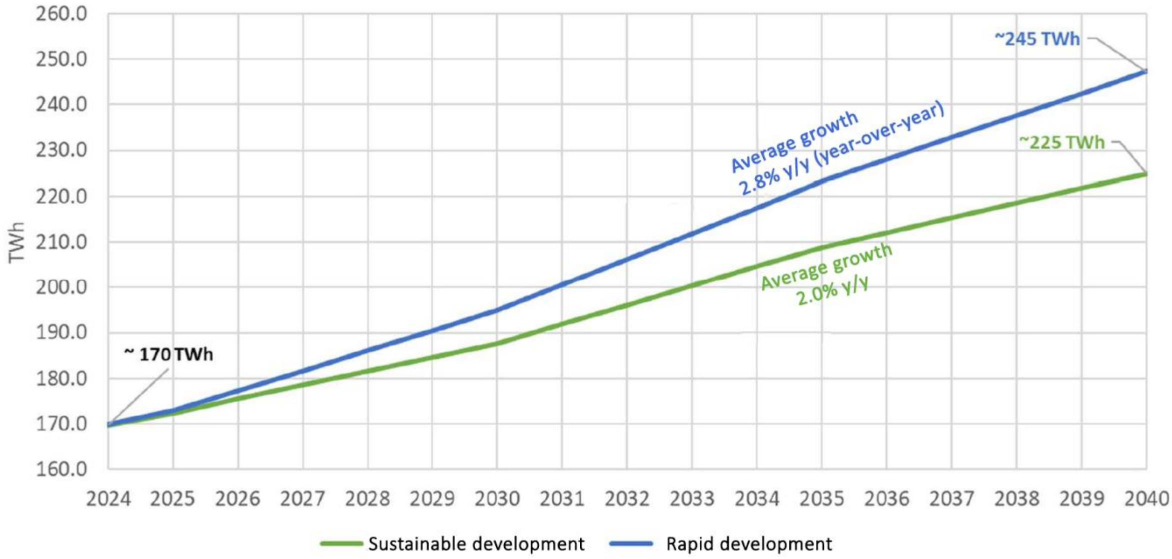

Figure 9 Forecast annual electricity demand for 2024–2040

Source: Own study based on PSE data

2.2.3. Analysis of the adequacy of generation sources

Based on the presented mix of installed capacity and projected electricity demand, the PSE Report presents the results of analyses of the sufficiency of generation sources and the security of the power system. Two power system reliability indicators, LOLE and EENS, were used for the assessment.

The first indicator, LOLE (Loss Of Load Expectation), indicates the average number of hours per year during which the power system is likely to be unable to meet electricity demand due to a shortage of (available) power in the system. This indicator helps the transmission system operator (PSE) assess whether the national power system is sufficiently reliable. The safety standard assumes LOLE values of no more than 3 hours per year (average for the climate years 1982-2019).

At the international level, LOLE is a standard used in reports prepared by organisations such as ENTSO-E (European Network of Transmission System Operators) as part of regional and pan-European analyses, such as the Mid-term Adequacy Forecast (MAF). It enables the comparison of the reliability of power systems in different countries and the identification of potential threats in the context of energy balance. LOLE is also a key element in analyses related to the implementation of new RES sources, such as offshore wind farms, where the variability of energy production requires precise estimates of demand and capacity availability.

The second indicator, EENS (Expected Energy Not Served), indicates the amount of electricity (in GWh) that will not be delivered to consumers as a result of a power shortage in the power system. This is the estimated amount of energy whose supply may be interrupted during the year due to insufficient availability of generation sources or transmission constraints.

The average LOLE and EENS values determined in the PSE Report[7] are presented below.

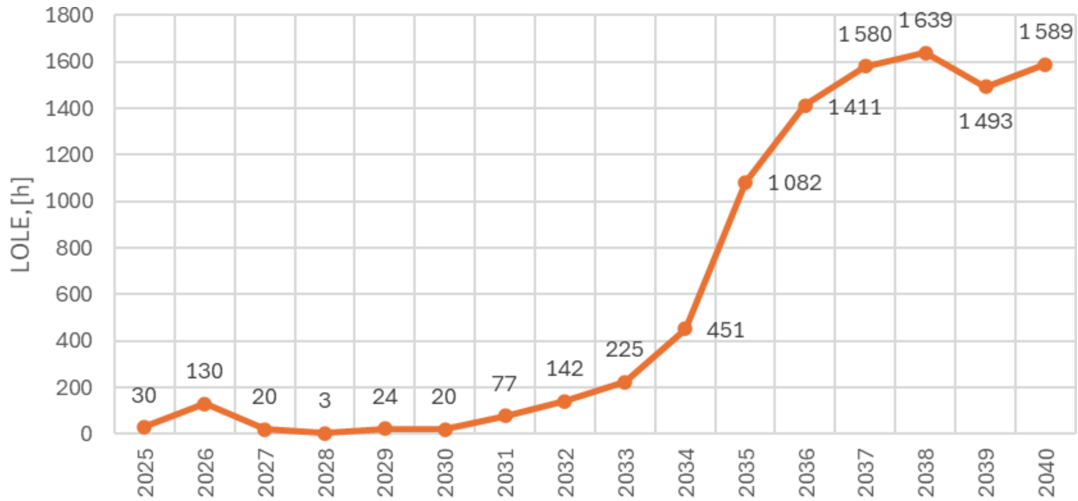

Figure 10 Average LOLE values [h/year] in 2025–2040

Source: Own study based on the PSE Report

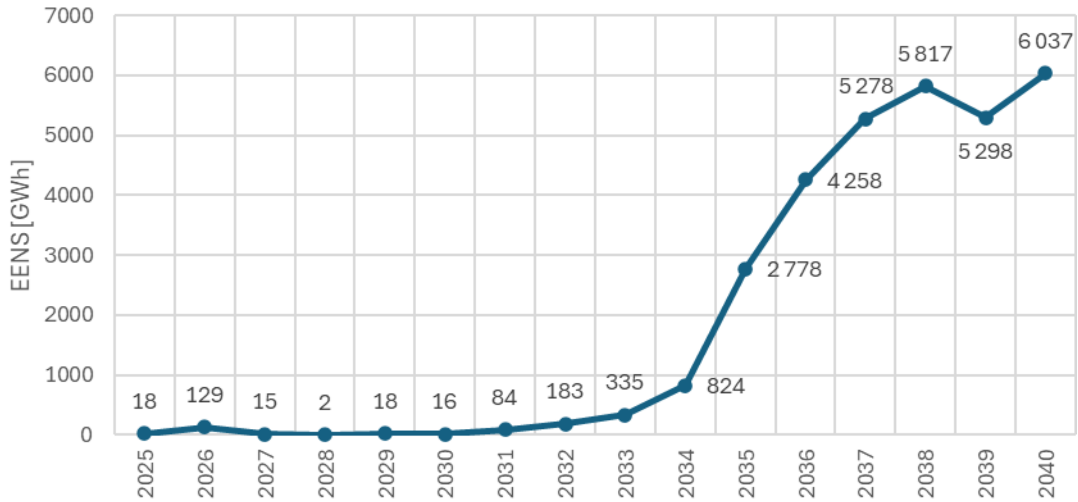

Figure 11 Average values of the EENS indicator [GWh/year] in 2025–2040

Source: Own study based on the PSE Report

Both indicators show a noticeable increase as early as 2026, followed by a decline and another increase after 2030. Between 2035 and 2040, the indicators are already several dozen times higher than the initial values. Over the entire period under review, there is only one year in which the LOLE indicator does not exceed the assumed 3 hours per year.

2.2.4. Additional available capacity required

The PSE Report presents a solution aimed at keeping the presented indicators as low as possible (including LOLE<3h). The amount of additional available capacity that would need to be added in a given year to ensure the security of the energy system has been estimated.

[7] *Development plan for meeting current and future electricity demand for 2025-2034; PSE; December 2024.* *https://www.pse.pl/-/projekt-nowego-planu-rozwoju-sieci-przesylowej-na-lata-2025-2034-uzgodniony*

Table 5 Required additional net available capacity in the National Power System [MW]

2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1,400	3,400	1,600	200	1,600	1,600	3,200	4,200	5,200	6,800	9,600	11,200	12,200	12,800	12,800	13,600

Source: Own study based on the PSE Report

As early as 2026, an additional 3.4 GWe of net available capacity will be required, and after 2030 this figure will continue to rise. By 2040, it will be four times higher (13.6 GW). As the authors of the Report mention, it should be borne in mind that the assumed additional capacity may be higher depending on:

- the pace of energy transition in the country – faster growth in electricity demand,
- climatic conditions in future years – harsher winters, less sunny summers,
- changes to the dates for decommissioning conventional units – earlier than assumed in the report,
- changes to the dates for commissioning new capacity – later than assumed in the report.

In addition, the authors of the report presented potential sources of additional available capacity, which may include:

- new gas-fired power plants (in addition to those contracted on the capacity market),
- extension of the operation of existing coal-fired units (including extension of the capacity market for them after 2025),
- new energy storage facilities (using various technologies) with accompanying new RES sources,
- new biomass and biogas power plants,
- new hydrogen and alternative fuel technologies,
- additional energy import opportunities and growth in demand-side response (DSR) services. Most of the solutions presented, apart from conventional units, are unlikely to ensure stable coverage of demand, especially in terms of high volume and continuity of supply.

2.3. Selection of optimal system structures

Based on the presented PSE forecast of demand growth and the energy mix, a team of scientists from the Silesian University of Technology in Gliwice performed a model optimisation of the power system structure in Poland.

First, for both PSE scenarios of electricity demand growth, an estimate of hourly demand changes for 2035 and 2040 was made. The figure below shows a comparison of the curves for different years, broken down into both scenarios.

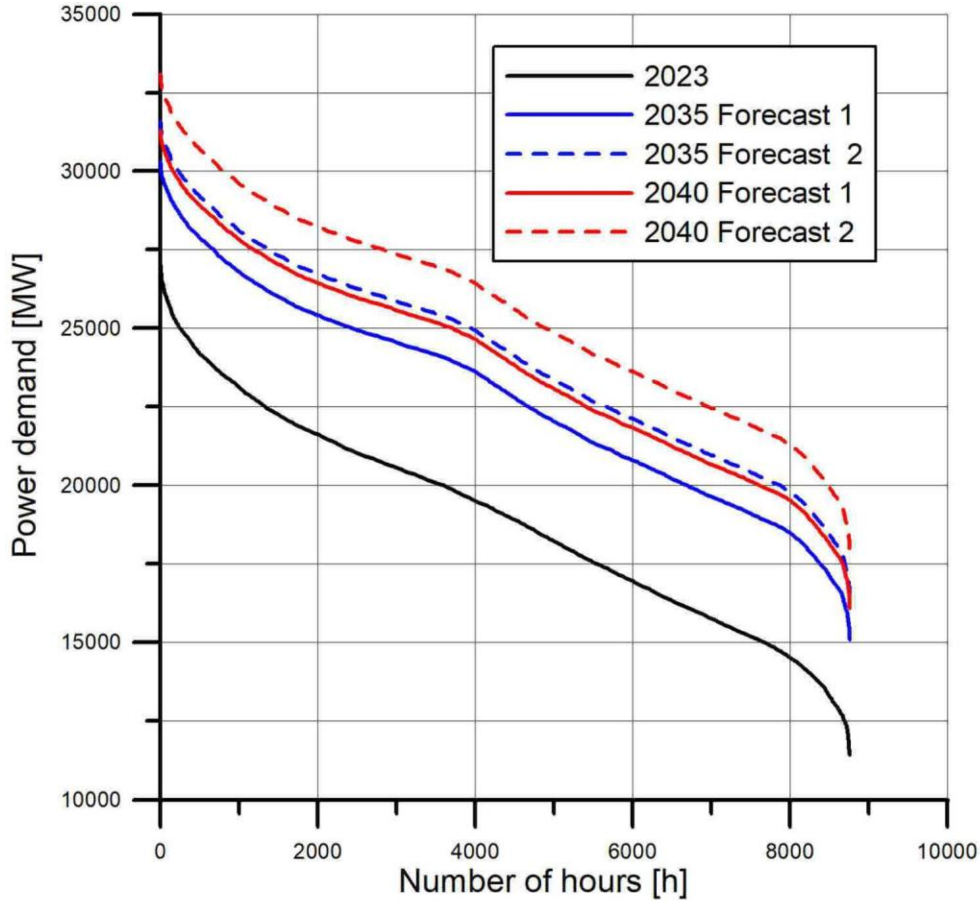

Figure 12 Power demand in 2023 and power demand forecasts for 2035 and 2040

Source: Presentation Nuclear investments and national energy security; A. Rusin, A. Wojaczek, PŚ

In the second step, the projected energy mix was determined in two cases, with greater and lesser development of nuclear energy (understood as large-scale units and SMRs). It was also assumed that the RES capacity projected for 2034 from the dynamic transformation scenario would be achieved in 2040. Furthermore, no coal-fired units were assumed in the mix after 2040, and it was assumed that no new gas-fired units would be added. The energy mix does not take energy storage facilities into account at this stage, as the required power and capacity of these facilities were the results of this optimisation.

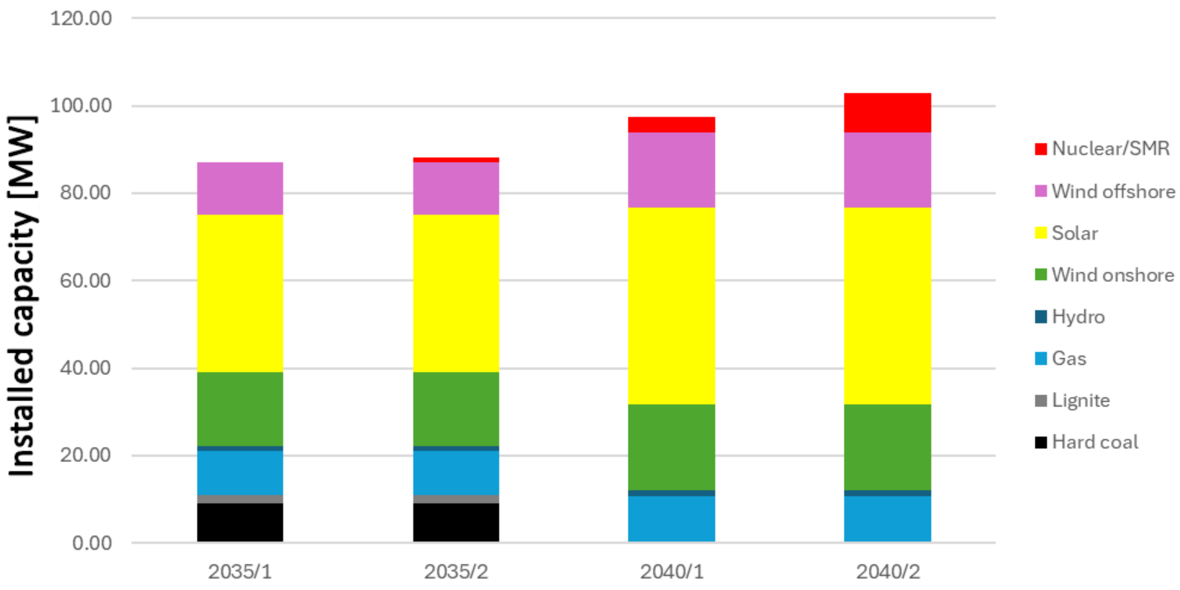

Figure 13 Forecast of generation sources in 2035 and 2040

Source: Own study based on the presentation: Nuclear investments and national energy security; A. Rusin, A. Wojaczek, PŚ

For the preliminary structure of power sources in the system and the characteristics of power demand in a given year, the optimal capacity and power of energy storage facilities were selected so that the energy system supported by these storage facilities would ensure the required reliability of energy supply. This required level of reliability was adopted as the limit value of the LOLE indicator, amounting to 3 hours/year.

Table 6 Results of optimising the parameters of energy storage faciltiies cooperating with energy systems with the adopted structures

Year/system	Demand forecast	LOLE initial [h]	Storage capacity [MWh]	Storage capacity [MW]	Number of hours of empty storage [h]	Number of hours of full storage [h]	Final LOLE [h]
2035/1	Forecast 1	30.5	7,300	1,400	65	7,791	3.00
2035/2	Forecast 2	156.1	16,400	2900	104	7,199	2.99
2035/2	Forecast 1	42.4	8700	1600	72	7696	2.99
2040/1	Forecast 2	811.6	220,000	5600	5	4822	3.22
2040/2	Forecast 1	3.7	Unnecessary storage				
2040/2	Forecast 2	90.5	11,100	2000	72	7607	3.03

Source: Own study based on the presentation: Nuclear investments and national energy security; A. Rusin, A. Wojaczek, PŚ

In conclusion, maintaining the reliability of the National Power System at an appropriate level requires the presence of a sufficient number of stable energy sources in the system to meet demand, which in the current situation cannot be fully replaced by wind and solar sources. Energy storage facilities with sufficient capacity and power must play a vital stabilising role in a system with a high proportion of renewable energy sources.

Until the aforementioned new energy sources and a sufficient number of energy storage facilities are built and commissioned, only existing coal-fired power units and new gas-fired power units can ensure the reliable operation of the energy system.

2.4. Summary of the energy market analysis

- When analysing the current situation on the electricity market, it should be assumed that demand for electricity will grow over the next few decades. Consequently, electricity production should also grow or remain at a level that allows the system to be balanced in conjunction with, for example, energy imports or demand reduction.
- The presented schedule for decommissioning coal-fired units indicates a significant decline in coal-based power generation in the coming years. In addition, most of these power plants are already quite old, and it will be difficult to extend their operation. The planned new gas-fired units will most likely not replace coal-based sources on a 1:1 basis. In Dolna Odra, some of the coal-fired units have already been replaced with combined cycle gas turbines, and the remaining ageing coal-fired units may be decommissioned after 2030.
- Given the current situation in the electricity generation sector and the direction set by EU countries towards a zero-emission system, it seems reasonable to develop new nuclear-based investments. On the other hand, gas-fired units with lower CO_2 emissions are transitional on the way to zero-emission electricity production, which will also be enforced by the EU (e.g. through investment financing mechanisms – exclusion of fossil fuels, taxonomy, carbon footprint, requirements regarding reporting on sustainable development, in particular the CSRD directive, etc.)
- The projected significant growth in renewable energy sources (over 30 GW in PV by 2034 according to PSE forecasts) and their "priority" in electricity sales may hinder the operation of large conventional units by limiting their use in the market. Even despite the assumed development of electricity storage, the system may still require dispatchable units to ensure security on the generation side, especially in the Dolna Odra location, which secures the north-western part of Poland.
- According to the SE optimisation carried out by the Silesian University of Technology, without stable generation sources (such as nuclear power), the power system in Poland will need very high-capacity storage facilities (even over 220 GWh) with a large number of cycles (which affects the service life of the storage facilities).
- In turn, according to PSE analyses, without additional available capacity, it may not be possible to ensure an adequate level of security for the power system, or other mechanisms (DSR, emergency energy imports) may be activated, which may lead to an increase in electricity costs or, in a critical situation, to a blackout.

3. A detailed assessment of the technical condition of the site's existing infrastructure in terms of its suitability for use by a nuclear power plant, including the infrastructure necessary for the plant's operation, i.e. transmission networks, road and rail infrastructure, and external and internal water sources

3.1. General information

The Dolna Odra Power Plant is part of the PGE capital group, PGE Górnictwo i Energetyka Konwencjonalna S.A.; it is located in Nowy Czarnów near Gryfino in the West Pomeranian Province. The full name of the branch is **"PGE Górnictwo i Energetyka Konwencjonalna S.A. *(PGE Mining and Conventional Energy S.A)* – Dolna Odra Power Plant Branch".** Its core business is the generation, distribution and trading of electricity, as well as the production and distribution of heat.

3.1.1. Existing generation units

The Dolna Odra Power Plant is a coal-fired thermal power plant. In the past, the power plant operated eight 200 MW units, which were gradually commissioned between 1974 and 1977. Based on the provisions of the IED Directive, units 1 - 4 were decommissioned between 2012 and 2020, creating a permanent power loss in the power system of approximately 850 MW, compensated by the power from the new coal-fired unit at the Turów Power Plant. Currently, the power plant has four coal-fired units with a total installed electrical capacity of 908 MW_e and a thermal capacity of approximately 91 MW_t. The power plant functions as a "must run" unit, which means that its operation is necessitated by grid security considerations.

All operating and decommissioned generating units (Nos. 1 - 8) use or used an open condenser cooling system using water taken from the Odra River.

Currently, two gas units with a gross electrical capacity of 683 MW each are in the start-up/commissioning phase on the premises adjacent to the PGE GiEK power plant. The units are based on a single-shaft system, a so-called combined cycle gas turbine (CCGT) unit, consisting of the following components:

- gas turbine,
- generator,
- recovery boiler,
- condensing steam turbine.

The GE turbines installed at the Dolna Odra Power Plant are designed so that they can be relatively easily adapted to burn gas mixed with hydrogen in the future. This will enable a further reduction in CO_2 emissions.

3.1.2. Planned generating units

The possibility of connecting new generation sources to the National Power System will depend heavily on the geographical allocation of generation sources and electricity consumers, the transmission capacity of the grid, and the time at which the connection of new generation units is to take place. The considerations covered in this study concern the connection of new generation units based on third-generation nuclear reactors to the power system, with a time horizon of more than a decade. Given the timeframe for the development of nuclear power sources outlined above, the feasibility of implementing this project at the site under consideration will be influenced by the transmission capacity of the grid, as well as by the power generation facilities currently planned for development, with which the project under consideration will compete once it becomes operational, in terms of network transmission capacity.

Pursuant to Article 7(8l)(1) of the Energy Law, an energy company involved in the transmission or distribution of electricity is required to compile information on entities applying for connection of sources to the power grid with a rated voltage higher than 1 kV, the location of connections, connection capacity, type of installation, dates of issue of connection conditions, conclusion of grid connection agreements and commencement of electricity supply.
The analysed project location is situated directly at an important network node, the Krajnik Power Station (*Stacji Elektroenergetyczne*j - SE). The main competitors for network transmission capacity with the analysed project will be the power generation sources and energy storage facilities (also reserving network capacity for power transmission from the facility) currently planned to be connected to the Krajnik SE and neighbouring stations, as well as distribution networks (with generation capacity). According to current data published by Polskie Sieci Elektroenergetyczne S.A. (PSE), i.e., the operator of the 220 kV and 400 kV transmission network in the area where the analysed project is planned, the following generation and storage facilities are planned to be built in the area of the Krajnik SE and its nearest stations:

Table 7 Selected facilities planned for connection to the transmission network, to SE Krajnik substation and neighbouring stations

No.	Connection point (SE)	Power [MW]	Type of installation	Date of delivery/determination of conditions Connection
1	Roadside	340	photovoltaic installation	20202.03.13
2	Baczyna	39.96	photovoltaic installation	2020.06.10
3	Baczyna	25	photovoltaic installation	2023.06.16
4	Recław	60	photovoltaic installation	2023.07.07
5	Dunowo	499.98	photovoltaic installation	2023.08.16
6	Krajnik	245.2	distribution system	2020.05.14
7	Krajnik	245.2	distribution system	2023.04.21
8	Baczyna	46	electricity storage	2023.05.26
9	Baczyna Systemowa	53.8	electricity storage facility	2023.10.05
10	Baczyna Systemowa	121.65	electricity storage facility	2023.10.06
11	Morzyczyn	200	electricity storage facility	2023.10.11
12	Krajnik	400	electricity storage facility	2023.12.18

In total, facilities with a combined capacity of ~2.3 GW are planned to be connected to SE Krajnik and stations in its immediate vicinity, including ~1.2 GW to SE Krajnik alone.

3.2. BAT conclusions and related planned decommissioning of coal-fired power units

In recent years, coal-based energy production in the EU has fallen dramatically, and most Member States plan to phase out coal-based energy by 2030. Coal as an energy source will not be economically viable in Poland, for example due to rising prices of CO_2 emission allowances and energy production costs.

In accordance with the current integrated permit[8], only coal-fired units 5-8 are currently in operation at the Dolna Odra Power Plant. In accordance with the above-mentioned permit, the fuel combustion installation comprising the above coal-fired units should meet the requirements of the BAT (Best Available Technqes) Conclusions for large combustion plants (i.e. Commission Implementing Decision (EU) 2021/2326) from 18 July 2021.

The above-mentioned permit for these units does not mention any derogations for installations or the inclusion of the above-mentioned units due to non-compliance with the BAT conclusions. In addition, this permit has been issued for an indefinite period. Nevertheless, due to the need to update BAT reference documents every eight years, it can be expected that the requirements for energy combustion installations will be reviewed and may be tightened, particularly with regard to coal fuel. Thus, the units operated in Kozienice may simply not meet the requirements of the new/stricter BAT Conclusions. The adaptation of the above-mentioned units, taking into account in particular the degree of wear and tear of the above-mentioned units, will simply be unprofitable.

At the Dolna Odra Power Plant, units 1 and 2 were shut down at the end of 2020. Based on the available data, the remaining 200 MW units 5-8 do not have a specific shutdown date at this time. In order to determine the possible end date of operation for the remaining units, the following diagram published by PSE was used. It shows the possible shutdown dates for JWCD (*Jednostka Wytwórcza Centralnie Dysponowana* - Centrally Dispatched Generating Unit) units in Poland in two scenarios, based on surveys conducted at the turn of 2020 and 2021[9].

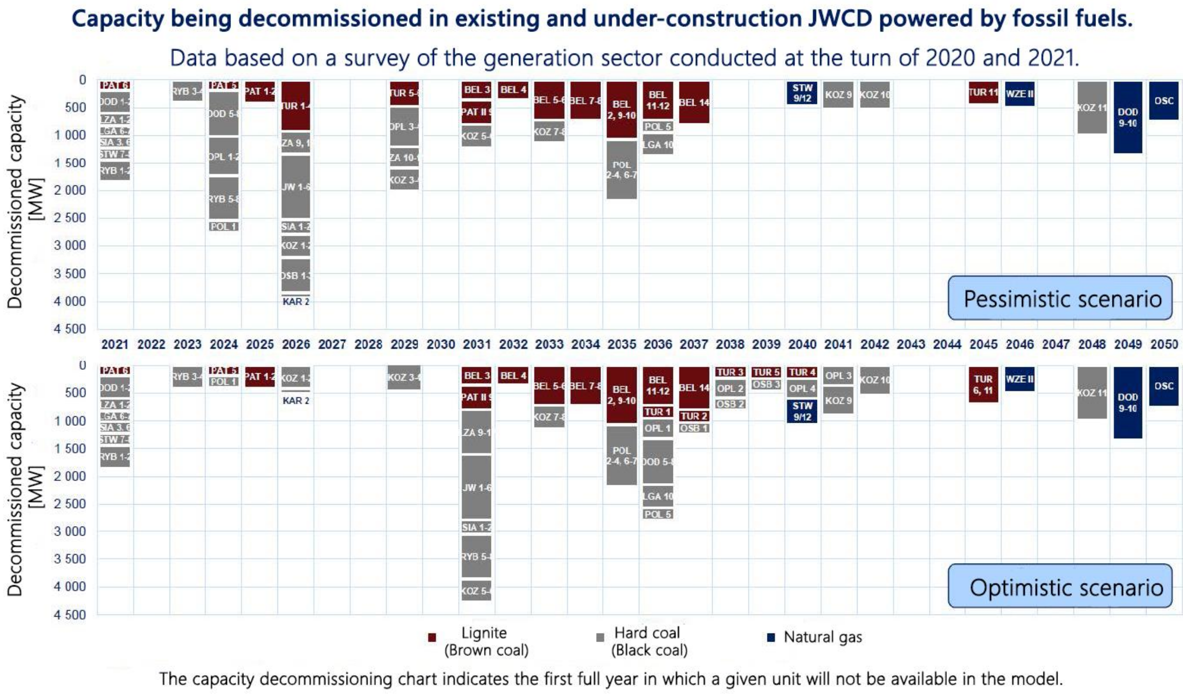

Figure 14 Power taken out of service

In the pessimistic scenario, units 5-8 were to be decommissioned at the end of 2024, while in the optimistic scenario, this would take place at the end of 2036. Due to the fact that the pessimistic scenario assumes decommissioning as early as 2024, PSE should have indicated this in advance in its report

[8] https://bip.wzp.pl/artykul/pge-gornictwo-i-energetyka-konwencjonalna-sa - 19 February 2024

[9] https://wysokienapiecie.pl/88275-polska-ma-szanse-na-utrzymanie-starych-weglowek-do-2028-r/ 25 March

Information on KSE generation resources announce the planned shutdown. No information on units 5-8 was provided, therefore it was assumed that the pessimistic scenario is no longer relevant.

It was assumed that the planned date of shutdown of units 5-8 at the Dolna Odra power plant could be no later than the end of 2036. This date seems to be the deadline due to the age of the units.

3.3. Characteristics of an open cooling system in the context of its use in a nuclear power plant

The 200 MW units of the Dolna Odra Power Plant have an open cooling system, where cooling water is sucked by pumps into the 200 MW unit pumping station. In the cooling water system, it is possible to heat surface water intakes in winter by directly supplying heated water to the discharge chamber. From the discharge chamber, part of the heated water stream is directed to a heating channel, which prevents the intake from freezing.

The Dolna Odra power plant has obtained an integrated permit for the permanent abstraction of water from the Odra River for cooling purposes, with a maximum volume of approximately 63.4 m^3/s. Currently, following the decommissioning of units 1–4, water abstraction has been reduced to 31.1 m^3/s. Water is supplied to the pumping station via open channels and surface water intakes from the Eastern Odra River, from where it is fed through a system of pumps and pre-treatment installations (rotary screens and self-cleaning filters) to the turbine condensers. After absorbing heat from the exhaust steam from the turbine NP section, the heated water is fed into discharge channels and leaves the cooling circuit. The heated cooling water leaves the cooling circuit directly into the warm water channels or indirectly into the Eastern Odra River.

The discharged cooling water must not exceed the maximum permissible temperature of 35°C (temperature resulting from environmental restrictions), which in unfavourable climatic/hydrothermal conditions may necessitate a reduction in generation capacity.

Balance calculations for PWR nuclear power plant units from various manufacturers show that the optimal range of steam outlet velocity from the turbine to the condenser is between 150 and 300 m/s. The steam outlet velocity from the turbine depends on the pressure in the condenser, i.e. the vacuum, which is directly related to the cooling water temperature. In order to ensure the required steam outlet velocity from the turbine, the cooling water temperature responsible for the vacuum level should not exceed 24°C.

The cooling circuit of the unit is designed to dissipate the waste heat generated by the power unit into the atmosphere. Two types of cooling circuits are possible at this location: an open or closed system. Heat from the system will be released into the atmosphere via a cooling tower (closed system) or via flow-through condenser cooling (open system).

The following is a comparison of the advantages and disadvantages of constructing a cooling tower or using an open cooling circuit:

Table 8 Comparison of an open cooling system with a cooling tower

Cooling tower	Open cooling system
High investment costs	No investment costs – existing system can be used after modifications
Noise emissions into the environment	No noise emissions
New facility	Use of existing infrastructure
Need to supplement the system	No need to supplement the system – flow cooling
Large building area	-

Possible operational problems when shutting down and operating at minimum load in winter conditions winter	Fewer operational problems in winter conditions – extensive possibilities for insulating the channels
Independence from the hydrothermal conditions of the river Odra	Significant operational problems in summer conditions due to due to possible water level reduction
The power plant's capacity is not dependent on external conditions (hydrothermal conditions of the river water)	Possibility of exceeding the cooling water temperature limit, leading to a reduction in power
Negligible impact on the aquatic environment of the Odra River:	Significant impact on the aquatic environment of the Odra River:
No heating of river water	Significant heating of river water
Negligible suction of living organisms – water intake only to replenish the system	Significant suction of living organisms into the system (larvae, fry, etc.)

The choice of a closed cooling system for the EPR nuclear power plant block involves the construction of a cooling tower. This is the preferred solution used by suppliers for facilities built in locations far from the sea.

3.4. Construction and road infrastructure

3.4.1. Description of the existing development plan

The Dolna Odra Power Plant site, within the existing units 1-8, contains a number of buildings, structures, roads and squares that serve directly or indirectly for production purposes (electricity generation).

Due to the nature of the analysed development of a new power unit based on a Generation III/III+ reactor, it is not possible to use most of the buildings and technological structures located on the premises of the Dolna Odra Power Plant. In order to enable the location of new units, it will be necessary to demolish most of the buildings and networks. Section 5.4 of this study presents the proposed area for the construction of the new nuclear unit. The demolition should cover units 1-8 together with the accompanying infrastructure (boiler rooms, engine rooms, IOS (*Instalacja Odsiarczania Spalin* - Flue Gas Desulphurisation Plant), coal yards and others). After demolition and removal of debris and steel structures, in many cases it will be necessary to replenish the ground to a level consistent with the surrounding area (macro-levelling) or to reclaim the land (in the case of coal yards). Due to the nature of the existing buildings (deep foundations), it should be expected that the depth of the necessary macro-levelling may in many cases be as much as 5 metres or more, which may significantly affect the cost of such a task.

3.4.2. Description of the existing road layout at the Dolna Odra Power plant

There are two entrance gates leading to the Dolna Odra Power Plant. Their schematic location is shown in the figure below

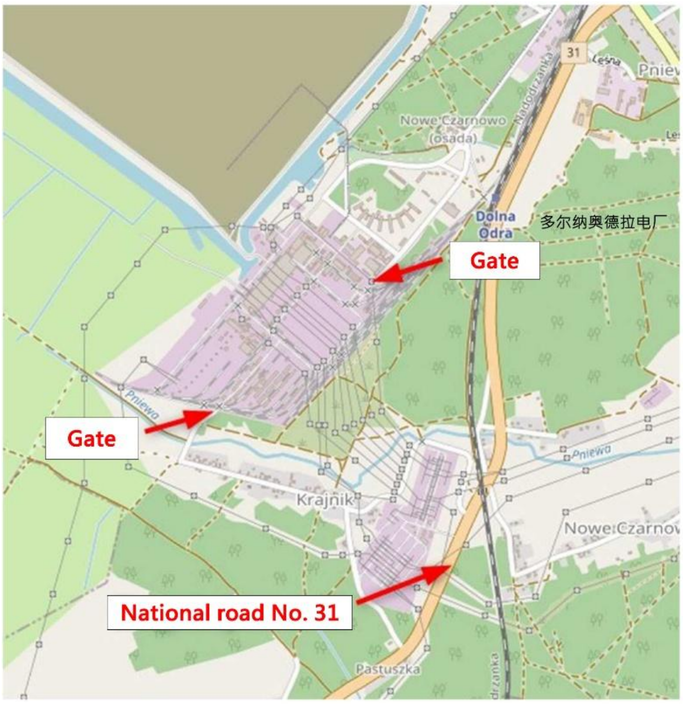

Figure 15 Layout of entrances to the Dolna Odra Power Plant[10]

The power plant has a system of internal roads with pavements, car parks and storage areas. [11]

The Dolna Odra Power Plant is surrounded by a network of public roads, including national and provincial roads:

- National road No. 31
- Provincial road No. 121
- Provincial road No. 120
- The S3 expressway

and the road networks are shown in the figure below:

[10] *https://www.geoportal.gov.pl/*

[11] *https://www.geoportal.gov.pl/*

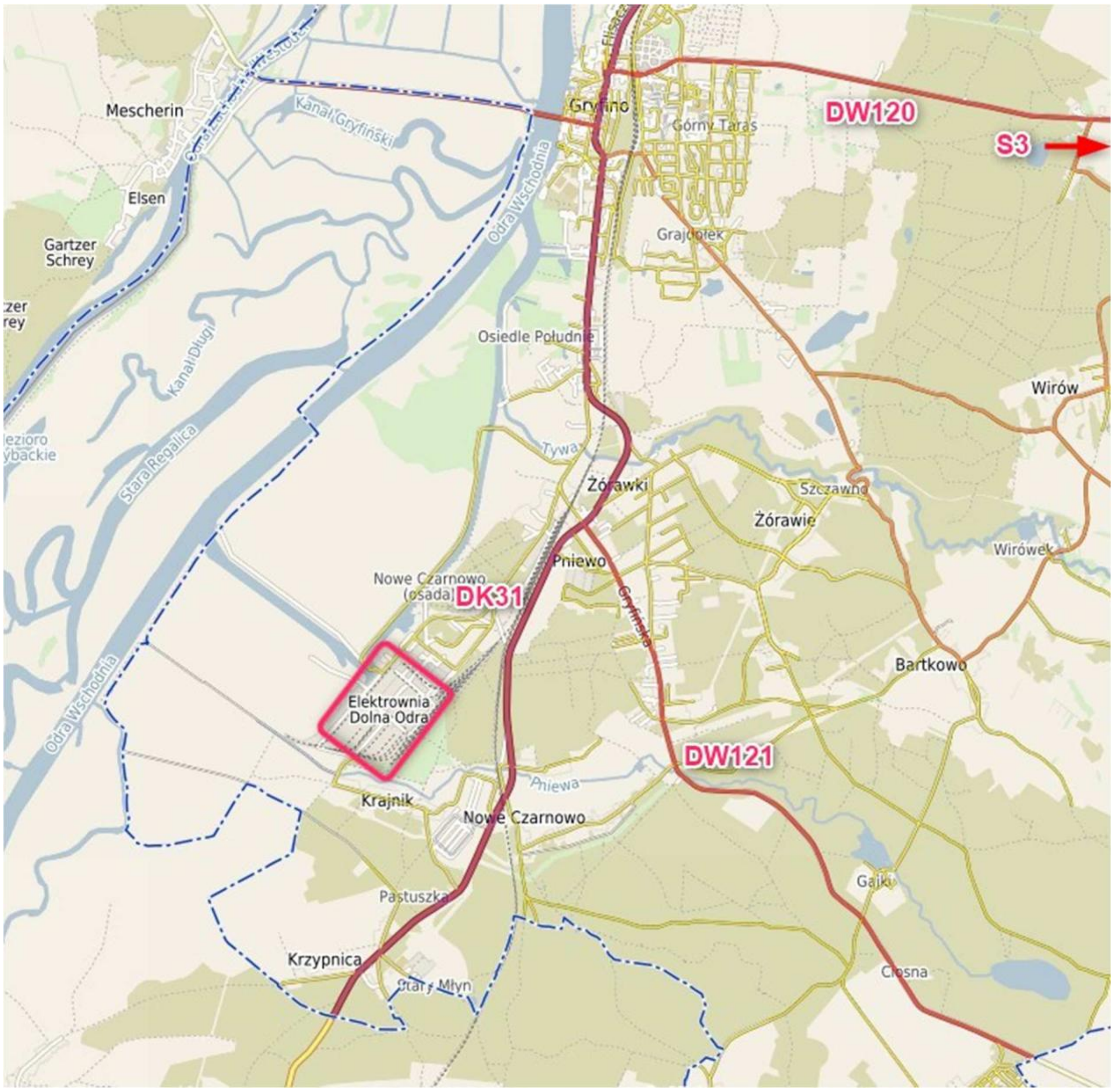

Figure 16 Road layout in the area of the Dolna Odra Power Plant[12]

3.4.3. Description of the existing railway system

Public railway lines

Railway line No. 273 Wrocław Główny – Szczecin Główny (commonly known as the Nadodrzańska line, Nadodrzańska main line, Nadodrzanka) – a railway line in western Poland connecting Wrocław with Szczecin via Brzeg Dolny, Wołów, Głogów, Nowa Sól, Zielona Góra, Kostrzyn nad Odrą and Gryfino. It is located within the borders of the Lower Silesian, Lubusz and West Pomeranian provinces and in the area of the PKP PLK Railway Lines Plant in Wrocław, Zielona Góra and Szczecin.[13]

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[12] *https://gryfino.e-mapa.net/*

[13] *https://pl.wikipedia.org/wiki/Linia_kolejowa_nr_273*

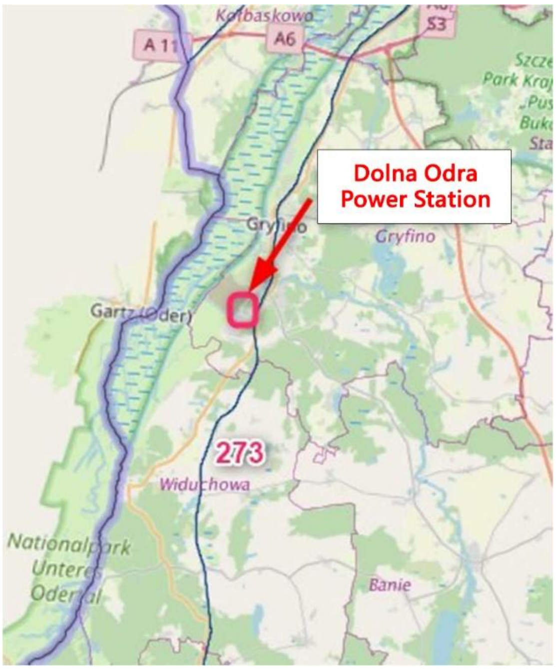


Figure 17 Diagram of state railway lines in the Dolna Odra Power Plant area[14]

Internal railway lines

The power plant has a railway track system connected to the Polish Railway Lines system via line no. 273

[14] *http://mapa.plk-sa.pl/*

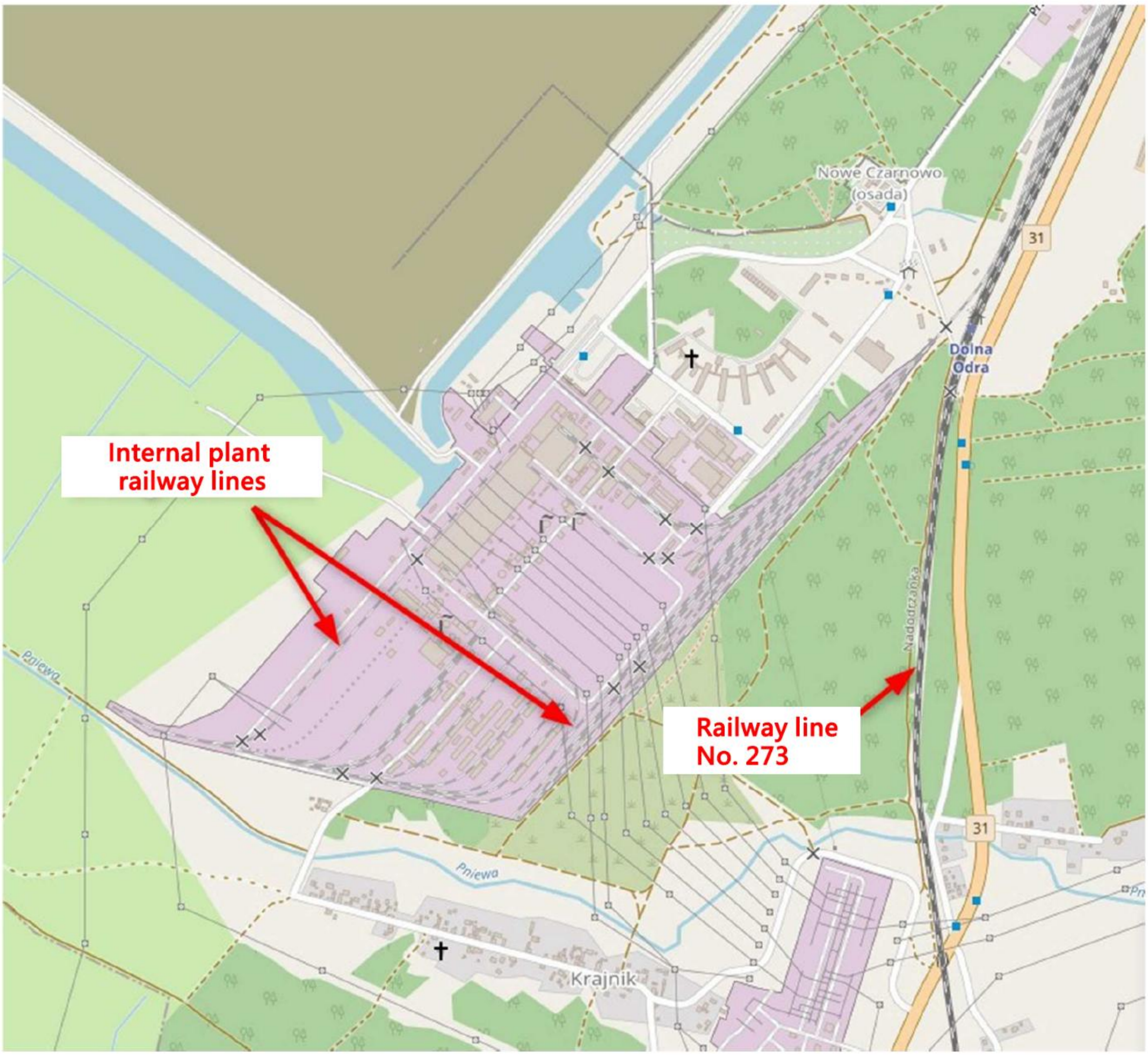


Figure 18 Diagram of railway lines on the premises of the Dolna Odra Power Plant[15]

3.4.4. Description of geological and water conditions

Geological conditions

The geological conditions were characterised on the basis of publicly available sources. [16]

The Dolna Odra Power Plant area is located within the Dolna Odra River basin. It covers the right bank of the Eastern Odra River. It is an area of low-lying flood terraces, built up with uncontrolled embankments. The area described is the eastern part of the Dolna Odra River valley, formed during the Pleistocene epoch. Among the river sediments – up to a depth of approx. 12 m – sand predominates. Below them, there are sands and gravels, located below a depth of 15.0–30.0 m. The surface of the area consists of anthropogenic sediments (uncontrolled embankments) with a thickness of 0.8–3.5 m, whose origin is related to the construction of a power plant.

[15] https://www.geoportal.gov.pl/
[16] https://geologia.pgi.gov.pl

Research boreholes are not available for the Dolna Odra Power Plant area

Areas at risk of flooding

The Dolna Odra Power Plant area in question is not located in a flood-prone area (once every 100 years) [17].

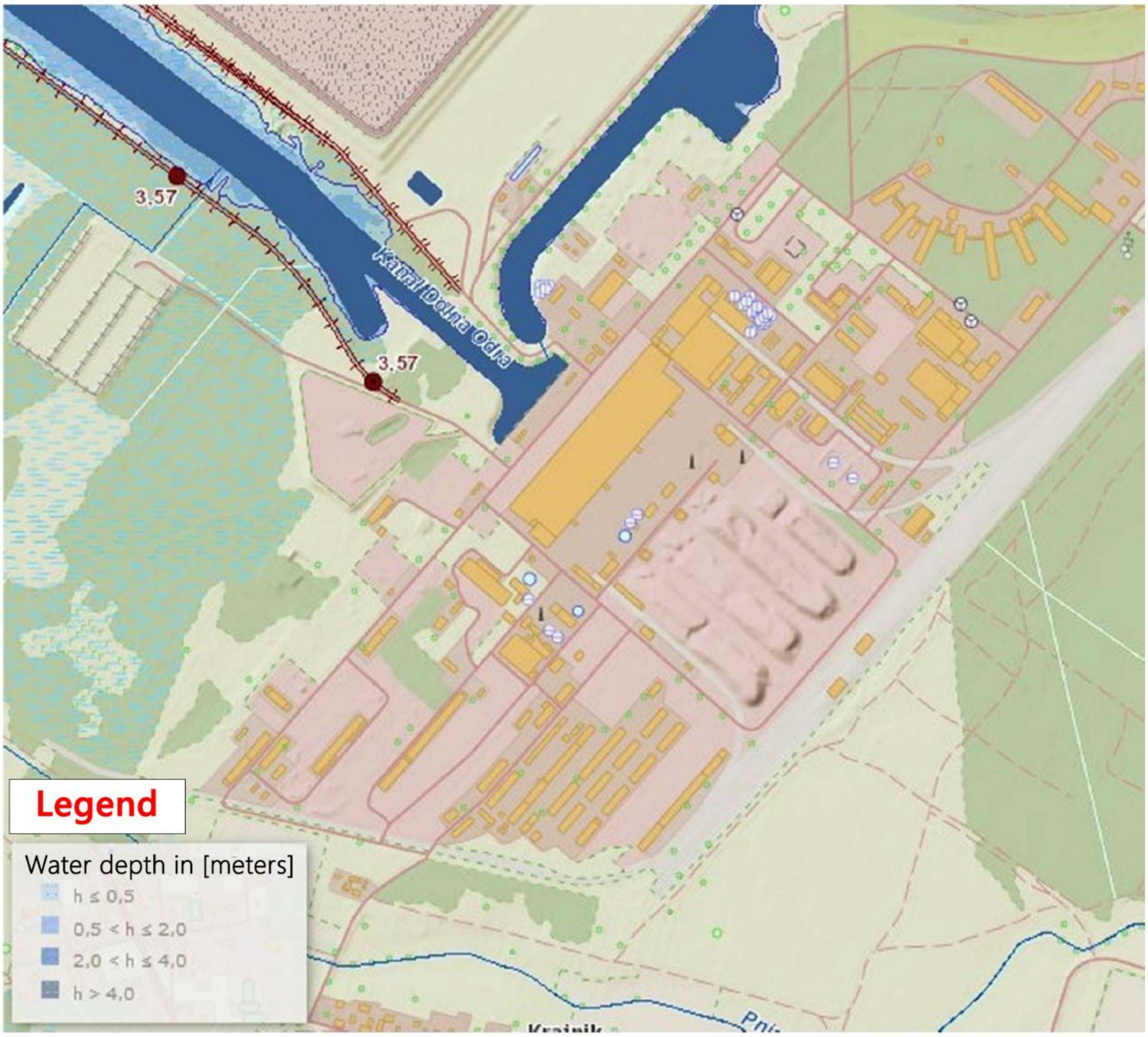


Figure 19 Flood risk area [18]

[17] https://wody.isok.gov.pl/

[18] https://wody.isok.gov.pl/

3.5. Electrical power supply system for the power plant's own needs

3.6. Power output

Blocks 1-8 have power output from generators via three-phase block transformers located along the engine room wall. The power is then transmitted via overhead lines suspended on poles attached to the boiler room roof and further via poles across the coal handling yard to the Krajnik Power Station.[19] The block lines run through the coal storage yard, which is currently a major problem as it is not in compliance with applicable regulations.

On 30 January 2020, a contract was signed for the construction of two combined cycle gas turbines with a capacity of approximately 700 MW.[20] The combined cycle gas turbine units No. 9 and No. 10 under construction will have their power output from the generators fed through two three-phase block transformers installed next to the boiler house building. The power will then be fed into the Krajnik Power Station via overhead lines. [21]

[19] https://pl.wikipedia.org/wiki/Elektrownia_Dolna_Odra
[20] https://pl.wikipedia.org/wiki/Elektrownia_Dolna_Odra
[21] https://www.polimex-mostostal.pl/page/projekt-dolna-odra-0

3.6.1. General characteristics

The general characteristics of blocks B1-B11 with assigned power ratings and power output system voltage levels[22]are presented below:

Table 9 General characteristics of units B1-B11

Power of power blocks [MW]									
Unit No. 1 Commissioned for service in 1974	Unit No. 2 Commissioned for service in 1974	Unit No. 3 Commissioned for service in 1975	Unit No. 4 Commissioned for service in 1975	Unit No. 5 Commissioned for service in 1975	Block No. 6 Commissioned for for service in1976	Block No. 7 Commissioned for service in 1976	Block No. 8 Commissioned for service in 1977	Unit No. 9	Block No. 10
222MW **Withdrawn from operation 31 December 2020**	232 MW **Withdrawn from operation 31 December 2020**	185MW **Withdrawn from operation 1 January 2014**	205MW **Withdrawn from operation 11 December 2012**	222MW	222MW	232 MW	232MW	Planned power rated 700MW - commissioned for service in 30 April 2024[23]	Planned power rated 700MW - commisioned for service in 30 April 2024
Block voltage level [kV]									
110kV	220kV	220kV	220kV	220kV	400kV After the commissioning of units 9 and 10, the power output from unit 6 will be at 220kV	400kV	400kV	400kV	400kV

3.6.2. Block transformers

The block transformers for blocks 1-8 are three-phase transformers, but due to their age (1970s), power and voltage levels, their use in the nuclear block may be limited. The block transformers for blocks 9 and 10 will also be new-generation three-phase transformers and will be adaptable to operation in the new nuclear block system.

3.6.3. Block transformer forefields

Blocks 1-8 have forefields with block transformers located on the cooling water channel side. The forefields are equipped with residual equipment (current and voltage transformers, earthing switches and surge arresters) located in the enclosures. The forefields are relatively small and narrow, with no possibility of expansion. Power from the units is transmitted via overhead lines to the boiler roof and further to the 400/220 kV Krajnik Power Station (owned by PSE).

[22] *https://zedolnaodra.pgegiek.pl/technika-i-technologia*
[23] *https://www.parkiet.com/surowce-i-paliwa/art39167891-gazowe-polaczenie-juz-jest-ale-nowa-elektrownia-w-dolnej-odrze-lapie-opoznienie*

3.6.4. Power transmission lines

Power transmission lines are part of the power system dedicated to transmitting power from specific generating units. Due to their purpose, their technical parameters do not require oversizing for future investment plans.

The existing power lines from the Dolna Odra Power Plant are used to transmit power from units 5, 7 and 8, which remain in operation. For unit 6, the line has been converted from 400 kV to 220 kV. New lines will be built for units 9 and 10, which are planned to be commissioned, following the route of the line for unit 6. [1]

Due to the technological layout of the Dolna Odra power plant, the power outlets from some of the units are located on the opposite side to the Krajnik substation (a solution used in power plants built during that period). This made it necessary for the unit lines to bypass/cross the power plant buildings.

- The 220 kV lines for units 5 and 6 are overhead lines running above the power plant buildings and coal yards. The line gates are located on the roofs of the existing boiler house buildings.
- The 400 kV lines of units 7 - 10 are overhead or overhead-cable lines and run between the Dolna Odra power plant and the 400/220 kV Krajnik station.

Due to the period when they were built, the power lines of units 5, 7 and 8 do not meet the current regulatory requirements for the design of overhead lines.

3.6.5. Krajnik power station

The SE Krajnik power station is located in the vicinity of the Dolna Odra Power Plant in the municipality of Krajnik and Nowe Czarnowo, and is used to transmit power from the Dolna Odra Power Plant, as well as for the transit and distribution of energy at 400 and 220 kV, and as a cross-border connection to the German power system. The station is owned by PSE S.A.

The 400/220 kV Krajnik substation was built in the 1970s. The existing 400 kV and 220 kV switchgears were rebuilt between 2014 and 2021 and meet the requirements of the current regulations.

The Krajnik power station is an important hub in the National Power System, particularly in terms of energy security for the Szczecin agglomeration and the north-western part of the country. The station consists of two switchyards: 220 kV and 400 kV, with 400/220 kV transformation.

- The 400 kV switchyard is an overhead switchyard operating in a one-and-a-half circuit configuration with 7 branches (with space reserved for 2 branches).
- The 220 kV switchgear is an overhead, 23-pole, dual-system switchgear with a bypass busbar.

Figure 20 Krajnik Power Station

For the purposes of expanding the 400 kV switchyard, land on the side of the 220 kV switchyard is to be reserved.

In accordance with the Development Plan for meeting current and future electricity demand for the years 2023-2032, the 400 kV switchyard is planned to be expanded for the purpose of connecting and feeding power from the Banie 2 photovoltaic farm (item II.31 of the plan).

The station (as of 2032) will be connected to the National Power System via six 400 kV lines, including two to the east (international lines to Vierraden), one to the north-east (Morzyczyn towards Dunowo) and three to the south (Baczyna, Gorzów), and two 220 kV lines to the north ("Szczecin loop"). The strong connection of the station to the power system, on the one hand, ensures good potential for the transmission of significant volumes of power through the node, while on the other hand, the station's ability to introduce additional generation capacity into the system is limited by "macro" north-south flows resulting from the planned significant generation in the north of the country (related to the decommissioning of conventional sources in the south) and international flows from northern Germany through Poland to the south.

3.6.6. Other power engineering systems

The Dolna Odra power plant has telecommunications links with the systems of PSE, the operator of the National Power System. These systems can be used in the new unit once the formal requirements between PSE and the new operator of the new nuclear unit have been met.

3.7. Water and sewage infrastructure (excluding technology)

The water and sewage infrastructure (excluding technology) at the Dolna Odra Power Plant consists in particular of internal networks:

- drinking water,
- fire water – a system supplied from the existing surface water intake on the Odra River,
- rainwater and industrial sewage system with a mechanical sewage treatment plant and an outlet (water device) for the above-mentioned sewage into the Odra River;
- domestic sewage system with a mechanical and biological sewage treatment plant and an outlet (water device) for the above-mentioned sewage into the Odra River.

3.8. Diagnosis of the possibilities of using the existing infrastructure of the facility – summary

Based on the assessment of the existing infrastructure, assuming that the construction of a new Generation III/III+ nuclear power plant for the Dolna Odra location will take place with maximum utilisation, especially in terms of internal and external water sources, transmission networks, and road and rail infrastructure, a preliminary diagnosis has been made for individual areas.

Technology sector

An analysis of the technical condition of the existing infrastructure of the Dolna Odra Power Plant in terms of technology revealed that the only usable system of the existing units 1 - 8 is the cooling water intake and discharge system, together with the intake and pre-filtering devices for the intake water. The use of other elements of the open cooling system, i.e. pumping stations and pipelines, will mainly depend on the type of cooling system chosen for the new nuclear power plant.

The use of the infrastructure of new BGP gas-steam units was not covered by this Feasibility Study, but may become necessary in the longer term.

Plumbing/installation sector

Considering the planned new layout of facilities related to nuclear units, a new system of internal networks should be planned: water for domestic purposes, firefighting water and sewage. This is because the existing system will not be able to be used in the planned new land development.

Potentially, at later stages of design, when all quantitative and qualitative parameters regarding water demand and wastewater discharge are known, the possibility of using existing wastewater treatment plants and wastewater outlets to the environment may be considered. However, given the long-term operation of these facilities to date and their potentially insufficient capacity for the new installation, this is not a recommended solution. Rather, it is necessary to anticipate the need for new wastewater treatment facilities, with only the potential possibility of using the existing water facilities for water intake and wastewater discharge. Of course, this is only on the assumption that their capacity/throughput and technical condition at the time of planned use will be sufficient.

Electrical sector

The age and quality characteristics of the existing electrical infrastructure of blocks 5-8 allow us to conclude that it cannot be used for the nuclear projects analysed in this study. The existing power transmission systems, including overhead lines, pylons, support structures, block and tap-off transformer stations, and the power supply systems for the units' own requirements, will be subject to dismantling and demolition.

4. Market analysis of suppliers of technologies required for the investment process

4.1. Assumptions

The decarbonisation plan for the national commercial energy sector relating to the Coal-to-Nuclear technology application assumes the use of Generation III/III+ nuclear reactors. Reactors of this generation have many advantages, including:

- Simpler and more durable reactor building design
- Most use passive cooling systems based on natural phenomena, such as evaporative cooling
- Lower probability of serious accidents involving core meltdown
- In the event of a core meltdown accident, its impact on society and the environment has been significantly reduced
- The reactor building structure is designed to withstand a direct impact from a large aircraft
- Extended fuel campaign and higher fuel burn-up
- Reduced amount of radioactive waste generated Operating life of up to 60 years

4.2. Supplier Market

Currently, the market offers several specific and proven technologies for this generation of reactors. Three PWR (pressurised water reactor) reactors were selected for further analysis:

- **AP 1000** – a reactor manufactured by Westinghouse (USA) with a net electrical power of 1,150 MW
- **APR 1400** – reactor manufactured by KHNP (South Korea) with a net electrical output of 1,450 MW
- **EPR (1600)** – a reactor manufactured by EDF (France) based on the experience gained from German KONVOI and French N4 reactors, with a net electrical power of 1,600 MW

AP1000 – Advanced Passive – an advanced, light water passive reactor with two cooling loops and a thermal power of 3,415 MWt. The cooling loops are equipped with main circulation pumps located directly on the steam generator outlet connections, i.e., on the cold side of the circulation circuit. This solution eliminates the need for pipelines between the steam generators and the pumps.

The reactor core consists of 157 fuel assemblies of seven types using UO_2 as fuel material. Individual fuel assemblies have varying degrees of enrichment and may contain burnable coating in the form of a thin layer of ZrB_2 (zirconium diboride) on the surface of the fuel pellets, and special ring-shaped rods made of $AL_2O_3B_4C$, which together allow for an even distribution of power in the core. The time between fuel replacements has been extended to 18 months with a power utilisation factor of approximately 93%.

The AP1000 reactor uses fully passive emergency cooling systems, i.e., these systems do not have pumps and do not require emergency power supplies such as diesel generators. The supply of borated water to flood the core in the event of a coolant loss accident is ensured by three water sources:

- two coolant purification and replenishment tanks
- two hydroaccumulators maintained at a pressure of 4.9 MPa by a nitrogen bladder
- a tank inside the safety enclosure used to condense pressure stabiliser vapour and collect post-shutdown heat, and as a water reservoir to flood the reactor in the event of core meltdown.

A nuclear power plant based on the AP1000 reactor has 35% fewer pumps, 80% fewer safety-related pipelines and half as many safety valves as a lower-generation nuclear unit of similar capacity. Most of the safety installations are housed in a two-layer safety enclosure: an inner steel layer and an outer concrete layer. The inner steel enclosure is designed to prevent any leaks from the reactor. The upper part of the containment building houses a water tank with a capacity of approximately 3,000 m^3, whose task is to cool the inner steel containment building.

Passive cooling systems are designed to ensure conditions for safe reactor shutdown for 72 hours after a failure without the need for operator intervention.

The probability of core meltdown is estimated at less than $2.4x10^{-7}$ per year

APR1400 – Advanced Power Reactor – an advanced pressurised water reactor with two cooling lines in each loop. The APR1400 reactor is manufactured by Korean Electric Power Corporation (KEPCO) and Korea Hydro and Nuclear Power (KHNP).

The reactor fuel system consists of 256 cassettes containing 236 fuel rods each. The fuel material is UO_2, but some cassettes contain an admixture of gadolinium trioxide (Gd_2O_3) as a burn-up additive. The reactor can also use reprocessed MOX fuel, which accounts for 33% of the primary fuel.

The main safety systems include the core emergency flooding system, the overpressure reduction system with steam removal, the containment sprinkler system, and the emergency feedwater system. The containment also houses a water pool for fuel reloading; in an emergency, water from the pool is used to flood the core. The flooding system has been simplified, equipped with four redundant lines with direct water injection into the reactor vessel and a dual electrical power supply system. Each emergency cooling line has an active part using a pump and a passive part with a coolant tank and flow regulator.

The safety enclosure is approximately 1.37 m thick and is made of compressed concrete covered on the inside with a steel coating to protect against leaks. The enclosure also provides resistance to earthquakes with an acceleration of 0.3G.

The probability of core damage is estimated at less than10^{-5}per year, and damage to the safety enclosure at less than10^{-6}per year.

Currently operating nuclear units with the APR1400 reactor include Shin-Kori-3, 4, 5 and 6.

EPR – European Pressurised Water Reactor – a German-French design, it is the largest PWR reactor with a maximum electrical output of approximately 1,650 MWe.

The main fuel for this reactor is UO_2, but MOX fuel with or without gadolinium, with a content of 2% to 8% as a burn-up additive, can also be used. An M5 alloy containing zirconium and 1% niobium was used to manufacture fuel cladding, spacer grids and cassette tubes. The use of M5 alloy increased corrosion and creep resistance as well as dimensional stability.

An innovative feature of the EPR reactor is the use of a heavy reflector, which limits the escape of neutrons hitting the tank wall. This has improved neutron management, contributing to a reduction in fuel enrichment and extending its operating time in the reactor. It is estimated that fuel costs can be up to 17% lower compared to other types of operating PWR reactors.

This reactor also features higher thermodynamic efficiency of the system, i.e. approximately 36–37%. Higher efficiency is achieved through high pressure on the secondary side of the reactor – 7.72 MPa.

The safety enclosure of the EPR technology consists of two layers of concrete. They cover the reactor, fuel storage and two buildings containing the most important safety systems. The containment is designed to withstand the impact of a large passenger aircraft. As with other Generation III/III+ reactors, the EPR has a steel liner inside the concrete containment to prevent leaks.

The safety system consists of four separate sections of emergency core flooding systems and feedwater systems, together with auxiliary infrastructure. Another safety system is the boron water pool, which is used during normal operation for fuel reloading and, in the event of an accident, as a source of water for cooling the core (including the molten core) and the containment.

Table 10 Comparative table of Generation III/III+ nuclear power plants

System/parameter		AP1000	APR1400	EPR
General characteristics				
Reactor type		PWR	PWR	PWR
Net electrical power	MWe	1,110	1,450	1,650
Thermal power of the core	MWt	3,415	4,000	4,500
Efficiency	%	32.6	35.1	36
Operating time	years	60	60	60
Number of blocks in operation/under construction	pcs	4	4/6	3/3
Cooling circuit (primary)				
Number of loops	pcs	2	2	2
Number of circulation pumps	pcs	4	4	4
Maximum water pressure	MPa	17.2	17.2	17.6
Working water pressure	MPa	15.51	15.51	15.5
Core inlet temperature	°C	279.4	290.6	295.7
Temperature at the core outlet	°C	324.7	323.9	329.9
Water temperature increase in the core	°C	45.3	33.3	34.2
Supply water temperature	°C	226.7	232.2	230
Coolant flow through the core	tonnes/ second	14.3	20.991	22.225
Steam temperature at turbine inlet	°C	272.8	285	293
Steam pressure at the generator outlet	MPa	5.79	6.9	7.72
Steam flow through generators	kg/s	1,889	1,130.8	2,604

Fuel cassette characteristics				
Cassette layout/grid		17x17	16x16	17x17
Number of fuel rods	pcs	264	236	265
Number of guide tubes	pcs	25	20	24
Number of cassettes in the core	pcs	157	241	241
Number of control rods in the core	pcs	53 (black) 16 (grey)	93	89 (black)
Length of fuel part of cassette (cold state)	cm	426.7	381	420
Average power density in the core	MW/m^3	109.7	100.9	94.6
Fuel rods				
Number of rods in the core	pcs	41,448	56,876	63,865
Average power density per unit length	W/cm	187	183.8	163.4
Fuel jacket material		ZIRLO	Zircaloy-4	M5
Fuel pellets				
Fuel material		UO_2	UO_2	UO_2 or MOX
Maximum enrichment	%	≤5	3.64	≤5
Fuel operating time in the reactor	m-ce	18	≥18	18.24
Reactor vessel				
Internal diameter at core level	m	4.039	4.655	4.870
Tank wall thickness	cm	20.3	28.4	25
Equivalent core diameter	cm	304	363	376.7

Thermodynamic calculations for the analysed nuclear reactors were performed using the STEAM PRO programme included in the Thermoflow package. The thermodynamic models take into account a number of technical parameters presented, among others, in the table above and in the report from task No. 3 performed by the Silesian University of Technology in Gliwice. In addition, data presented by the International Atomic Energy Agency (IAEA) was also used.

The model mainly takes into account the steam part of the nuclear block, without a detailed analysis of the reactor, whose parameters were adopted in accordance with the guidelines. Furthermore, at this stage, no cooling system has been determined; for comparison purposes, all models were made for an open system at the same ambient temperature of 15°C. The final results of the model may differ from the data presented in the table due to different cooling system parameters.

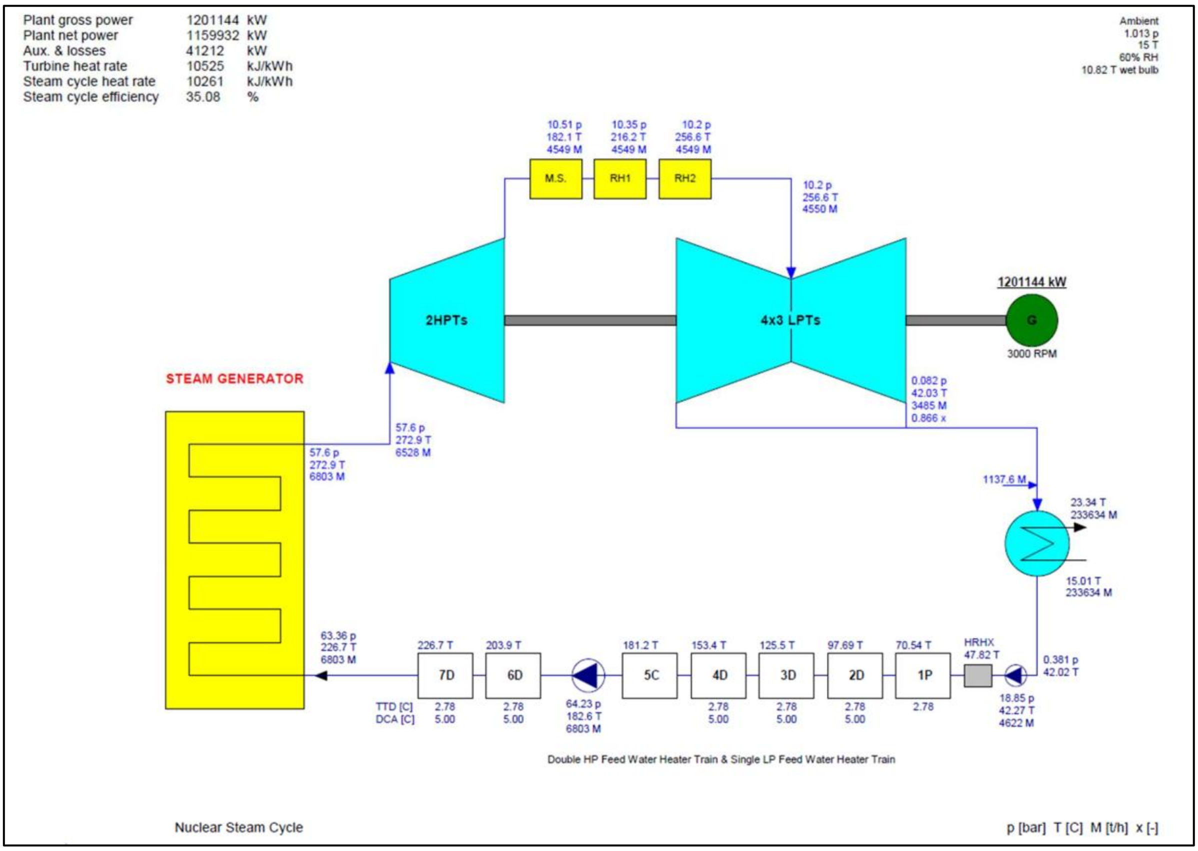


Figure 21 Steam diagram of the AP-1000 unit

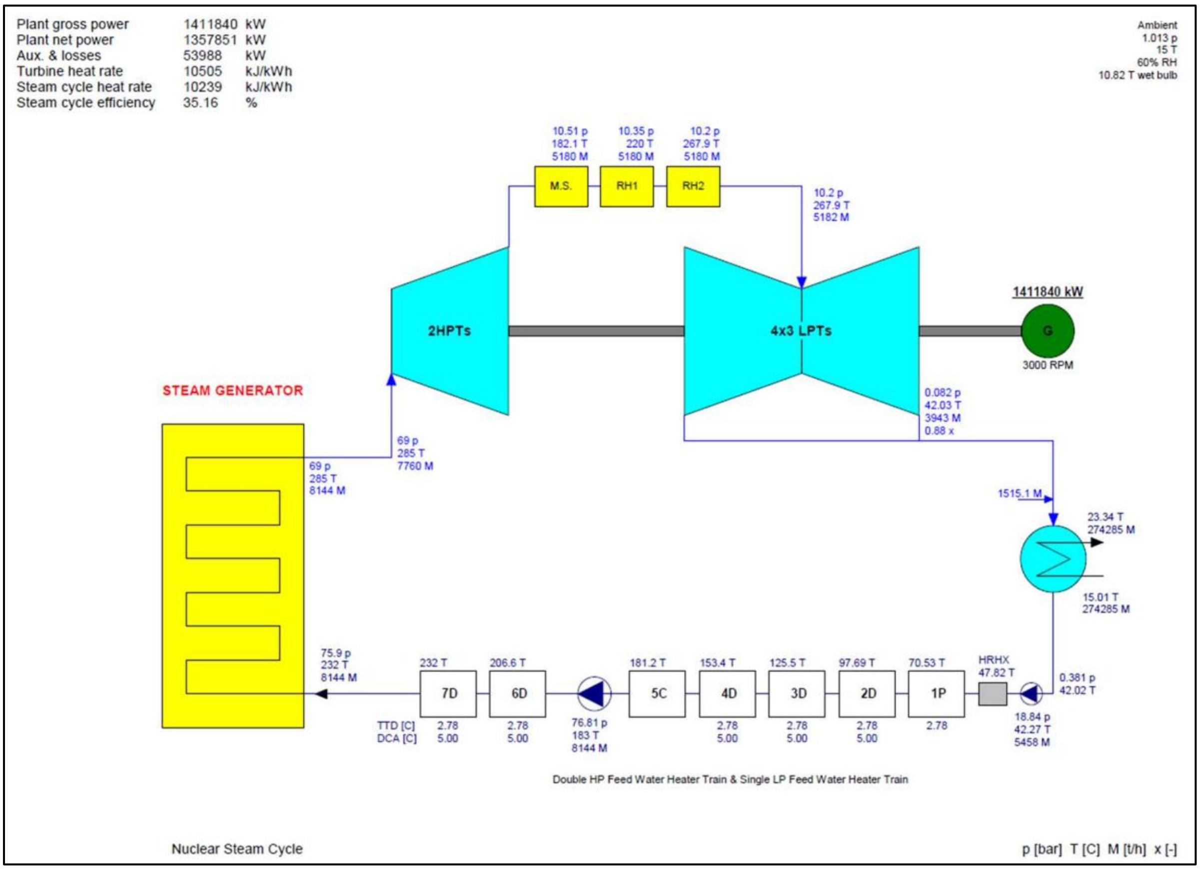


Figure 22 Steam diagram of the APR-1400 unit

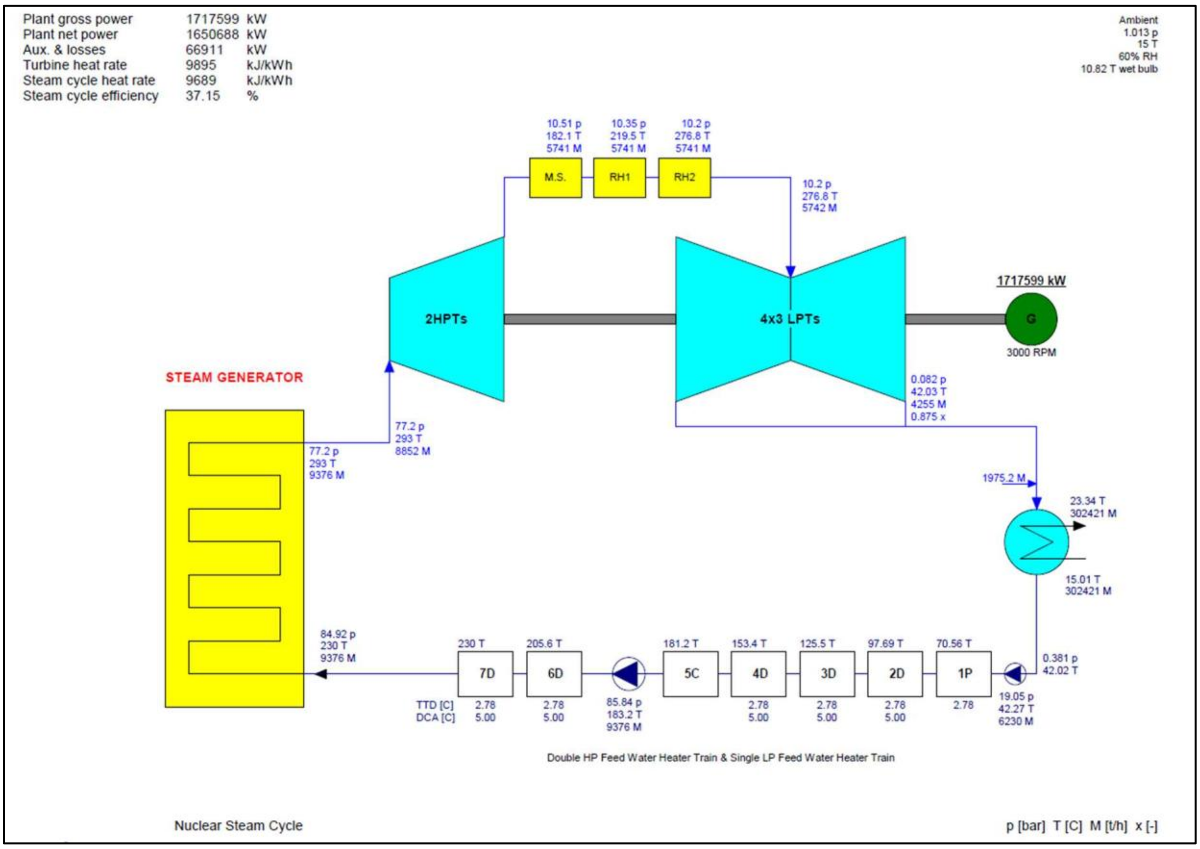


Figure 23 Steam diagram of the EPR-1600 unit

4.3. Recommendation of the type of reactor (nuclear power plant) type selected for further analysis

Based on an analysis of available materials and data obtained, it was decided that further work would be based on EPR reactor nuclear power plant technology. The choice of EPR power plants is mainly due to local conditions and the possibility of generating electricity at a similar level to that generated by the coal-fired units to be replaced. The overall dimensions of all the power plant buildings and the dedicated cooling tower allow for the location of one single EPR nuclear unit (1,600 MW) in the site under consideration, while maintaining the necessary auxiliary infrastructure, roads, safety zones, etc.

5. Description of the adopted solution

5.1. General scope of dismantling works

The project assumes that no major technological components of the power plant in question will be retained for the retrofit with Generation III/III+ reactors. For this reason, the scope of dismantling and demolition work will cover the entire infrastructure of 200 MW units, with minor exceptions such as the power output system or hydrotechnical equipment/structures of the cooling water system, e.g. water intake and discharge channels, suction and discharge pipelines, etc. The above-mentioned power engineering and hydrotechnical infrastructure will probably require reconstruction or adaptation to meet the requirements and ensure the safe operation of the nuclear power plant.

The sketch below shows the area of the coal-fired power plant infrastructure designated for demolition and development for a new EPR nuclear power plant unit, as well as the area used for the construction of new gas-steam units.

Main facilities of the 200MW units (1-8) to be demolished and/or cleared for construction:

- Unit transformers
- Boiler room
- Engine room
- Exhaust gas discharge system (rotary air heaters, electrostatic precipitators, fans, exhaust gas ducts, chimneys)
- SCR installation for NO_x reduction
- Wet flue gas desulphurisation system consisting of:
  - Exhaust duct system with booster fan
  - Lime slurry production system
  - Absorber
  - Gypsum dewatering system
  - Wastewater treatment system
- Coal yard and coal feeding system

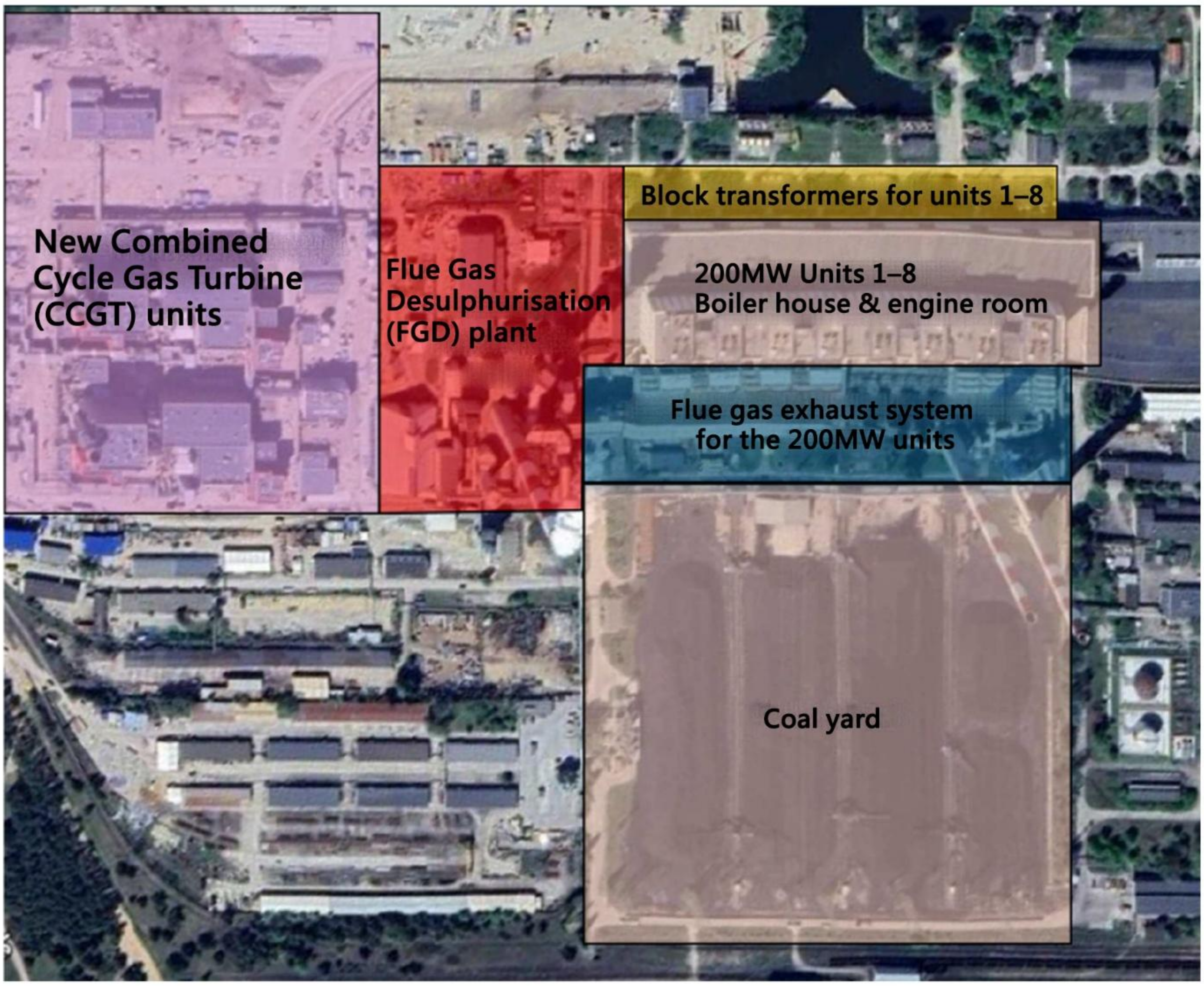


Figure 24 Location of the main facilities of the coal-fired power plant and the area of investment in new CCGT gas and steam units

5.2. Recommendation of the type of cooling system selected for further analysis

The comparative analysis of cooling systems described in section 3.3 shows that the best solution in terms of safety and environmental impact is to use a closed cooling system with a cooling tower. The most important advantages of constructing a cooling tower are independence from the hydrothermal conditions of the river, which, during the assumed operating life of a nuclear power plant, usually 60 years, will affect the safety of the power plant and reactor by ensuring a stable source of cooling for the unit.

In addition, the construction of a cooling tower will significantly reduce the facility's impact on the natural environment, mainly the Odra River and protected areas such as the Natura 2000 Special Protection Area "Dolna Odra Valley".

Water intake from the river for the purposes of replenishing the cooling system of the EPR unit of the nuclear power plant is approximately 5.2 thousand m^3 /h, i.e. 4.6% of the current water intake volume flow (i.e. 31.7 m^3 /s) for the flow cooling of the existing (operating) four 200MW coal-fired units.

5.3. Modifications to the existing open-circuit cooling system

The use of a closed cooling system necessitates the reconstruction of the existing cooling water supply and discharge system. It is assumed that the existing cooling water supply channel to the water intake will be retained. Due to the reduced amount of water consumed as a result of the use of a cooling tower, it will be necessary to install new pumps in the raw/river water intake. For one nuclear power plant unit, it is assumed that the intake will be equipped with a new 3x50% pump system. The capacity of each pump will be approximately 2,600 m^3/h. For safety reasons, this system may be expanded with an additional emergency pump. The capacity of the new pumps will be based on the water demand for replenishment and desalination of the closed cooling system, as well as water intake for the preparation of demineralised water (DEMI water) and replenishment of the steam-water system of the steam generator and turbine. The cooling system is replenished mainly due to water losses caused by evaporation and water drift (droplet carry-over) in the cooling tower.

Due to the small amount of water discharged from the desalination process, it is planned to construct a new discharge pipeline and demolish/modify the existing discharge channels adapted to discharge water from the current open cooling system.

5.4. Development area

For one EPR nuclear unit, it is planned to use the infrastructure of all eight neighbouring 200MW coal-fired units. Currently, the operator has four operating coal-fired units at its disposal, numbered 5 - 8.

The main components of a nuclear power plant can be divided into three basic areas: the nuclear island, the turbine island with power output, and a number of ancillary installations.

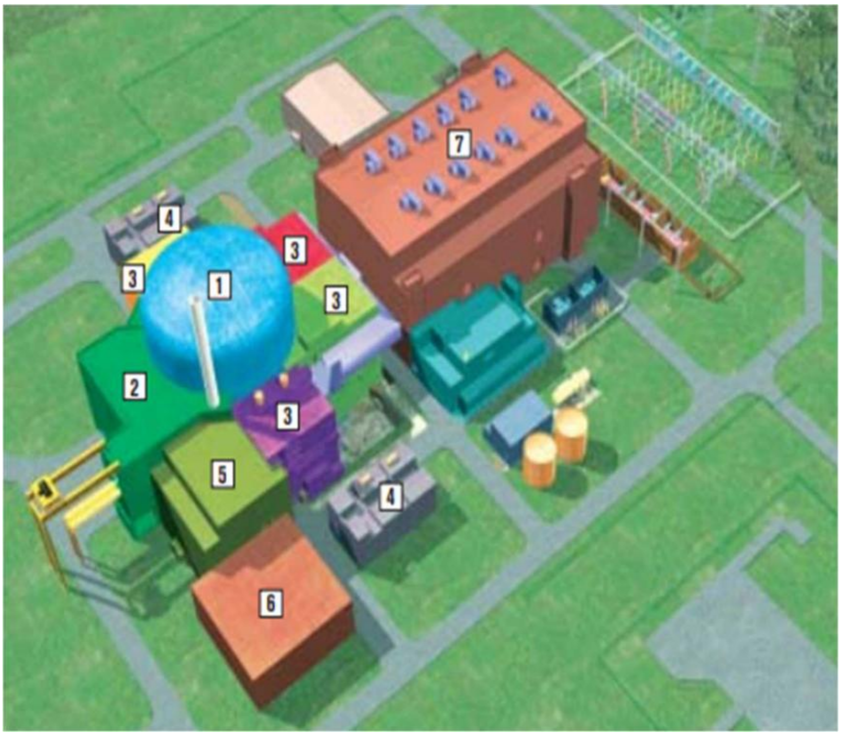


Figure 25 Layout of the main installations of the EPR nuclear unit

The turbine island and the nuclear island of the unit are to be located on the site of the existing coal yard of the 200 MW units. The area of the boiler and turbine islands of units 1 - 6 is to be used for the construction of a new cooling tower. The remaining space available after the demolition of units 7 and 8 and the flue gas duct system with desulphurisation installation (IOS *(Polish)*/FGD *(English)*) will be used for the construction of a new water treatment plant (*stacji uzdatniania wody* - SUW) and the organisation of construction facilities. The power output system, together with transformers, should be located on the railway track side in order to shorten the overhead lines to the switchgear.

The sketch below shows an example of the preliminary layout of the main components of the EPR nuclear power plant.

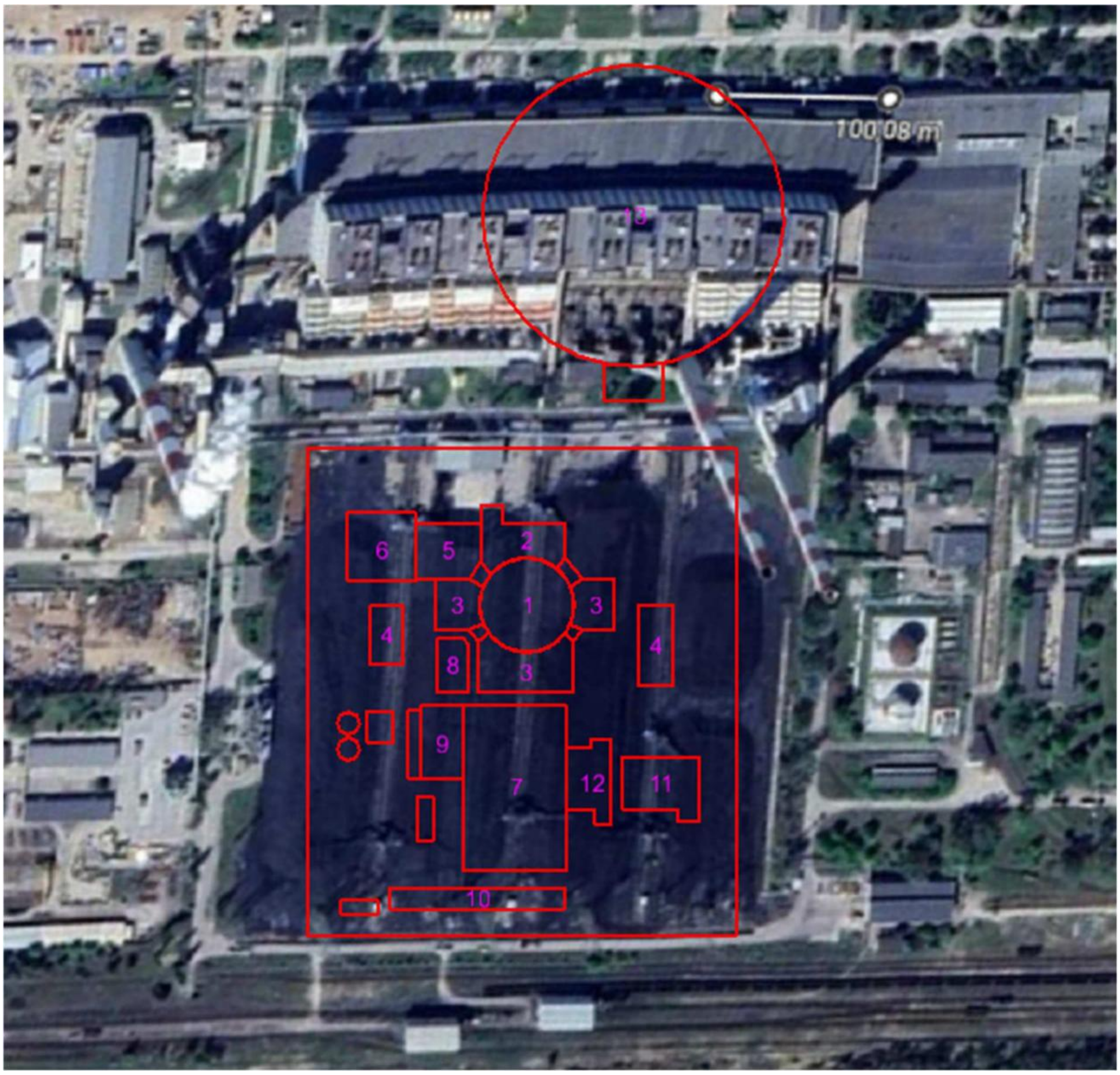


Figure 26 Layout of the EPR nuclear unit in Dolna Odra

The main facilities of the nuclear power plant include:

- Reactor building (steam supply system and water tank for refuelling) (1)
- Fuel building (2)
- Safety system buildings (3)
- Diesel generator buildings (4)
- Auxiliary building (5)
- Radioactive waste building (6)
- Turbine building (7)

Other power plant facilities:

- Access building (8)

- Electrical building (9)
- Transformer system (10)
- Cooling water pump station (11)
- Cooling water outlet (12)
- Cooling tower (13)

The reactor building located in the centre of the nuclear island houses the main equipment of the nuclear steam supply system and a water tank for refuelling. Its main function is to protect the environment from internal and external hazards and to contain ionising radiation during normal operation as well as in emergency conditions. It consists of a cylindrical, compressed concrete shell with a metal lining, surrounded by an outer shell of reinforced concrete. This ensures the safe operation of the power plant under all conditions.

The fuel building is located on the same common foundation slab as the reactor building and safety system buildings. Fresh and spent fuel and related facility operating equipment are stored there. For safety reasons, low-activity areas are separated from high-activity areas. The upper floor houses the fuel pool cooling systems, the emergency boron injection system, and the chemical and volumetric control systems.

The buildings housing the safety systems are divided into four separate areas containing safety systems such as the Safety Injection System and the Emergency Water Supply System, as well as their support systems. The Safety Injection System is connected to the Residual Heat Removal System. These are located in internal radiologically controlled areas, while the corresponding Component Cooling Systems and Emergency Water Supply Systems are installed in external uncontrolled areas. One of the four buildings houses the Main Control Room.

The buildings housing the diesel generators are located at a distance from the nuclear island buildings, which ensures a safe and reliable emergency power supply for the EPR facility in the event of disruptions to the primary power supply. They house four emergency diesel generators and their support systems.

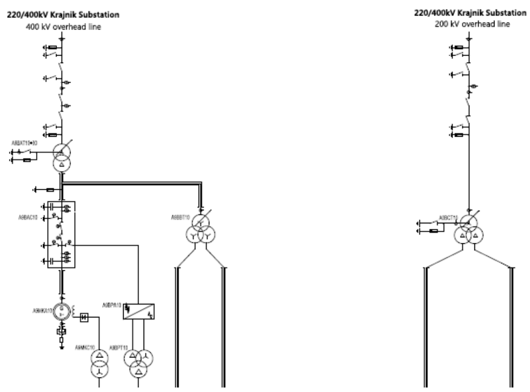
Part of the auxiliary nuclear building has been designed as a non-radiologically controlled area, which houses parts of the cooling water system. Special sampling laboratories are located on the lowest level. The maintenance area and some transport areas used during the refuelling phase are located on the highest level. All air exhausts from radiologically controlled areas are directed, collected and analysed in the auxiliary nuclear building before being released through the chimney.

The waste building is used for the collection, storage and processing of liquid and solid radioactive waste, in particular:

- shipping contaminated clothing for processing outside the facility
- processing and packaging of dry waste
- processing of chemical waste
- collection and storage of empty waste containers

The turbine building houses all the main components of the steam-condensate-feedwater system. In particular, it contains the turbine, generator assembly, condenser and their auxiliary systems.

5.5. The electrical system for auxiliary power



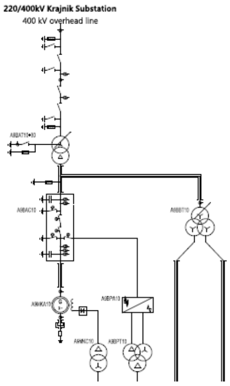
Example of self-supply based on block no. 9

The primary power supply will be provided by tap transformers powered from the busbar power output from the generator at MV voltage. The size of the units must be selected to match the power requirements of the switchgear for own needs. The MV/MV kV transformers will be three-winding, three-phase.

The backup power supply will be provided by a three-winding, three-phase transformer from the 220kV network. The transformer ratio will be 220/MV.

The voltage level for internal power supply and connection to the Transmission System Operator's network requires consultation with the Operator and obtaining the connection conditions from them.

5.6. Power output



Power is supplied via a busbar system to a generator circuit breaker (e.g. ABB HEC type) and then via a busbar bridge to the front field equipped with three-phase block transformers. From the transformer, the power will be supplied to SE Krajnik via the block front field in an overhead system at a voltage of 400kV.

The transfer of power from the unit to the national power system (KSE) requires obtaining connection conditions from the Transmission System Operator (Operatora Systemu Przesyłowego - OSP) on which the unit can be connected to the grid.

5.6.1. Legal framework

In accordance with the applicable Energy Law (Journal of Laws 2024.0.266), an entity applying for connection to the grid must submit an application for determining the conditions for connection to the grid, hereinafter referred to as the "Connection Conditions", to the energy company to whose grid it is applying for connection, attaching the relevant documents and paying an advance payment towards the grid connection fee in the amount of PLN 30 for each kilowatt of connection power specified in the application for determining the connection conditions. The amount of the advance payment may not exceed the amount of the anticipated grid connection fee and may not exceed PLN 3,000,000.

In the case of devices, installations or networks connected directly to the power grid with a rated voltage higher than 1 kV, an expert opinion on the impact of these devices, installations or networks on the power system shall be prepared.

The energy company responsible for transmission is obliged to conclude a connection agreement with the entity applying for connection to the grid.

The Connection Conditions shall specify the investment obligations of each party, including technical parameters, property boundaries and electricity billing arrangements.

If an energy company refuses to conclude a grid connection agreement, it is obliged to immediately notify the President of the Energy Regulatory Office and the interested party of the refusal, stating the reasons for the refusal.

New nuclear units will be classified as type D generating units (power above 75 MW and connection voltage above 110 kV).

Journal of Laws 2024, item 412

ANNOUNCEMENT BY THE SPEAKER OF THE SEJM OF THE REPUBLIC OF POLAND
dated February 26, 2024

Regarding the publication of the consolidated text of the Act on the preparation and implementation of investments in nuclear power facilities and accompanying investments.

The requirements for connecting generating units to the grid are specified in the network code (Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators - NC RfG)

5.6.2. Block transformers

Due to the location of the power plant, there is a potential possibility of supplying and installing three-phase units (single-phase units are also acceptable). In the event of a failure, it is recommended to set up a backup unit on a standby bay. In three-phase transformers are used, a three-phase unit should be used as a spare, and in the case of single-phase units, one single-phase unit should be used as the spare.

5.6.3. Block transformer forefields

For the purposes of power output and cooperation with the National Power Grid, it is recommended to install power output transformer forefields (bays).

An example of a block forefield topology is shown below:

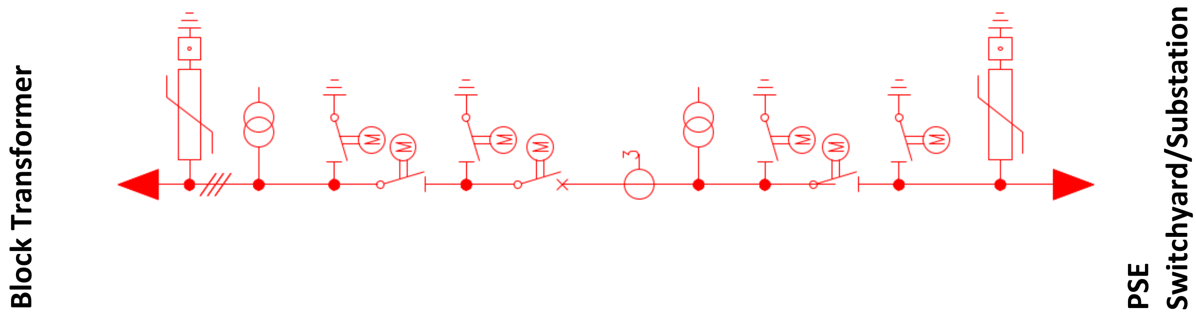


Figure 27 Example topological layout of a block bay

Proposed block forefield equipment

Example equipment in order when viewed from the block transformer side:

- surge arresters – voltage transformers – disconnector with two earthing switches – circuit breaker – current transformers* – voltage transformers* – disconnector with two earthing switches – surge arresters

* Instead of separate current and voltage transformers, a combined current-voltage transformer can be used

5.6.4. Power transmission lines

The existing overhead lines have been in operation for many years (with the exception of lines 9 and 10). Despite regular inspections and maintenance, significant wear and tear must be taken into account. Due to their location, the lines may not be suitable for power transmission and may not be technically adapted to it. Changing the technical parameters would require obtaining administrative decisions and thus adapting to current standards and environmental regulations. They are not expected to be used for power transmission from the nuclear power plant.

5.6.5. Expansion of the Krajnik power station

The nearest power station that could potentially accept the generated power is the 400/220 kV Krajnik power station. The current infrastructure of this substation potentially allows for the introduction of a new unit line to the 400 kV switchyard. The infrastructure at the 400/220 kV substation, including structural elements, was rebuilt in 2014-2021. There are technical possibilities for the expansion of the 400 kV switchyard.

5.7. Preliminary technical description of the selected reactor

The EPR reactor core, consisting of 241 fuel assemblies, has a CRDM (Control Rod Drive Mechanisms) rapid shutdown control system and the ability to implement multiple fuel management strategies (such as IN-OUT/OUT-IN), enabling it to meet the requirements of energy companies. The key features of the core and its operating conditions translate into competitive fuel management cycle costs. In addition, the EPR core offers significant benefits for sustainable development:

- 17% savings in uranium consumption per unit of energy produced (MWh)
- 15% reduction in long-lived actinide emissions per MWh
- significant flexibility in the use of MOX (mixed UO_2-PuO_2) fuel assemblies in the core, enabling the recycling of plutonium recovered from spent nuclear fuel.

A fuel assembly consists of a bundle of fuel rods containing nuclear material. The fuel rods and the coolant surrounding them are key components of the reactor core's active zone. The main attributes of a fuel assembly include:

- enrichment level of uranium-235 isotopes up to 5%, which enables high combustion of the fuel assembly.
- the choice of M5 material (a zirconium-based alloy with exceptional resistance to corrosion and hydration, i.e. water absorption) as a cladding and structural material, which guarantees increased resistance and excellent dimensional stability at high burn-up levels.
- The design of the spacer grid, which ensures low flow resistance and high thermal resistance.
- the use of an effective anti-splash device that almost completely eliminates failures related to fuel contamination.

The EPR design is based on the evolution of existing PWR reactors and incorporates a number of improvements to prevent potential failures:

The reactor pressure vessel (RPV) is equipped with a heavy neutron reflector, which allows for efficient fuel utilisation by limiting neutron leakage from the core and protects the reactor pressure vessel from ageing and embrittlement. In addition, it ensures progress in terms of the mechanical behaviour of the internal structure surrounding the core:

- smooth stress distribution within the structure, thanks to efficient reflector cooling, which reduces loads and prevents deformation,
- no discontinuities such as welds or bolts in the most irradiated areas.
- significant reduction in decompression loads

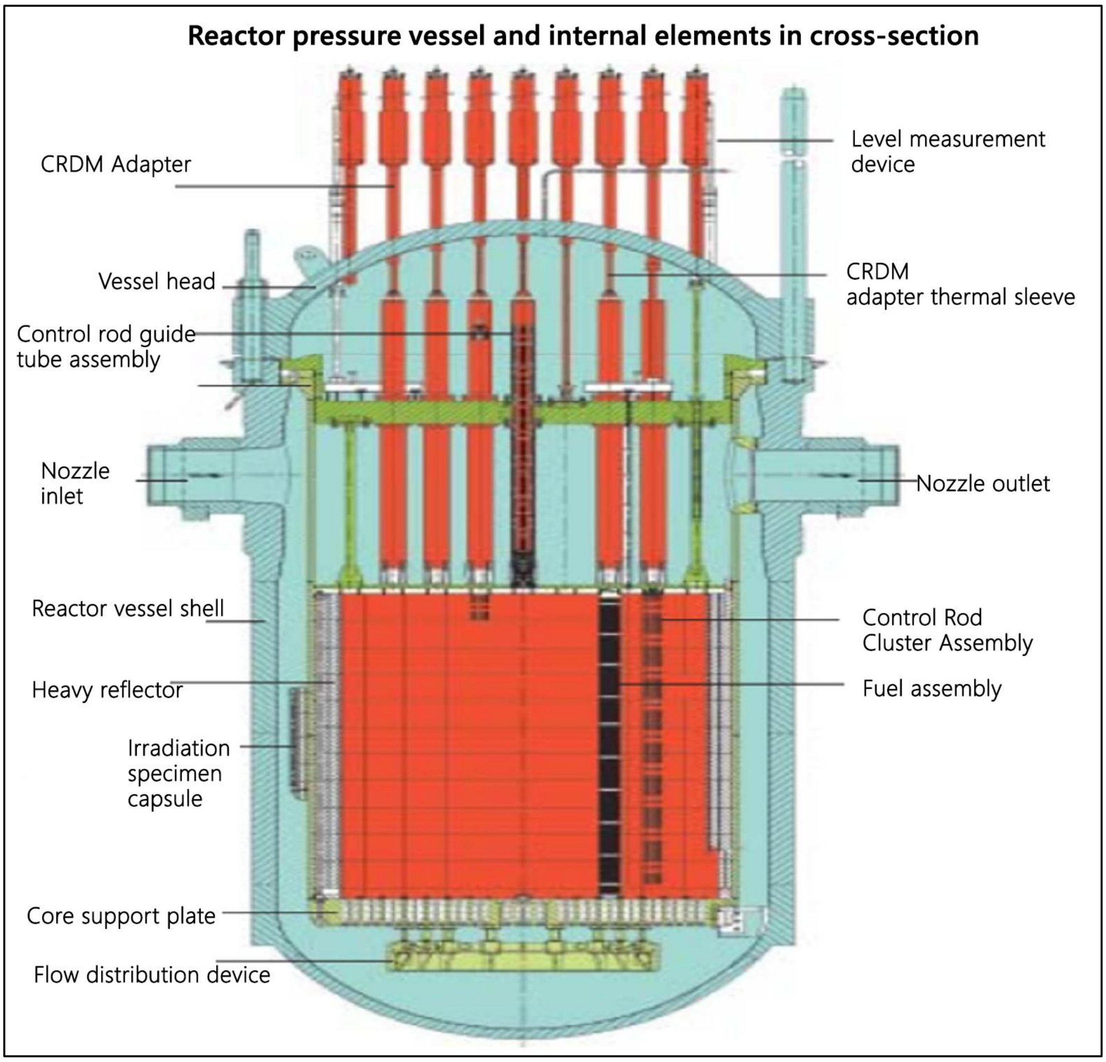


Figure 28 Reactor building

The improved steam generator allows for a 3 bar increase in steam outlet pressure compared to conventional designs, without compromising access to the tube bundle for inspection and maintenance. The very high steam saturation pressure at the tube bundle outlet (78 bar) contributes to high EPR efficiency (approximately 37%). The increase in steam volume and pressure of the secondary safety valves prevents liquid leakage into the environment in the event of a tube rupture.

Reactor cooling pumps (RCPs) are an improved version of the model used in N4 reactors and ensure forced circulation of the coolant in the reactor cooling system. This circulation process removes heat energy from the reactor core to the steam generators, where it is transferred to the secondary system.

The pumps are located between the steam generator outlet and the reactor vessel inlet of each of the four primary loops. They are characterised by extremely low shaft line vibration levels thanks to the use of a hydrostatic bearing mounted at the end of the rotor. The capacity of the circulation device has been increased to ensure compliance with the EPR operating point. The reactor coolant pump consists of three main components: the circulation device itself, shaft seals to ensure tightness in emergency situations, and a drip-proof squirrel-cage induction motor. All parts of the pump are replaceable and can be easily removed from the housing, allowing for quick maintenance in the event of a controlled leak on site.

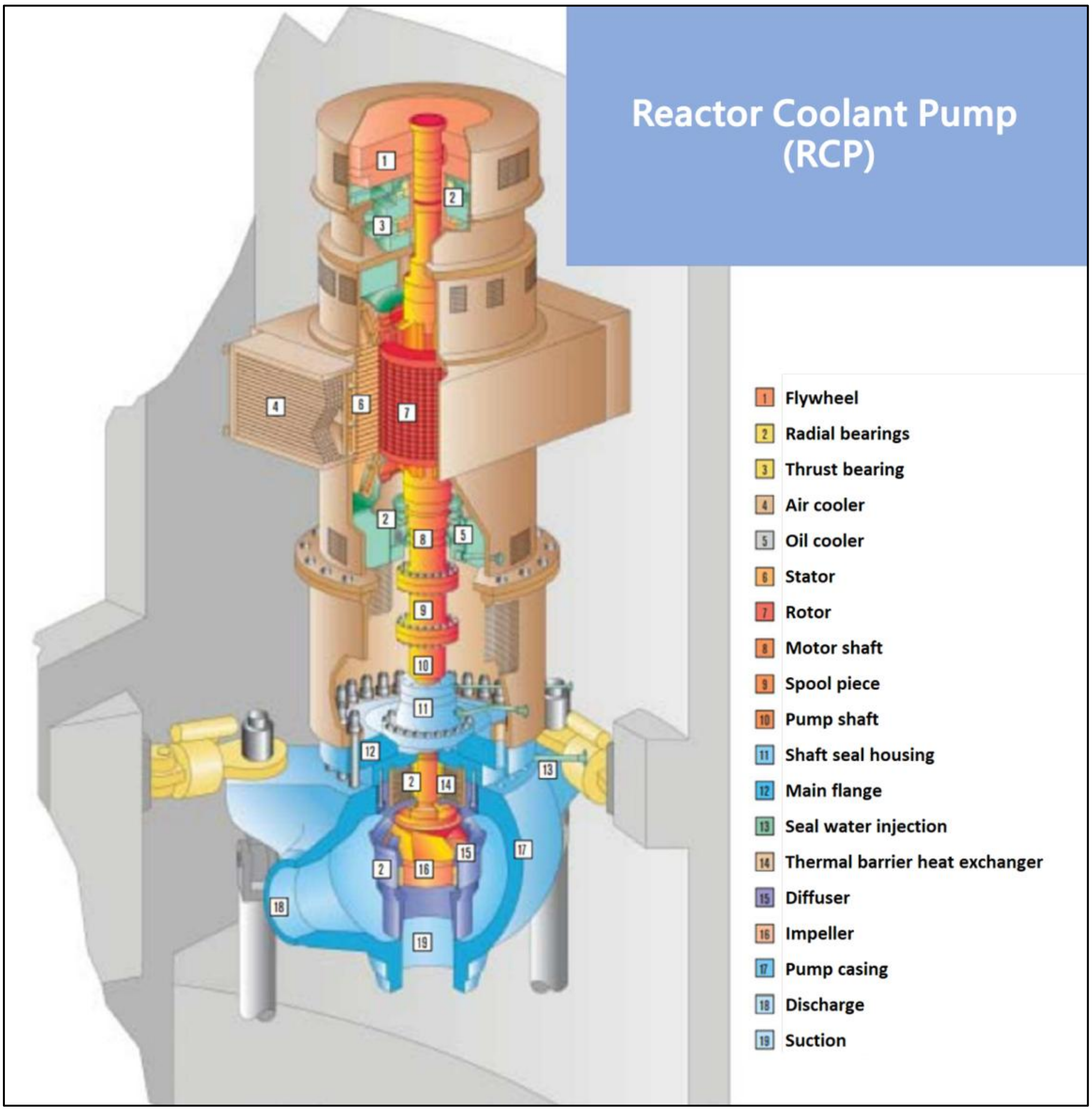


Figure 29 Cross-section diagram of an RCP pump

A pressure reducer with increased volume ensures a 60-year design life for the equipment and allows for more effective operation in the event of anomalies or emergency situations. In addition, a dedicated set of valves has been installed on the reducer to prevent the risk of a high-pressure core meltdown accident.

5.8. EPR nuclear reactor systems

The systems used in EPR are a set of advanced technologies and solutions that ensure a high level of safety, efficiency and cost-effectiveness of a nuclear power plant based on this reactor.

The most important of these include:

The **Chemical and Volume Control System** (CVCS) ensures continuous control of water reserves in the reactor cooling system (RCS) and constant monitoring of the boron concentration of all fluids injected into the RCS.

The **Safety Injection System/Residual Heat Removal System (SIS/RHRS)** allows heat to be transferred from the RCS to the cooling water system when heat transfer through the steam generators is no longer sufficiently effective. Additionally, in the event of an emergency, it maintains the RCS core outlet temperature below 180 °C after reactor shutdown.

In-containment Refuelling and water storage tank (IRWST) its main function is to supply water to the main reactor systems, including SIS and CVCS.

The **Emergency Feedwater System** (EFWS) is designed to ensure that water is supplied to the steam generators when all other systems that normally supply them are unavailable.

The **Extra Borating System** (EBS) provides sufficient borating of the RCS to transition to a safe shutdown state, with the boron concentration required for cold shutdown.

The **Component Cooling Water System** (CCWS) removes heat from safety-related systems, auxiliary operating systems and other reactor equipment to the radiator under all operating conditions.

The **nuclear sampling system** is used to collect gas and liquid samples from systems and equipment located inside the reactor containment.

The **venting and drainage system** collects gaseous and liquid waste from systems and equipment for reprocessing.

The **steam generator blowdown system** prevents the accumulation of solids in the secondary water.

The **waste treatment system** ensures the treatment of solid, gaseous and liquid waste.

The safety of nuclear reactors is a key aspect of nuclear energy. The introduction of stringent safety standards aims to protect people and the environment from the potential effects of radiation. The first important choice, in line with the recommendations of the French and German safety authorities, was to build the EPR design based on an evolutionary approach, drawing on the experience of 96 reactors previously built by Framatome or Siemens. This choice makes it possible to offer an evolutionary reactor based on the latest designs (N4 reactors in France and KONVOI in Germany) and to avoid the risks associated with adopting untested technologies.

In order to further reduce the likelihood of core meltdown, EPR activities are focused on three areas:

Expanding the range of operating conditions taken into account at the design stage, including:

- use of probabilistic safety assessments
- increasing protection against risks arising from internal and external hazards

Conscious selection of equipment and systems to reduce the risk of an abnormal situation turning into an accident:

- simplification of safety systems and optimisation of their redundancy and diversification
- optimised repair activities in the event of accidental rupture of a steam generator pipe

Increased operator reliability in emergency situations; extension of the operating time available to the operator

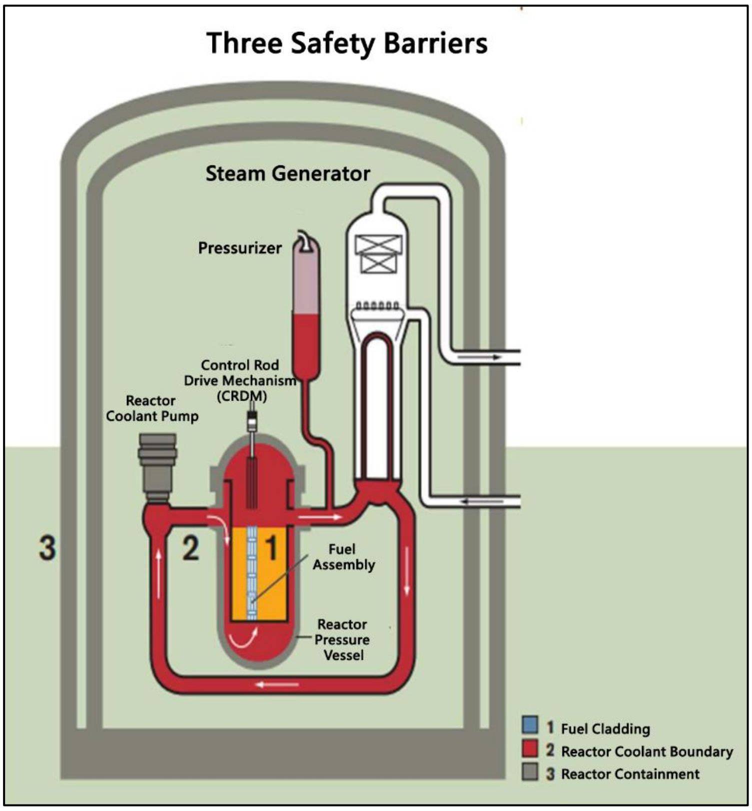


Figure 30 Diagram of the three protective safety barriers of the EPR reactor

Focus was also placed on specific design decisions aimed at minimising the consequences of a severe accident:

The use of special valves to prevent core meltdown under high pressure.

A reactor vessel with high mechanical strength to prevent high-energy reactions between the corium and the coolant.

Design of the reactor inner shell with the following functionalities in mind:

- the shell design is intended to withstand the pressure that may result from hydrogen combustion.
- a sealed heat dissipation system and a device for long-term removal of residual heat.
- use of a dedicated spray system with heat exchangers and a special radiator.
- Possibility of feeding water directly to the core catcher instead of to the spray system.
- 6 mm thick metal lining covers the inner shell made of compressed concrete
- internal penetrations equipped with excess shut-off valves and leak recovery devices
- the architecture of peripheral buildings and culvert sealing systems eliminate the risk of direct leakage from the shell into the environment.
- the space between the inner and outer shells is passively maintained under slight negative pressure to allow leaks to accumulate there.
- special ventilation and filter system in front of the chimney

5.9. Nuclear power plant control system

In PWR reactors, power adjustments are mainly achieved by changing the position of the control rods, and precise reactivity control in the reactor core is achieved by changing the concentration of boric acid in the primary circuit.

In Generation III nuclear power plants, power adjustments from 100% PN (Nominal Power) to 25% PN are taken into account from the very beginning of the design process. For example, two load-following profiles have been designed for the EPR reactor:

- Keeping up with the load within the range of 60% to 100% PN at a rate of 5% PN/min (with fuel consumption up to 80%),
- Keeping up with the load within the range of 25% to 60% of PN at a rate of 2.5% PN/min.

New nuclear power plants can vary their power output between 1,260 MW and 630 MW at a rate of approximately 63 MW/min. As shown in the figure below, this flexibility is better than that of coal-fired or gas-fired power plants, but it is not possible to achieve the minimum power level of, for example, a gas-fired unit.

Figure 31 Comparison of load (power) change rates in different types of grid-connected power plants

As shown in the figure, the time intervals during which the output of grid-connected power plants can be adjusted are similar. A nuclear power plant can change its output by 630 MW in 10 minutes, a coal-fired power plant by 480 MW in 12 minutes, and a CCGT (combined cycle gas turbine) power plant by 500 MW in 21 minutes. This gives power change rates of 63 MW/min, 26 MW/min and 38 MW/min, respectively.

It follows from the above that nuclear power plants can not only operate in a load-following system, but can do so better than coal and gas power plants.

5.10. Construction section

- Description of geological and engineering conditions

In accordance with section 3.4.4 of this study, the geological structure of the area was described on the basis of publicly available information; no information on geological and engineering conditions was found in publicly available resources.

Before project work commences, a detailed ground investigation must be carried out in accordance with the Regulation of the Minister of Transport, Construction and Maritime Economy of 25 April 2012 on the determination of geotechnical conditions for the foundation of building structures and the Regulation of the Council of Ministers of 10 August 2012 on the detailed scope of the assessment of land intended for the siting of a nuclear facility, cases precluding the possibility of deeming the site to meet the requirements for the siting of a nuclear facility, and on the requirements concerning the siting report for a nuclear facility

- Construction site facilities

The construction site facilities will consist of a number of temporary structures used for the construction of the power plant. The basic facilities include:

- Staff and office buildings for employees
- Gatehouses
- Concrete mixing plants
- Warehouses and storage yards
- Halls for assembling prefabricated elements
- Workshops
- Electrical switchboards
- Waste management facilities
- Temporary roads

- Description of buildings and structures

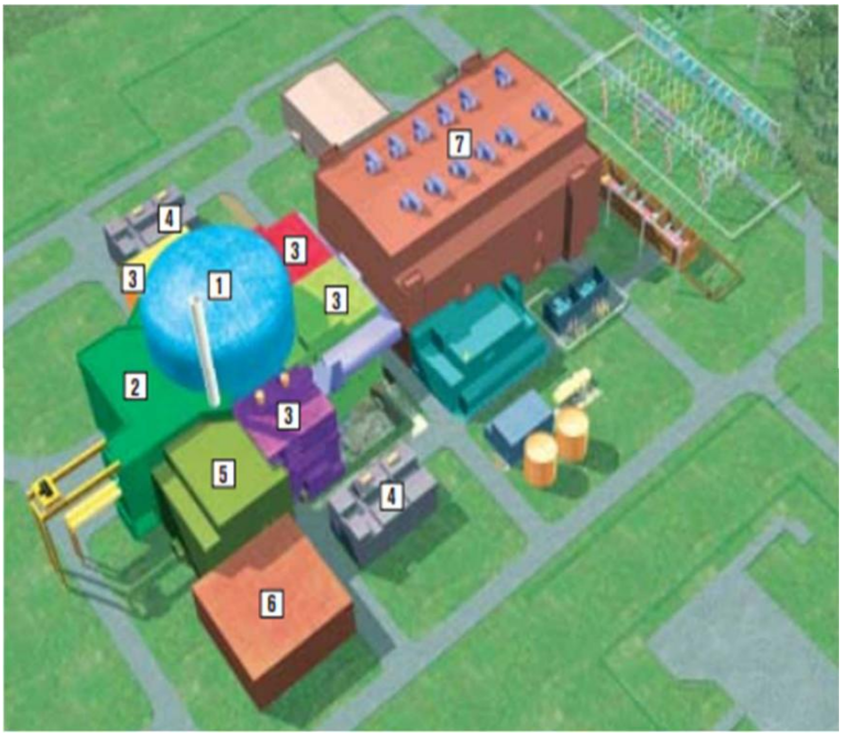


Figure 32 Main buildings of the EPR nuclear power plant

- Reactor building (steam supply system and fuel replenishment water tank) (1)

The reactor building is a massive reinforced concrete structure of the "double containment" type – consisting of an inner steel and concrete casing (primary containment) and an outer reinforced concrete shell (secondary containment). Inside, there is a pressurised reactor vessel, steam generators and cooling systems. The facility also includes a reactor tank that replenishes water in the event of a failure, as well as systems for loading and unloading fuel. The building meets the requirements for resistance to external impacts (including aircraft), radiation and seismic loads. The building is founded on piles on a massive foundation slab.

- Fuel building (2)

This is a reinforced concrete, secured technological facility used to store fresh and spent nuclear fuel.

It contains a spent fuel pool with biological shielding, fuel cassette handling rooms, overhead cranes and radiation monitoring systems. The design includes radiation protection, filtered ventilation and safeguards against radioactive substance leakage.

- Safety system buildings (3)

Located symmetrically on both sides of the reactor building, these are heavily reinforced concrete structures housing emergency core cooling systems, safety injection systems, safety valves and pumps. These buildings are independent of each other, ensuring redundancy and physical separation. The structures are resistant to seismic shocks, flooding and mechanical impacts.

- Diesel generator buildings (4)

Each diesel generator is housed in a separate reinforced concrete hall with increased structural resistance. These buildings house power generators, fuel tanks, start-up and cooling systems, as well as independent ventilation and filtration systems. Their design guarantees autonomous power supply to safety systems in the event of a total loss of external power (Station Blackout -SBO).

- Auxiliary building (5)

It is a multifunctional reinforced concrete structure adjacent to the reactor building. It houses auxiliary equipment such as ventilation, water treatment, measurement, electrical and automation systems. It also contains control, technical and access rooms. The facility ensures the continuity of support systems and communication with other areas of the facility.

- Radioactive waste building (6)

Designed as a sheltered reinforced concrete hall with separate zones for segregation, processing, conditioning and temporary storage of low- and medium-level radioactive waste. It includes radiological control, ventilation and air filtration systems. Its design ensures complete isolation from the environment and resistance to external factors.

- Turbine building (7)

This is a steel and reinforced concrete hall with a frame structure, housing a steam turbine, generator and condenser. The building is equipped with overhead cranes for the assembly and servicing of equipment.

5.11. Technological assessments

Thermodynamic calculations for the selected EPR-1600 nuclear reactor were performed using the STEAM PRO programme included in the Thermoflow package. The model takes into account the technical parameters presented by the IAEA (International Atomic Energy Agency) and the results from the report on the previous DEsire project task.

The model takes into account the steam part of the nuclear unit, without a detailed analysis of the reactor, which was treated as a black-box. Only the power level that the reactor will transfer to the steam generator, which will then be fed to the steam turbine, was taken into account. The unit operates 100% on condensation, and a cooling chimney is used for cooling.

Furthermore, based on an analysis conducted by the Silesian University of Technology, a solution with a series connection of condensers was used in the cooling system, as this reduces the amount of water in the cooling system required for the unit to operate. A detailed comparison of the method of connecting condensers and their impact on the amount of cooling water can be found in the report from task no. 3.

The figure below presents the results of model calculations for the steam part of the EPR-1600 unit for the average annual ambient temperature (9°C) prevailing in Dolna Odra (Gryfino municipality), determined on the basis of data from the Institute of Meteorology and Water Management.

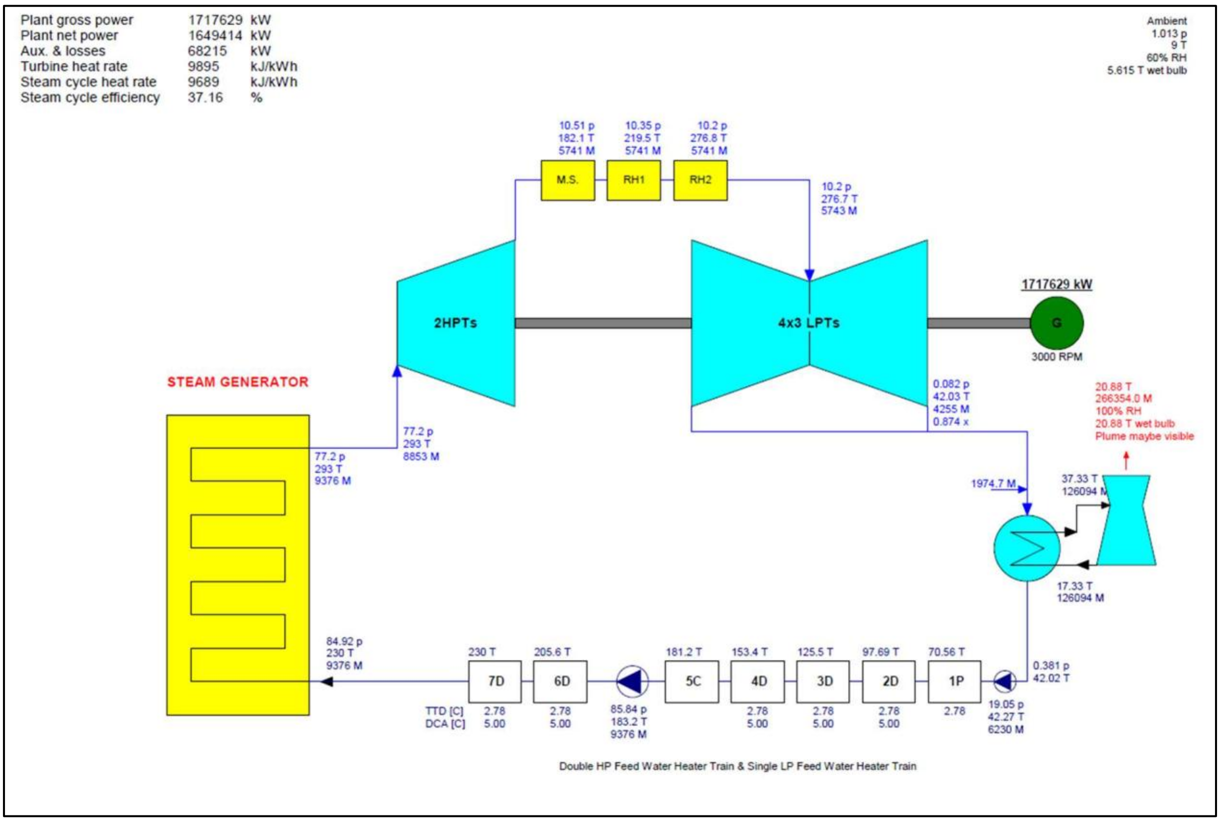


Figure 33 Steam diagram of the EPR-1600 unit with cooling system

The table below summarises the main parameters of the EPR-1600 unit modelled for the Dolna Odra location. The level of internal consumption has been increased compared to the above diagram, as it did not take into account other power plant equipment (apart from the steam part). In accordance with IAEA data, the level of internal consumption for the entire unit was set at 6.8%.

Table 11 Forecast parameters of EPR-1600 units at the Dolna Odra site

Parameter	Unit	EPR-1600
Reactor thermal power	MWt	4,500
Gross electrical power of the unit	MWe	1,717
Net electrical power of the unit	MWe	1,600
Gross unit efficiency	%	38
Cooling water flow	t/h	126,094
Water replenishment to the cooling system	t/h	3,693
DEMI water replenishment	t/h	29.71
Nuclear fuel	kg	3.21

The annual projected production and consumption of the analysed unit were determined for an availability level of 84.2%. This is the availability presented in the Polish Nuclear Power Programme. This level is close to the European average (82.5%). Similar availability rates in recent years have been reported, among others, in the Czech Republic (83.9%) and Switzerland (83.4%), where there are relatively few reactors, 6 and 4 respectively.

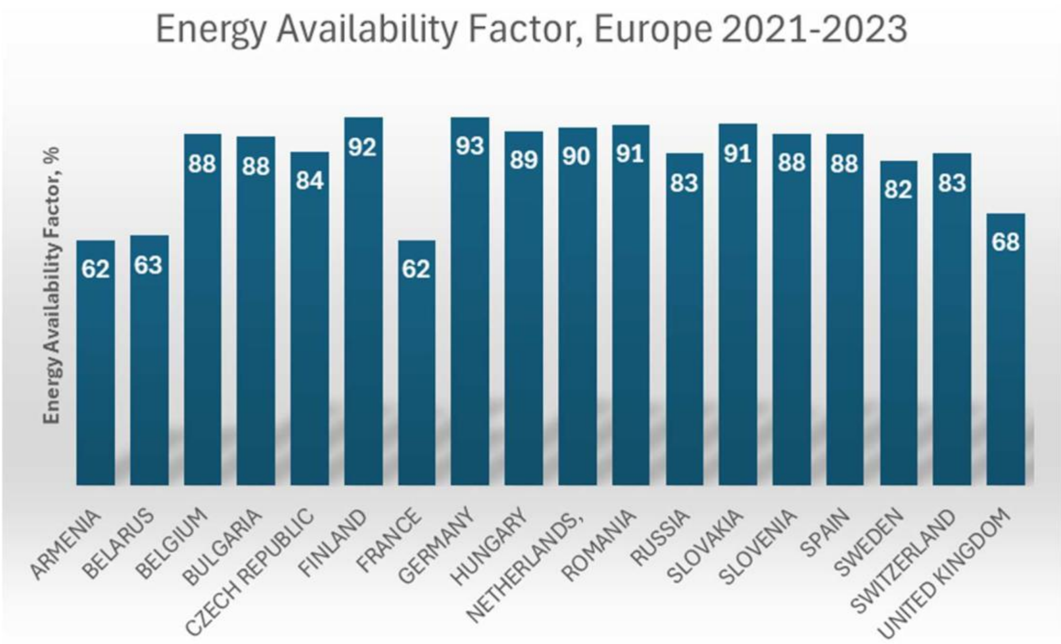


Figure 34 Availability rate of nuclear power units in Europe for 2021-2023 according to the IAEA24

[24] *https://pris.iaea.org/PRIS/WorldStatistics/ThreeYrsEnergyAvailabilityFactor.aspx*

Table 12 Forecast annual production data for EPR-1600 units at the Dolna Odra site

Parameter	Unit	EPR-1600
Availability	%	84.2
Electricity production	GWh	12,664
Electricity sales	GWh	11,801
Nuclear fuel	tonnes/year	23.7
Water replenishment for the cooling system	thousand tonnes/year	27,245
DEMI water replenishment	thousand tonnes/year	219

The values presented will form the basis for an analysis of the economic efficiency of the project described, which will be presented in the next section of the study.

6. Estimated investment expenditure

6.1. CAPEX structure

In international nomenclature, CAPEX investment costs are divided into successive levels of complexity as follows:

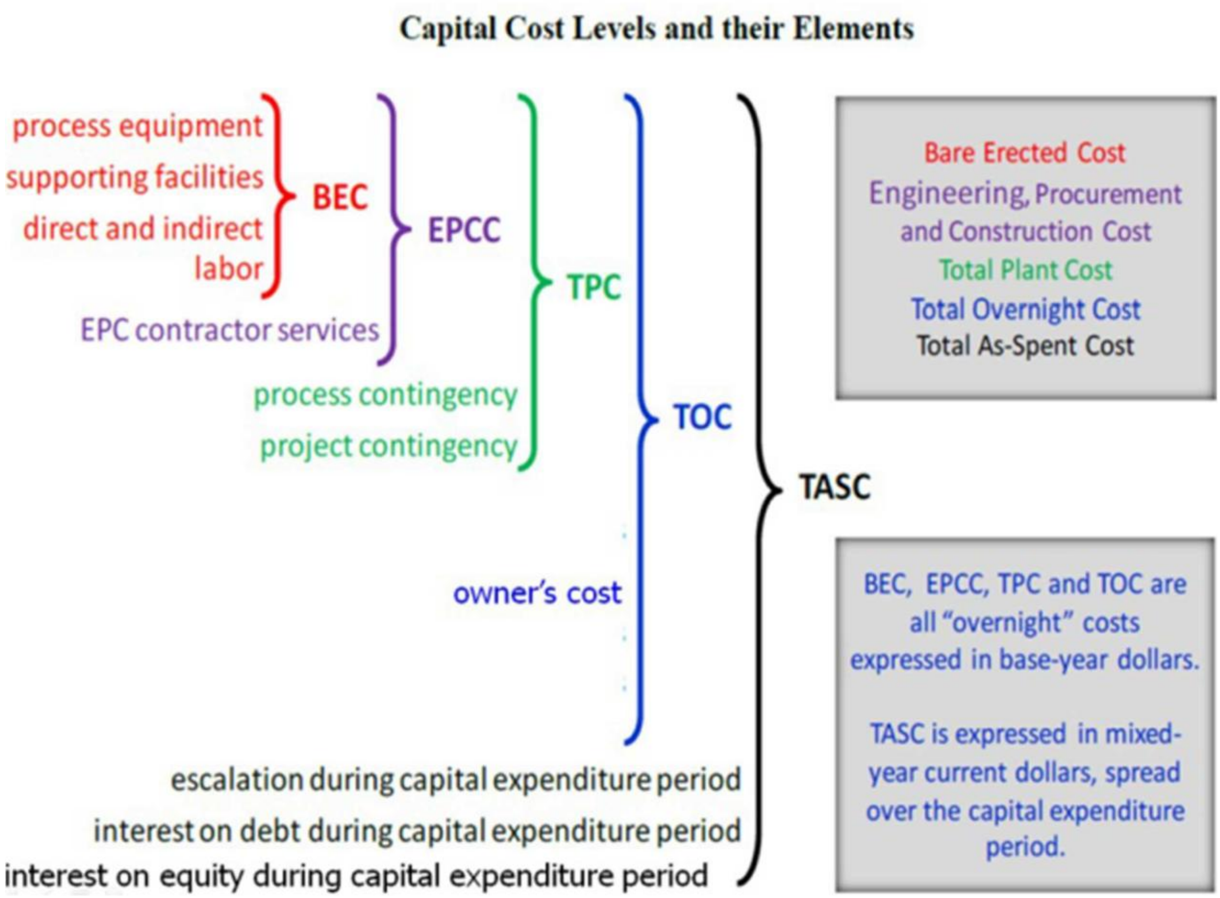


Figure 35 CAPEX structure

Data source: NETL, April 2011. Quality guidelines for energy systems studies: cost estimation

Methodology for NETL assessments of power plant performance. U.S. Department of Energy, National Energy Technology Centre, Pittsburgh, PA (Report DOE/NETL-2011/1455)

- BEC – these are so-called "hard, direct" costs, covering the supply of materials and equipment, labour costs and equipment.
- EPCC – these costs include BEC and indirect costs of the EPC General Contractor (e.g. project coordination and management, certification and acceptance by Certification and Supervision bodies, preparation and maintenance of construction facilities, utilities during assembly, training, insurance, commissioning, etc.)

- TPC – these costs include EPCC and the contractor's risk costs and financial reserves for the project.
- TOC – these costs include TPC and the Investor's costs (e.g. the Investor's implementation team, Contract Engineer services, warranty measurements, fees, expert opinions, consulting, insurance, etc.).

(All CAPEX cost groups listed above are expressed in fixed prices.)

- TASC – these costs include TOC and are calculated at variable prices over the duration of the investment (from the construction of the facility until its commissioning), taking into account capital costs, interest and contract indexation.

This section of the study estimates the level of capital expenditure in the TOC cost group. Variable costs are included in the economic analysis presented later in this study.

6.2. Methodology

In order to determine the costs of constructing one new EPR-1600 unit at the Dolna Odra power plant, the following steps were taken:

- The percentage distribution of the costs of individual CAPEX elements was determined according to industry studies.
- The unit cost of constructing an EPR-1600 unit in the Greenfield formula was determined on the basis of press releases
- The remaining costs associated with locating the new EPR-1600 unit on the site of the existing power plant were estimated, taking into account the savings in this respect.
- An estimated CAPEX for the construction of one EPR-1600 class unit at the Dolna Odra power plant was developed

6.3. Determination of the percentage distribution of capital expenditure

Below is a calculation of the possible percentage distribution of costs for individual cost groups of the EPR-1600 unit in the Greenfield formula, based on the document "Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants" prepared by the U.S. Department of Energy and published in 2022.

Due to the fact that in the above-mentioned study, direct costs account for as much as 58% of TOC costs, which, in the opinion of the author of this study, is an overestimated value, it was decided to adjust the percentage distribution of investment expenditure based on the study "Capital cost estimation for advanced nuclear power plants" prepared by the Department of Nuclear Science and Engineering, Massachusetts Institute of Technology, USA, published in 2022.

Despite the differences in technology, the author of this study believes that the breakdown of costs between direct and indirect costs is closer to the truth than that presented in the U.S. Department of Energy's report.

For the purposes of this study, it was assumed that the percentage distribution of EPR-1600 unit expenditures would be identical to the corresponding distribution for the AP-1000 unit.

In the study by the Department of Nuclear Science and Engineering at the Massachusetts Institute of Technology, the share of indirect costs is 9.09 percentage points higher than in the study by the U.S. Department of Energy. Therefore, indirect costs were increased by 9.09 percentage points and direct costs from the U.S. Department of Energy study were reduced by 9.09 percentage points in such a way as to maintain a proportional distribution of the individual components of direct costs between the indirect and direct cost groups. The results are presented in the table below.

Table 13 Percentage distribution of estimated investment costs for the EPR-1600 unit

No.	Specification of TOC costs (1 EPR-1600 unit) Greenfield	% share in investment capital
1	Initial fuel inventory	8.5%
2	Owner's costs	11.8%
3	Land and land rights	0.4%
4	Supporting infrastructure	12.6%
5	Reactor island	15.2%
6	Turbine island	12.6%
7	Electric island	4.2%
8	Other apparatus and equipment	1.7%
9	Condenser and heat dissipation system	2.5%
10	Total indirect costs	30.4%
11	Total share in investment capital	100.0%
12	Direct costs (Nos. 4-9) % TOC	48.9%
13	Indirect costs (Nos. 1-3 and 10) % TOC	51.1%

Data source: own calculation based on the document "Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants"; U.S. Department of Energy; 2022 and "Capital cost estimation for advanced nuclear power plants"; Department of Nuclear Science and Engineering, Massachusetts Institute of Technology, USA; 2022.

6.4. Determination of the unit cost index for the construction of the EPR-1600 unit according to press releases

The above-mentioned study, "Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants," shows the unit cost of constructing a PWR unit in the TOC cost group at **USD 4,572/kWe.** In the opinion of the author of this study, this indicator may be underestimated due to the increase in the prices of services and materials that has occurred in recent years as a result of the pandemic and the geopolitical situation. Therefore, it was decided to base the valuation on press releases.

In December 2022, press reports appeared (https://energetyka24.com/atom/analizy-i-komentarze/ile-zaplaci-polska-za-elektrownie-jadrowa-komentarz) suggesting that the unit cost of constructing an AP-1000 unit may be approximately **USD 5,267/kWe** (PLN 31.26 billion/1 AP1000 unit at an exchange rate of 4.7477 on 28 October 2022).

However, the latest press release from April 2024 published by PEJ (https://www.money.pl/gospodarka/polski-atom-za-150-mld-zl-sa-tez-prognozy-ws-terminu-7018323225906112a.html) mentions a cost of PLN 150 billion for three AP-1000 units, which gives a unit cost of **USD 10,000/kWe** for the construction of one AP-1000 unit. The article lacks information about the content of this indicator – whether it is a net or gross amount, whether the prices are fixed or variable, whether it includes maintenance services, etc. Depending on the interpretation, in the opinion of the author of this study, this indicator may range from **approximately 6,500 to 10,000 USD/kWe**.

In turn, according to the latest study by the Massachusetts Institute of Technology, "2024 Total Cost Projection of Next AP1000", the TOC costs for subsequent AP1000 units currently range between **$9,300 and $11,625/kWe.**

Taking the above information into account, it was decided to set **a unit rate of USD 10,000/kWe** for the purposes of this study**.** This is consistent with the press release issued by PEJ and falls within the range set out in the latest MIT study, "2024 Total Cost Projection of Next AP1000".

Press releases indicated that the EPR-1600 unit may be cheaper per unit, but it was decided to equalise both indicators due to the uncertainty of this information and the early stage of cost estimation. Therefore, it was decided to adopt the above unit indicator for the AP-1000 block **of USD 10,000/kWe for the EPR-1600 block**. The final unit levels will be determined by the tender process, and it cannot be ruled out that press reports suggesting that the EPR-1600 is cheaper per unit than the AP1000 will ultimately prove to be true.

The economic section presented later in this study contains an analysis of the sensitivity of results to the level of CAPEX, which covers possible positive/negative deviations from the assumed level of CAPEX.

6.5. Determination of additional costs and savings related to the location of the planned investment

The table below presents additional costs (increasing the CAPEX value), savings (reducing the CAPEX value) and potential avoided costs resulting from the location of the investment at the Dolna Odra Power Plant.

- **Additional costs**

The following additional and non-unit costs must be incurred in order to carry out the investment at the Dolna Odra Power Plant

- Costs of clearing the site – demolition, dismantling and levelling (8 x 200 MW units, including exhaust gas systems, coal yard and transformer stations). These costs were not included in the Capex calculation because they are costs that the Investor would have to bear in any case, regardless of whether a new power unit is built at the existing power station or not.

In the absence of a new investment, the site must still be cleaned up and the installations dismantled at the end of the life cycle of the old coal-fired units.

These costs have been estimated at PLN 350 million net.

- Costs of renovating the intake points, discharge points and cooling water pumping station building. These costs are estimated at PLN 2 million net.
- Costs of power transmission to SE Krajnik – 400 kV line. These costs have been estimated at PLN 10 million net.

➢ **Savings**

- Savings from the use of the intake, discharge and cooling water pumping station building – no need to construct these elements.

  These savings are estimated at PLN 27 million net.
- Savings resulting from the fact that there is no need to purchase the land.

  These savings are estimated at PLN 227.3 million net.

➢ **Potential avoided costs** (group outside the scope of nuclear power plant construction indicators)

Below is a summary of the avoided costs of using the Dolna Odra power plant site compared to a site not connected to the existing energy and logistics infrastructure. Potential avoided costs result from the assumptions made by the author of the study based on other nuclear power plant locations with different location conditions. Therefore, average hypothetical estimate values were adopted.

- The cost of constructing a water intake and discharge channel to the river – assuming a 1 km intake channel and a 1 km discharge channel

  These savings were estimated at PLN 220 million net.
- Access road costs – 25 km assumed These savings were estimated at PLN 125 million net.
- Costs of a single-track railway line – assumed to be 25 km

  These savings were estimated at PLN 625 million net.
- The costs of constructing the operator's power station, where the project is located some distance from existing stations, are estimated by the Power Grid Operator; depending on the terms of the bilateral agreement, the investor may contribute to these costs. The cost of such a station may amount to approximately PLN 80 million net.

6.6. Determination of CAPEX

➢ **Assumptions**

- All amounts given below are exclusive of VAT and are presented in constant 2024 prices.
- The unit level of capital expenditure for the construction of the APR-1600 unit was estimated on the basis of press releases and industry publications presented in section 6.4. It amounts to USD 10,000 net/1 kWe. The percentage breakdown of costs into individual groups was determined on the basis of information from industry publications.
- Elements outside the scope of the unit indicator for the construction of PWR class units, as well as additional costs and savings, were estimated on the basis of publicly available market price bulletins for works and investment facilities published by such publishers as Bistyp and Sekocenbud, as well as price indicators from B.S.P.i R Energoprojekt - Katowice S.A. price indices based on many years of experience in designing and estimating the costs of installations similar in size and technical parameters.
- The following exchange rate was used for currency conversion: 1 USD = 4 PLN.
- EPR-1600 unit capacity used for calculations: 1770 MWe (gross)
- This study is at the preliminary feasibility study stage. In accordance with the AACE International Recommended Practice classification system, the expected accuracy of the valuation range is presented in the table below, which shows the accuracy of the valuation range between the concept stage and the actual feasibility study

Table 14 Classification of CAPEX estimation accuracy according to AACE International Recommended Practice

	Primary Characteristic	***Secondary Characteristic***		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Cost Estimate Classification Matrix for Process Industries

➢ **Calculations**

The total block costs for one EPR-1600 block were determined as follows: USD 10,000 million/MWe x

1,770 MWe = 10 x 1,770 = USD 17,770 million net

The dollar exchange rate according to the National Bank of Poland in 2024 fluctuated around PLN 4.0. For the purposes of this study, this standardised value was adopted.

After converting the above at an exchange rate of 1 USD = 4 PLN, we obtain:

17,700 x 4 = 70,800 million PLN net

Next, the above cost was divided into individual components according to the assumptions presented in the above points, based on industry information.

In the next step, additional costs were added and savings resulting from the location of the facility at the Dolna Odra Power Plant were deducted. The results are presented in the table below.

Table 15 Estimated costs of constructing one EPR-1600 class unit at the Dolna Odra Power Plant

No.	Specification of works (1 EPR-1600 unit)	% share in the index	Value in PLN million net
1	Initial fuel inventory	8.5%	6,028.6
2	Other costs (ownership, transmission)	11.8%	8,353.9
3	Land and land rights	0.4%	258.4
4	Supporting infrastructure	12.6%	8,955.6
5	Reactor island	15.2%	10,746.7
6	Turbine island	12.6%	8,955.6
7	Electrical island	4.2%	2,985.2
8	Other apparatus and equipment	1.7%	1,194.1
9	Condenser and heat dissipation system	2.5%	1,791.1
10	Total indirect costs	30.4%	21,530.8
11	Total block costs	100.0%	70,800.0
12	Costs of power transmission to SE Krajnik – 400 kV line		10.0
13	Savings from the use of intake, discharge and cooling water pumping station building		-25.0
14	Savings from not having to purchase land		-258.4
15	Total investment expenditure		70,526.6

Source: own calculations

The above calculations do not include avoided costs because they do not affect CAPEX, do not need to be incurred and fall outside the scope of the nuclear power plant construction indicator, so they do not reduce the above-mentioned costs.

However, the avoided costs represent added value in light of the location of the investment at the Dolna Odra Power Plant. Their level varies greatly depending on the potential location of the nuclear power plant. Therefore, it is not possible to determine the exact savings, as such calculations can only be made in relation to another specifically situated location.

The table below presents avoided costs based on average, hypothetical estimate values:

Table 16 Potential avoided costs based on hypothetical bill of quantities values

No.	Potential avoided additional costs related to the location of the investment in El. Dolna Odra	Value in PLN million net
1	Costs of constructing a water intake and discharge channel to the river - 1 km of intake channel and 1 km of discharge channel assumed	220
2.	Costs of the access road - 25 km assumed	125
3.	Costs of a single-track railway line - assumed 25 km	625
4	**Total potential avoided costs**	**970**

Data source: own calculation

6.7. Comparison of Greenfield vs. Brownfield

A comparison was made of the costs of one EPR-1600 unit at the Dolna Odra site versus a Greenfield site. The results are presented in the table below:

Table 17 Cost comparison

No.	Specification of works (1 EPR-1600 unit)	Brownfield Value in PLN million net	Greenfield Value in PLN million net
1	Preliminary fuel inventory	6,028.6	6,028.6
2	Other costs (ownership, transmission)	8,353.9	8,353.9
3	Land and land rights	0	258.4
4	Supporting infrastructure	8,955.6	8,955.6
5	Reactor island	10,746.7	10,746.7
6	Turbine island	8,955.6	8,955.6
7	Electrical island	2,985.2	2,985.2
8	Other apparatus and equipment	1,194.1	1,194.1
9	Condenser and heat dissipation system	1,791.1	1,791.1
10	Total indirect costs	21,530.8	21,530.8
11	Savings from the use of the intake, discharge and cooling water pumping station building, including the costs of necessary renovations	-25.0	0
12	Power connection costs, 2 x 1 km assumed for Greenfield	10.0	20.0
13	Costs of constructing a water intake and discharge channel to the river - assumed 1 km of intake channel and 1 km of discharge channel	0	220
14	Costs of the access road - 25 km assumed	0	125.0
15	Costs of a single-track railway line - 25 km assumed	0	625.0
16	Total investment expenditure	70,526.6	71,790.0

Data source: own calculation

As can be seen from the table above, Brownfield costs are approximately 1.8% lower than for the Greenfield option. However, it should be noted that there are also

Two important aspects

- social aspect, i.e. maintaining local jobs, retaining people with energy experience at the existing power plant and continuing the organisational culture of the energy company.
- infrastructure aspect, i.e., the use of existing energy infrastructure (lines and stations) and transport infrastructure (roads, railways), which would become redundant if the power plant were to be decommissioned.

7. Analysis of economic efficiency for the specified assumptions, supplemented by an analysis of investment risk (sensitivity analysis to changes in the legal and economic environment)

7.1. Subject and objective of the analysis

A DCF economic model was prepared for the project in question, using the FCFF (free cash flow to the firm) formula. As part of the analysis, the LCoE indicator was calculated, which determines the minimum price of electricity that balances the production costs in a given type of generation unit. It is also the minimum price at which the sale of energy allows the investment to exceed the break-even point.

Standard profitability indicators such as NPV and IRR were not calculated because the LCoE indicator makes it easier to compare different technologies and does not require assumptions about future electricity prices. Forecasting energy prices 70-80 years into the future, given the current realities and changes in the markets, is subject to a large margin of error.

The LCoE [PLN/MWh] Levelised Cost of Energy indicator determines the average cost of producing 1 MWh of electricity, calculated according to the following formula:

$$\text{LCoE}=\frac{\sum_{t=1}^{n}\frac{(I_t+M_t)}{(1+r)^t}}{\sum_{t=1}^{n}\frac{E_t}{(1+r)^t}}$$

Figure 36 Formula for determining LCoE

where:
I_t – CAPEX investment expenditure in year t

M_t – OPEX costs in year t

r – pre-tax discount rate

E_t – heat production in year t

The economic analysis also includes an analysis of the sensitivity of LCoE to key variables in the economic calculation.

7.2. Assumptions

- The analysis period is 70 years, consisting of:
    - Investment (construction) period: 10 years
    - Operational period: 60 years
    - It is assumed that the unit will be commissioned after 2040.
- The calculation is made on an annual basis, in net prices (excluding VAT) and in real terms (without taking inflation into account).
- CIT income tax rate – 19%
- RV – residual value is calculated as the net value of fixed assets

7.2.1. Capital expenditure

Capital expenditure is presented in detail in Chapter 6. The table below shows the capital expenditure schedule broken down into Greenfield and Brownfield options.

Table 18 Schedule of capital expenditure, PLN million net

CAPEX	TOTAL	1	2	3	4	5	6	7	8	9	10
Greenfield, PLN million net	**70,527**	1,411	3,879	8,463	13,929	11,461	7,758	8,463	7,405	4,761	2,997
Brownfield, PLN million net	**71,790**	1,436	3,948	8,615	14,179	11,666	7,897	8,615	7,538	4,846	3,051

7.2.2. Discount rate

Pre-tax WACC discount rate in real terms equal to **6.98%**

$$WACC_{nom} = K_W * k_W * + K_O * k_O * (1 - T_c)$$

K_W – cost of equity (15.3%)

K_W = Risk-free rate (5.24% [25]) + Market risk premium (5.15% [26]) + Project risk premium (2%)

k_W – equity capital share (30%)

K_O – cost of debt capital (7.24%)

K_O = Risk-free rate (5.24%) + Debt margin (2%)

k_O – share of debt capital (70%)

Tc – corporate income tax (19%)

$$WACC_{realny} = \frac{WACC_{nom} + 1}{CPI + 1} - 1$$

[25] *Announcement by the President of the Energy Regulatory Office; Q3 2024*

[26] *Damodaran – Equity risk premium Poland 01.07.2024*

CPI – inflation over a 5-year period (assumed to be 2.5% [27])

Details of the WACC calculation are presented in the .xslx model.

7.2.3. Exchange rates

The EUR/PLN exchange rate was adopted on the basis of data published on the website nbp.pl "Macroeconomic forecasts of professional forecasters Results of the NBP Macroeconomic Survey Round: March 2024" in the amount of 4.3 as the median of forecasts for the years 2024-2026 and left until the end of the calculation period.

The National Bank of Poland (NBP) set the exchange rate of the US dollar (USD) against the Polish zloty (PLN) on Friday, 22 March 2024, at PLN 3.9928, which rounded to two decimal places gives a value of PLN 4.00/USD. According to other forecasts, including those by Blomberg, a similar EUR/USD ratio will be maintained in the coming quarters, which is why analyses assume that this trend will continue.

Table 19 Assumed exchange rates

Currency	Unit	Value
US dollar	[PLN//USD]	4.0
Euro	[PLN/EUR]	4.3

7.3. Operating costs

$$OPEX = variable\ OM\ cost + fixed\ OM\ cost\ per\ year$$

The economic analysis covers the following operating costs:

- Fuel costs
- Waste disposal costs
- Water replenishment costs (for the cooling system and DEMI)
- Repairs and upgrades
- Property insurance
- Civil liability insurance for nuclear damage
- Property tax
- Costs of salaries and employee benefits
- Costs of future decommissioning of the unit (decommissioning fund)

7.3.1. Fuel costs

Fuel costs were calculated based on the volume of electricity produced, expressed in MWh. The annual production of the unit was assumed on the basis of technological analysis from the site. With the assumed base availability, the new unit will produce **12,664,455 MWh** of electricity per year.

The unit price of nuclear fuel according to various sources over the years is shown in the chart and table below.

[27] *Inflation target of the National Bank of Poland and the Monetary Policy Council*

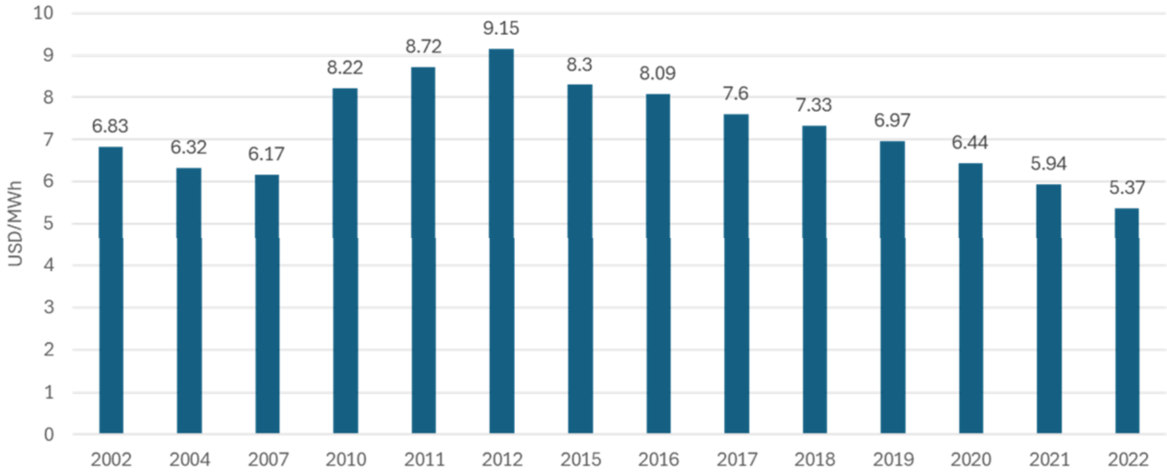


Figure 37 Nuclear fuel costs over time

Source: NEI, Nuclear Costs in Context, 2023

Table 20 Sources of nuclear fuel prices

Other sources	Value	Unit/year
IAEA; Economic Assessment of the Long-Term Operation of Nuclear Power Plants	7.00	USD_{2018}/MWh
MIT; Overnight Capital Cost of the Next AP1000	6.15	USD_{2022}/MWh
MIT; 2024 Total Cost Projection of Next AP1000	6.25	USD_{2023}/MWh

For the calculations, the unit cost of fuel expressed in USD/MWh was assumed, based on a study by the Nuclear Energy Institute[28], to be **USD 5.37/MWh** (after taking into account US inflation, fuel costs will amount to USD 5.73/MWh). Ultimately, annual fuel costs will amount to approximately **PLN 290 million**.

7.3.2. Spent nuclear fuel disposal costs

The costs of fuel disposal were also calculated based on the amount of electricity produced. The unit indicator was adopted in accordance with the following studies:

- *A. Strupczewski, Analysis and assessment of electricity costs from various energy sources in Poland (Analiza i ocena kosztów energii elektrycznej z różnych źródeł energii w Polsce), NCBJ, 2015.*
- *K. Kołacińska, R. Sasin, Analysis of the costs and benefits of implementing nuclear energy in Poland (Analiza kosztów i korzyści wdrożenia energetyki jądrowej w Polsce), Energy Market, 2016*.

where the rates are USD 2.33/MWh and EUR 2.17/MWh, respectively. No information is available on other Polish sources for this cost.

A rate of **USD 3.53/MWh** (averaged value after indexation) was used for the analyses. This amount includes the removal, storage and disposal of spent fuel. Converted into annual values, the cost of fuel disposal amounts to approximately **PLN 179 million**.

[28] *Overnight Capital Cost of the Next AP1000; Koroush Shirvan; March 2022*

7.3.3. Water replenishment costs

Raw water and DEMI (Demineralised water) consumption was determined in section 5.11. The DEMI water cost calculation was based on a rate **of PLN 10.35/t** typical for power plants, obtained from the operation of another nuclear power plant.

For raw water, it was assumed that raw water for cooling system replenishment would be taken from the river. The unit rate for raw water was set at **PLN 1.5/tonne** based on the Council of Ministers Regulation on water abstraction rates[29], which also includes the costs of physical water abstraction from the river. The annual costs are as follows: approx. **PLN 2.3 million** for DEMI water and approx. **PLN 41 million** for raw water.

7.3.4. Payroll and employee benefits costs

Nuclear energy creates more jobs than any other energy source. The standard number of people employed at a nuclear power plant (1 GWe reactor) ranges from 500 - 800 permanent employees for regular operation and maintenance.[30] Other sources[31] indicate a higher number for an EPR-1600 unit – 600 employees – and this figure was ultimately adopted in the analysis.

The gross remuneration of one person was assumed to be the same as in the second location, at PLN 14,700/month, where data on employment in the ENEA SA group at the Kozienice power plant was obtained. However, no data on this subject was obtained for the Dolna Odra location. The level of social security and other benefits payable by the employer was assumed to be 21%.

The annual costs of salaries and employee benefits amount to approximately **PLN 128 million**.

7.3.5. Property insurance costs

Property insurance costs were assumed as a percentage of total investment expenditure at 0.323% per annum, which translates into approximately **PLN 228 million**. The insurance rate was assumed as for the second location (Kozienice), where detailed information was obtained about a similar-sized hard coal-fired unit.

7.3.6. Civil liability insurance for nuclear damage

Civil liability insurance costs are calculated based on the assumed maximum amount of insurance coverage for nuclear damage and a fixed percentage of this amount, paid annually during the period of operation. The maximum amount covered by insurance is PLN 1,350 million (i.e. 300 million SDR in accordance with the Atomic Energy Act) and the annual insurance premium (as a percentage of the maximum amount covered by insurance) is 0.25%. The final value of the insurance, at the assumed exchange rate of SDR = PLN 5.28, is approximately **PLN 4 million**.

7.3.7. Property tax

Property tax is calculated as a percentage of the value of buildings, which account for approximately 13% of total investment expenditure. Under current regulations, the tax rate on buildings is 2% per annum of the value of the building. Ultimately, the annual tax costs amount to approximately **PLN 183 million**.

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[29] *REGULATION OF THE COUNCIL OF MINISTERS of 26 October 2023 on unit rates for water services*

[30] *https://info.westinghousenuclear.com/poland/news-and-insights/kariera-w-przemysle-jadrowym.*

[31] *Overnight Capital Cost of the Next AP1000; Koroush Shirvan; March 2022*

7.3.8. Renivation costs (building maintenance)

Renovation costs were assumed based on Total Generating Cost indicators presented in a study by the Nuclear Energy Institute [32], which are divided into three components:

- Fuel – fuel cost
- Capital – capital expenditure, which includes the cost of spare parts, improvements and infrastructure outside the unit. Regulatory, ICT and maintenance costs.
- Operating – operating costs, which include the costs of materials and services, fuel management, external services, training and salaries.

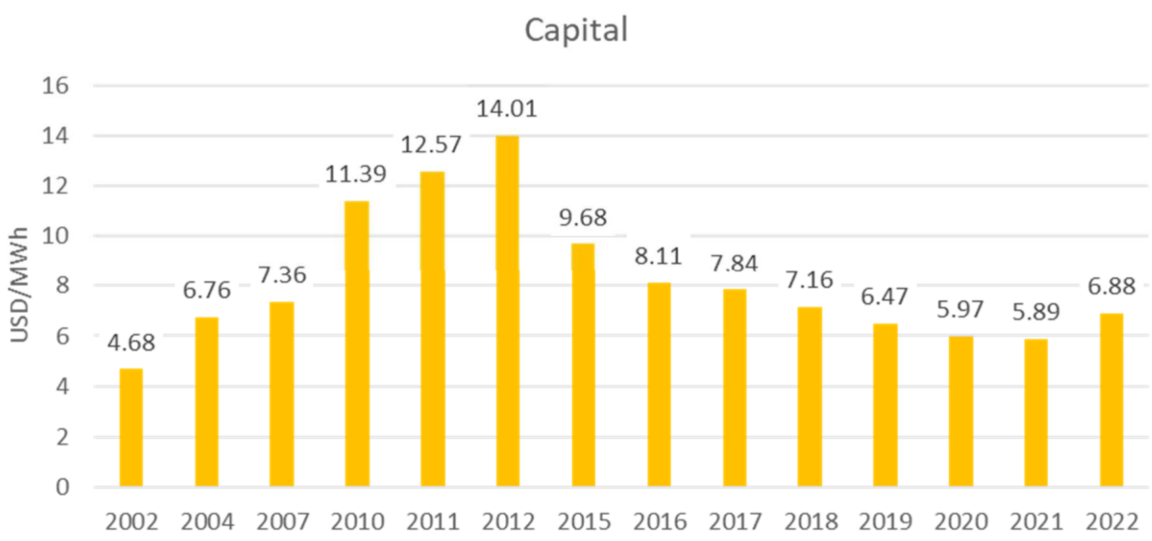

Figure 38 Unit capital costs

Source: NEI, Nuclear Costs in Context, 2023

[32] *Overnight Capital Cost of the Next AP1000; Koroush Shirvan; March 2022*

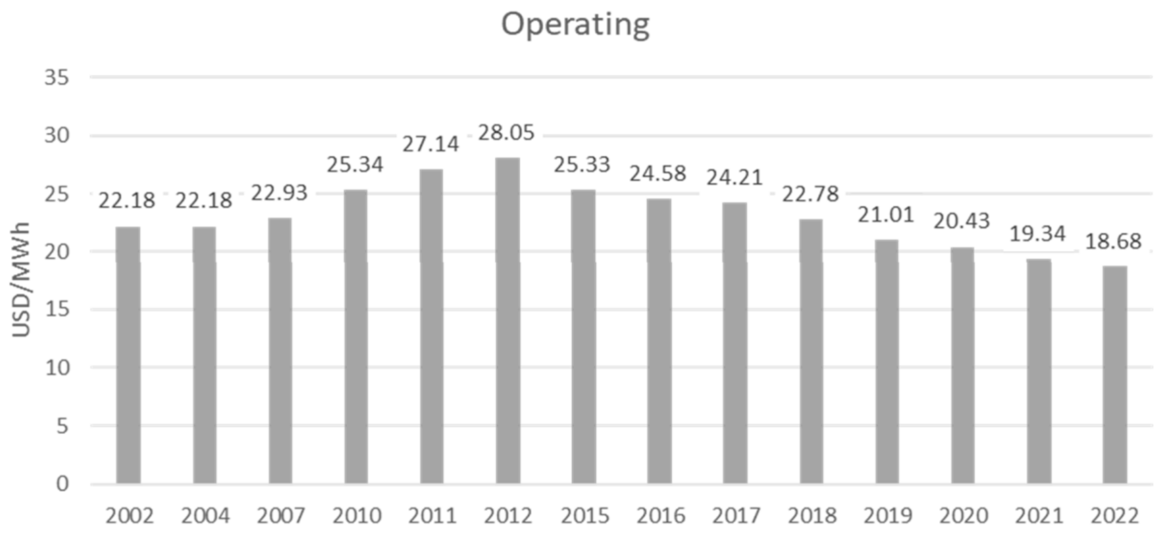

Figure 39 Unit operating costs

Source: NEI, Nuclear Costs in Context, 2023

The costs of repairs were calculated as the total capital expenditure plus a portion of the operating costs corresponding to the costs of third-party services. The total costs amount to USD_{2022} 12.75/MWh, which, after taking into account US inflation, gives **USD 13.62/MWh**. The total annual costs of repairs and modernisation amount to approximately **PLN 690 million**.

7.3.9. Future decommissioning costs

Based on an IAEA study[33] , the costs of future decommissioning of the facility were adopted, which will commence after the end of the unit's operation and will last for six years. For this purpose, it was assumed that in each year of operation, an amount corresponding to the future decommissioning costs of the nuclear facility will be set aside in equal installments. The total cost may amount to approximately 15% of the total capital expenditures. The annual contribution to the renovation fund will be approximately **179 million PLN**.

[33] *Economic Assessment of the Long Term Operation of Nuclear Power Plants: Approaches and Experience; IAEA Nuclear Energy Series*

The total annual operating costs for the EPR-1600 unit were calculated at **PLN 1,925 million**. The chart below shows the share of individual costs in OPEX.

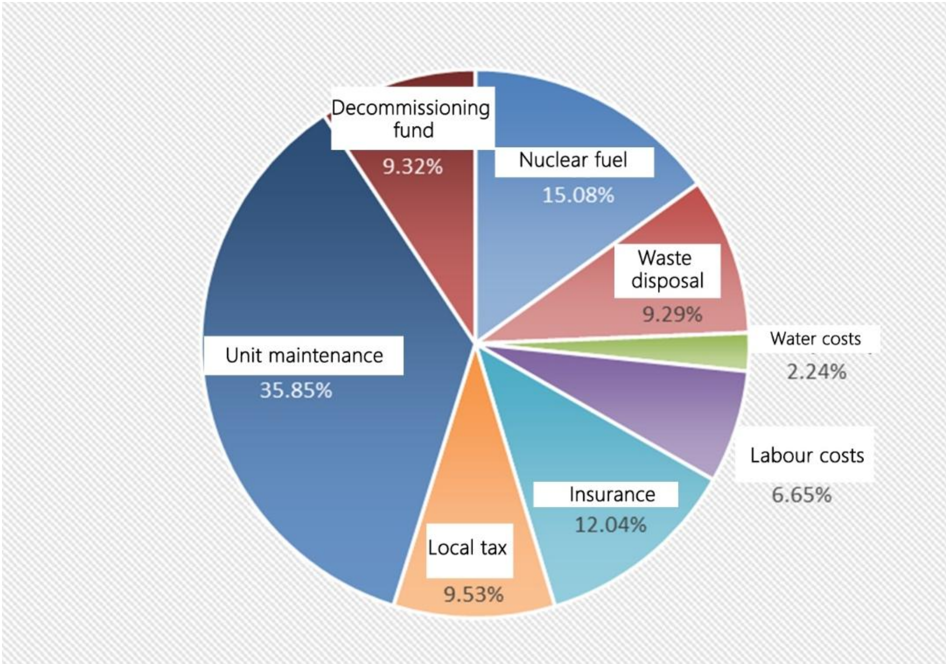

Figure 40 Annual operating costs of the EPR-1600 unit

7.4. LCoE results

For the previously described capital expenditure and operating costs of the unit, assuming electricity production, the LCoE was determined separately for the Brownfield and Greenfield options.

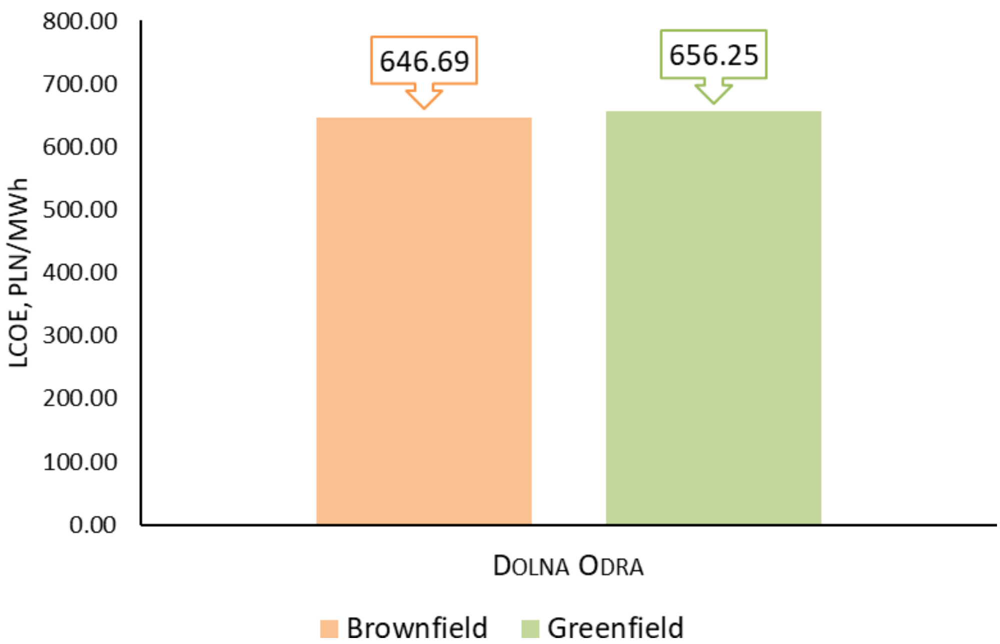

Figure 41 Comparison of LcoE Brownfield vs. Greenfield

The LCoE structure for the Brownfield variant is shown below.

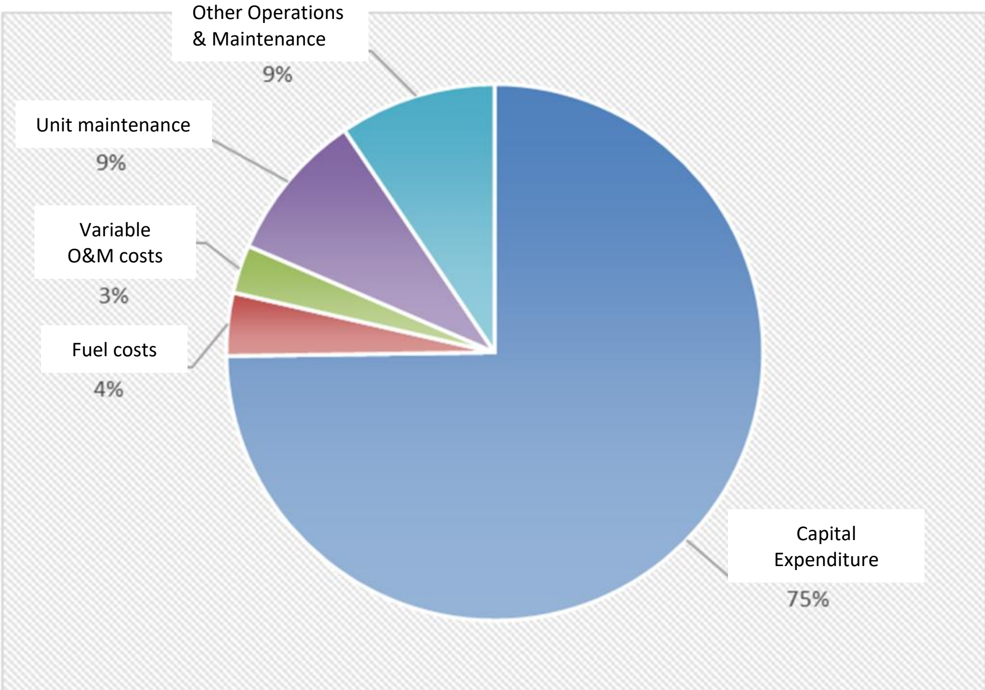

Figure 42 Structure of the determined LCOE for Brownfield

7.5. Sensitivity analysis

A sensitivity analysis was performed for the Brownfield variant, analysing the following key variables within a range of +/- 50% (the first two items) or within a range of possible values (the last two items):

- capital expenditure,
- nuclear fuel price,
- unit operating/availability factor (GCF).
- weighted average cost of capital (WACC)

It was assumed that only one variable would change at a given moment. The other variables would remain at the same base level.

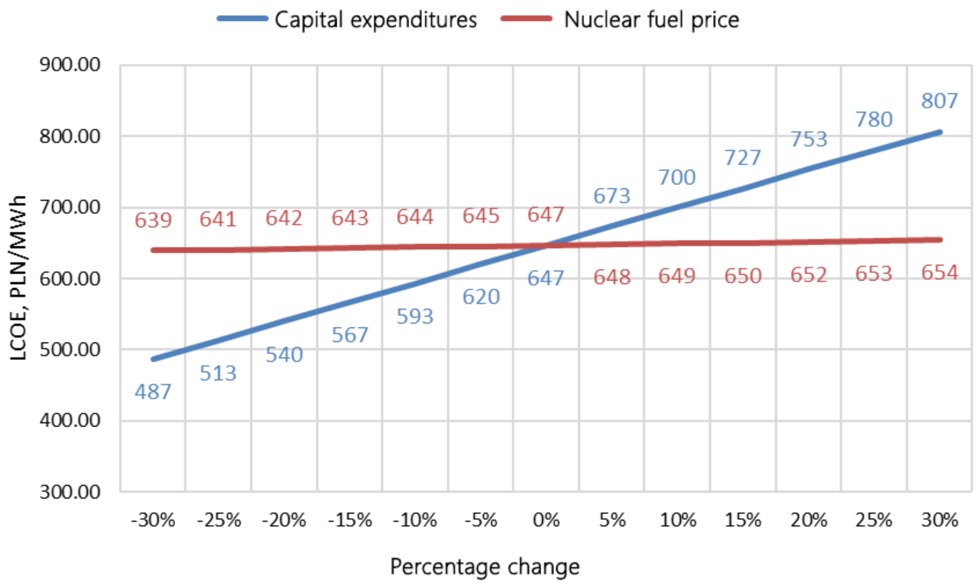

Figure 43 Sensitivity analysis results – capital expenditure and nuclear fuel price

Capital expenditure has a greater impact on LCoE, while changes in fuel costs have a negligible impact on the cost of electricity production.

The sensitivity analysis for **changes in production** was conducted based on a change in the assumed capacity factor (GCF) ranging from 20% to 92%. A GCF of 100% would most likely not be achievable, therefore the maximum value of the capacity factor is 92% – the figure given by the IAEA[34] as the typical availability of an EPR-1600 unit.

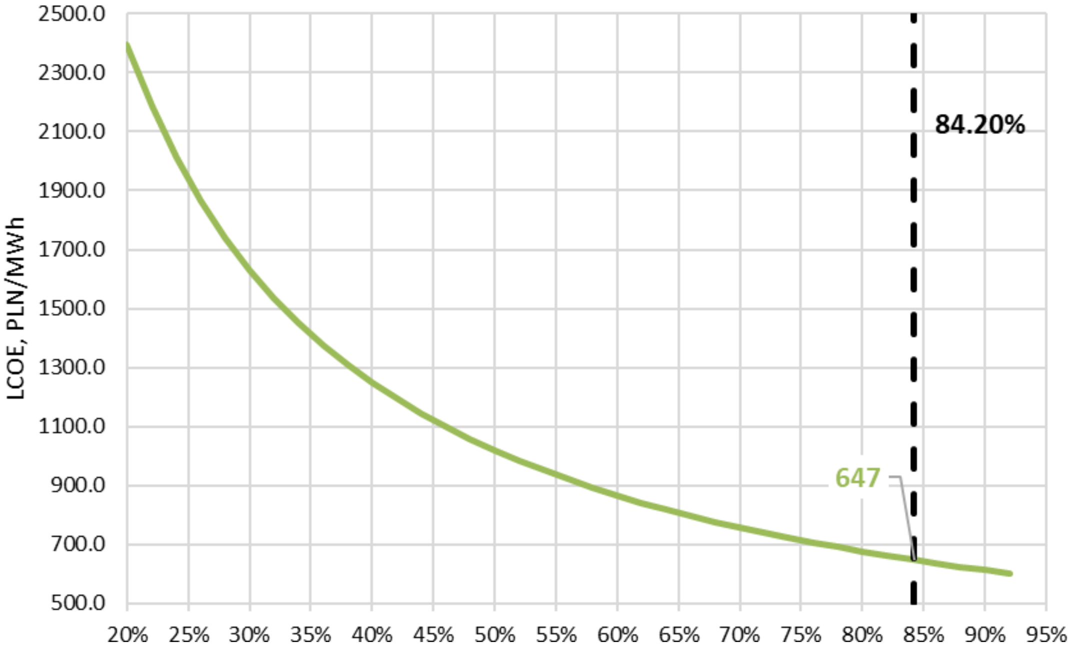

Figure 44 Sensitivity analysis results – unit availability

[34] *IAEA, Status report 78 – The Evolutionary Power Reactor (EPR)*

The graph shows how strongly the LCoE indicator depends on production; in the case of very low availability, the production cost rises to over PLN 2,000/MWh.

In addition, **the WACC discount rate** was subjected to a sensitivity analysis in the range of 4%–10%. The graph shows the assumed WACC rate of 6.98%.

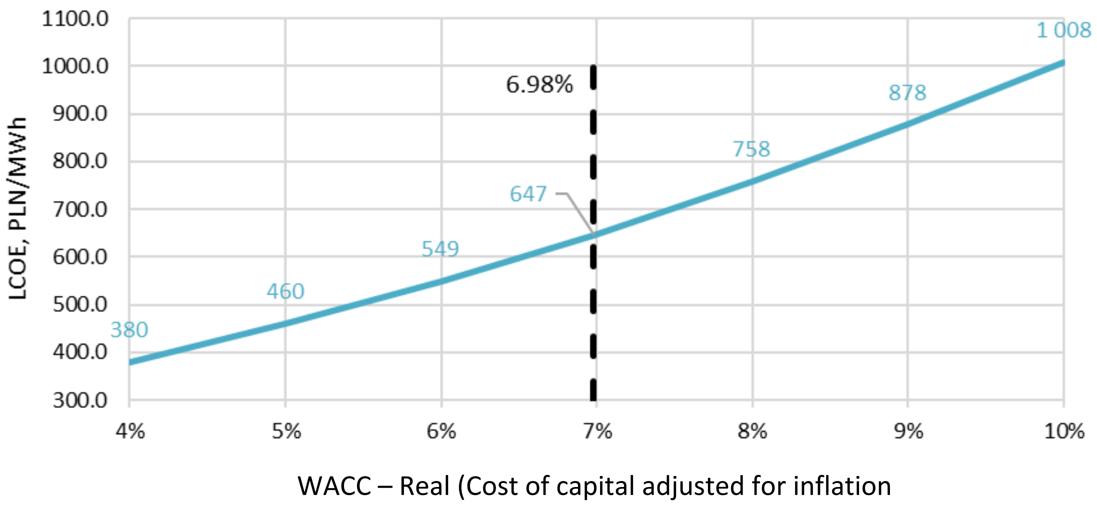

Figure 45 Sensitivity analysis results for the variable discount rate

A change in WACC has a significant impact on LCoE, but changing it is not easy in reality and depends on many macro- and microeconomic factors in the country.

7.6. Summary of economic analysis

- Based on the assumptions used for modelling, the LCoE for EPR-1600 technology in Dolna Odra is approximately PLN 647/656/MWh (Brownfield vs Greenfield).
- The use of existing infrastructure in the investment process (brownfield) allows for an LCoE that is approximately PLN 10/MWh lower.
- The LCoE structure shows that capital costs are the main component of the cost – approx. 75%.
- A sensitivity analysis has shown that the project is most sensitive to changes in capital expenditure. The discount rate (WACC) is also an important parameter. The price of nuclear fuel has a negligible impact on profitability indicators.
- It is crucial to ensure adequate productivity of the unit on the market, as a decrease in the unit's availability leads to a drastic increase in electricity generation costs.
- With the designated LCoE level, the implementation of this type of investment must be based on guaranteeing revenues at an appropriate level, e.g. through a contract for difference, which will ensure a return on the investment expenditure incurred.

8. Analysis of required competencies for the management and operation of a nuclear power plant with characteristics specific to the investment option (based on the database of required competencies resulting from Research Task No. 6)

The energy transition from coal-to-nuclear technology (C2N) requires a restructuring of the technical and engineering workforce. Generating added value to the economy and society in this process may also involve utilising the skills of coal-fired power plant employees in nuclear power plants.

A rationally conducted power plant transformation process can have positive effects such as:

- no need to lay off a large proportion of employees;
- no need to recruit a large number of new employees;
- no need for some of the staff to relocate.

Significant negative effects and risks associated with the C2N transition for coal-fired power plant employees include:

- unemployment during the transition period;
- the need for further training;
- the need to acquire new qualifications.

The transformation of a coal-fired power plant into a nuclear power plant also results in a lack of demand for certain specialisations and the need to employ people with new specialisations.
A rational design of the C2N transition may therefore also include a strategy regarding the use of technical and engineering staff at coal-fired power plants.

The procedure for expanding or acquiring the competences required by engineering and technical staff can be started by determining the structure of the staff in existing and planned power plants and power units. The employment structure in a power plant or nuclear power unit determines the target human resources and their competences. The literature in this field presents lists of employee occupations together with the percentage share of a given type of position[35]. This data, together with the total number of employees, allow the target employment structure in individual occupations to be determined. Similarly, for coal-fired power plants, a list of occupations and their percentage share is provided. A direct comparison of this data for a given location allows for an assessment of the possibilities for direct transition, often requiring only a slight expansion of qualifications.

In order to prepare procedures for expanding or acquiring the competences required by the engineering and technical staff of modernised power plants and power units, sample case studies were presented, the essence of which was to determine the positions and number of jobs that require staff with completely new qualifications or that require further training. Similarly, positions and number of jobs were identified for coal-fired power plant personnel who would not be able to find employment in the new power plant or nuclear unit due to the need for complete retraining.

Based on these analyses, it is possible to examine in greater detail the competencies required for the most important positions at a nuclear power plant, along with identifying opportunities for further training or retraining.

In this regard, it is also possible to indicate proposed paths for further training or retraining.

35 Hansen J., Jenson W., Wrobel A., Stauff N., Biegel K., Kim T., Belles R., Omitaomu F.: *Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants. Systems Analysis and Integration; Revision 2 Prepared for U.S. Department of Energy 13 September 2022 ;INL/RPT-22-67964*

8.1. The most important elements of procedures for expanding or acquiring the competences required by the engineering and technical staff of modernised power plants and power units

The use of the competences of the engineering and technical staff of a power plant or coal-fired unit in a nuclear power plant or unit can bring many economic and social benefits. These effects can be achieved by rationally defining possible procedures for expanding or acquiring the competences required in new power plants.

The most important issues to consider when designing the process are:

- determining the positions necessary in the new power plant or unit;
- determining the number of positions for each job in the new power plant or unit;
- determining the positions in the power plant or unit being decommissioned;
- determining the number of positions in the decommissioned power plant or unit;
- determining the timetable for the creation of positions and full-time positions in the new unit or power plant;
- determining the timetable for the liquidation of positions and full-time positions in the power plant or coal-fired power unit.

With the information provided, it is possible to determine the matrix of positions and jobs in the plant being liquidated and the one being established. Such a matrix makes it possible to determine the positions and jobs in which:

- there is little or no need to expand employees' skills;
- it is possible to retrain or acquire new competences in a relatively short period of time;
- for which complete retraining is necessary.

The timetables for the decommissioning and commissioning of power plants or power units allow the process to be supplemented with information on possible career paths and opportunities for employees to upgrade their skills, e.g., during the construction of a new power plant or unit.

8.2. List of jobs with the highest employment in a nuclear power plant

A list of the job roles with the highest number of employees helps to determine the demand for the most important job roles. The analyses first identified the number of posts for ten job roles (those with the highest number of employees) for a nuclear power plant with an electrical capacity of 1 GW (Table 21). The data was compiled on the basis of [9]. This source indicates that employment at a modern nuclear power plant built on the basis of 10 SMR units amounts to 341 full-time positions (directly employed). These figures were compared with the number of jobs that would be lost at a coal-fired power station also with a capacity of 1 GW. In this case, it was assumed that the total number of direct jobs is 145.

Table 21 List of the most common jobs in a nuclear power plant

Coal-fired power plant				Nuclear power plant		
Percentage of employees	Number of jobs 1GW	Percentage of jobs increasing	Job title	Percentage of employees	Number of full-time positions in 1GW	Percentage of positions increasing by
0.31	-0.45	0.31	Nuclear engineers	13.07	44.64	13.07
0.31	-0.45	0.62	Nuclear reactor operators nuclear	10.96	37.44	24.03
0.52	-0.75	1.14	Security guards security	10.96	37.44	34.98
0.62	-0.9	1.75	Nuclear technicians	7.17	24.48	42.15
4.33	-6.3	6.09	First-line managers of production and operational staff	5.06	17.28	47.21
5.37	-7.8	11.46	Electrical and electronic equipment repairers, power stations, substations and relays	3.06	10.44	50.26
0.52	-0.75	11.97	Training and development specialists development	2.85	9.72	53.11
4.64	-6.75	16.62	Electrical engineers	2.85	9.72	55.95
0.83	-1.2	17.44	Managers for Architecture and Engineering	2.74	9.36	58.69
3.20	-4.6	20.64	Industrial machine mechanics Industrial	2.74	9.36	61.43

An analysis of the data shows that the ten jobs listed account for as much as 61% of the jobs at a nuclear power plant. The same jobs account for approximately 21% of the jobs at a coal-fired power plant. These jobs include: Nuclear engineers; Nuclear reactor operators; Security guards; Nuclear technicians; Training and development specialists; Architecture and engineering managers - whose share in a coal-fired power plant is less than one per cent. It can be assumed that these positions must be filled almost entirely by people from outside the nuclear power plant or by people from the coal-fired power plant who have undergone comprehensive training.

Due to the greater number of jobs in total at a nuclear power plant, some positions at coal-fired power plants may be transferred in their entirety to nuclear power plants. The positions in question include First-line managers of production and operational staff; repairers of electrical and electronic equipment, power plants, substations and relays; electrical engineers; industrial machine mechanics.

8.3. List of positions with the highest employment at a coal-fired power plant

A list of the most common positions at a coal-fired power plant is also helpful in determining procedures for the use of engineering and technical staff. As in the previous section, a comparison with the requirements of a nuclear power plant allows us to identify groups of positions that will not find employment at a nuclear power plant or require complete or partial retraining.

The analyses identified fourteen jobs with the highest number of positions (Table 22). Data from studies based on [36]

Table 22 List of the most common jobs in a coal-fired power plant

Coal-fired power plant				Nuclear power plant		
Percentage of employees	Number of jobs 1GW	Percentage of full-time positions cumulative	Job title	Percentage of employees	Number of full-time positions 1GW	Percentage cumulatively
17.44	25.4	17.44	Power plant operators	0.63	2.2	0.63
7.02	10.2	24.46	Installers and repairers of power lines	0.74	2.5	1.37
5.37	7.8	29.82	Electrical and electronic equipment repairers, power stations, substations and relays	3.06	10.4	4.43
4.64	6.8	34.47	Electrical engineers	2.85	9.7	7.27
4.33	6.3	38.80	First-line managers of production and operational staff	5.06	17.3	12.33
3.61	5.3	42.41	Customer service representatives customer	0	0	12.33
3.20	4.7	45.61	Industrial machine mechanics Industrial	2.74	9.4	15.07
3.10	4.5	48.71	First-line managers mechanics, installers	2.53	8.6	17.60
2.37	3.4	51.08	Installers and repairers of control systems and valves, except for mechanical doors mechanical	0.21	0.7	17.81
2.06	3	53.15	Electricians	1.69	5.8	19.49
2.06	3	55.21	Distributors and electricity dispatchers	0.32	1.1	19.81
1.86	2.7	57.07	Chief executives and operational managers	0.74	2.5	20.55
1.75	2.55	58.82	Project management specialists and business operations specialists, all others	2.11	7.2	22.66
1.44	2.1	60.27	Management analysts	0.63	2.2	23.29

In the case of coal-fired power stations, 60% of full-time positions are accounted for by fourteen job roles. These roles account for approximately 23% of the workforce at a nuclear power station.

36 *Hansen J., Jenson W., Wrobel A., Stauff N., Biegel K., Kim T., Belles R., Omitaomu F.: Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants. Systems Analysis and Integration; Revision 2 Prepared for U.S. Department of Energy September 13, 2022 ;INL/RPT-22-67964*

Within this group of occupations, although some account for only a small percentage of posts at a nuclear power station, due to the significant disparities between the workforce at nuclear and coal-fired power stations, only some of these roles will not be filled at a nuclear power station. This applies in particular to Power plant operators; Power line installers and repairers; Customer service representatives; Installers and repairers of control systems and valves (except for mechanical doors); Electricity distributors and dispatchers

8.4. List of jobs with the greatest shortage at nuclear power plants and the greatest surplus at coal-fired power plants

By comparing the number of jobs for individual positions at coal-fired and nuclear power plants, it is possible to identify shortages and surpluses. A list of the jobs with the largest surplus at coal-fired power plants and the largest shortage at nuclear power plants allows for an assessment of the possibility of retraining some employees to work at the new power plant. A list of the most important positions, together with the number of jobs for a 1GW nuclear and coal-fired power plant, is presented in Table 23.

Table 23 Summary of the most important positions with shortages and surpluses of jobs in coal-fired and nuclear power plants

Nuclear power plant	Shortage		Surplus	Coal-fired power plant
Nuclear engineers	44.19		23.19	Power plant operators
Nuclear reactor operators	36.99		7.68	Power line installers and repairers
Security guards	36.69		5.25	Customer service representatives
Nuclear technicians	23.58		2.73	Installers and repairers of control systems and valves (except mechanical doors)
First-line managers of production and operational staff	10.98		1.92	Electricity distributors and dispatchers
Training and development specialists	8.97		1.8	Operations engineers and other staff
Architectural and engineering managers engineering	8.16		1.05	Plant and system operators water and sewage treatment
Industrial machinery mechanics Industrial	4.71		0.9	Stationary engineers and boiler operators
Project management specialists and business operations specialists, all other	4.65		0.78	Welders, cutters, solderers and brazers
Various first-line managers, security personnel	4.53		0.75	Gas plant operators
First-line managers of mechanics, installers and repairers	4.14		0.6	Accounting, auditing and auditing staff
Industrial engineers	4.02		0.6	Bus and lorry mechanics and diesel engine specialists Diesel engine specialists
Health and safety specialists	3.57		0.6	Calibration technologists and technicians and engineering technologists and technicians, engineering, except draughtsmen, all others

Personal services managers, all other; entertainment and recreation managers, excluding gambling managers, all other	3.42
Electrical engineers	2.97
Office clerks, general	2.91
Electricians	2.76
Production managers	2.76
Production, planning and dispatch clerks	2.76
Repairers of electrical and electronic equipment, power plants, substations and relays	2.64
Training and development managers	2.37
Chemists	2.07
Chemical technicians	1.92
Mechanical engineers	1.86
Service managers and facilities	1.83
Executive secretaries and administrative assistants	1.62
Engineers, all others	1.56
Technical writers	1.44
Compliance specialists	1.41
Security analysts information	1.35
Industry engineers, technicians and technicians	1.29
Inspectors, testers, sorters, samplers and weighers	1.14
Chemical engineers	1.08
Crisis management directors	1.08
Environmental and safety technicians protection technicians, including health services	1.08

0.6	Construction managers
0.6	Truck and tractor operators Industrial
0.6	Meter readers, utilities
0.6	Mobile heavy equipment mechanics equipment, except engines
0.6	Hydraulic engineers, pipeline fitters and steam fitters
0.45	Dispatchers, except police, fire and ambulance Emergency services
0.45	Electrical and electronic designers
0.45	Assistants — installation, maintenance and repair workers Installation, maintenance and repair
0.45	Lawyers
0.45	Maintenance workers, machinery
0.45	Plant and systems operators,

Based on the data provided, it can be seen that the largest group of positions in a coal-fired power plant for which there is no equivalent in a nuclear power plant are power plant operators (control, operation and maintenance of machinery and equipment for electricity generation and auxiliary systems).

People in these positions have specialist technical knowledge and skills related to machinery, equipment and installations that are not found in such quantities, or at all, in nuclear power plants. Due to their technical education and the relatively large number of positions available, they may consider undertaking supplementary studies which, after completing an internship, would enable them to work in technical and engineering positions related to nuclear reactor operation. This retraining path is quite long and may involve a temporary reduction in salary (during the period of re-education and internships), so it may be more suitable for younger people. Often, during the transition from a coal-fired power plant to a nuclear power plant, there may be a longer period during which the coal-fired power plant is no longer in operation and the nuclear power plant is not yet commissioned. On the one hand, this gives time to retrain some of the employees, but on the other hand, it may be unacceptable due to the temporary lack of livelihood (taking up employment during the training period may be burdensome).

The analyses also highlight another group of people working as power line installers, where there is a surplus of jobs in relation to coal-fired power plants. These positions are often filled by people with electrical training who can obtain jobs as electricians, electrical and electronic equipment repairers, or electrical engineers, where there may be shortages.

8.5. List of information about selected positions in a nuclear power plant

The literature contains a range of information on jobs in nuclear power plants and the nuclear sector.

[37] presents a summary of literature with characteristics in which classifications of occupations related to the nuclear sector can be found. It lists several studies, mainly from countries where the nuclear sector is of significant importance. These summaries differ significantly in terms of the names of positions and their characteristics, which may be due to the fact that different countries often draw on their own experience in this field.

[38]contains a list of positions related to the nuclear sector, including the operation of nuclear power plants. Selected positions are described in terms of initial qualifications, competences (divided into the scope of knowledge and responsibility), additional training and development. Within the indicated areas, additional distinctions are made between technical, operational, business and personnel issues.

Based on [39], it can be concluded that the positions that are significant in terms of the number of jobs and the need for training are: nuclear engineer and nuclear reactor operator. These positions are described in more detail in the following subsections.

8.6. Nuclear engineer

According to the Standard Occupational Classification (SOC)[40] which was the basis for the analysis of the matrix of positions and posts, this position involves conducting research on nuclear engineering projects or applying the principles and theories of nuclear science to problems related to the release, control and use of nuclear energy and the storage of nuclear waste.

37 ERIKSSON, A. and ERIKSEN, B. Job Classification and Taxonomy in the Nuclear Sector, European Commission, Petten, JRC132572

38 *C. Chenel Ramos, Nuclear Job Taxonomy. Final Report, EUR 29126 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-73842-5, doi 10.2760/090414, JRC110868*

39 *Hansen J., Jenson W., Wrobel A., Stauff N., Biegel K., Kim T., Belles R., Omitaomu F.: Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants. Systems Analysis and Integration; Revision 2 Prepared for U.S. Department of Energy 13 September 2022 ;INL/RPT-22-67964*

40 *Standard Occupational Classification Manual Executive Office of the President; Office of Management and Budget; United States, 2018*

Based on [41] this position can be described in terms of functions, knowledge and skills.

Functions:

- Responsible for core calculations in strict compliance with nuclear safety regulations during all operations with new and spent nuclear fuel.
- Calculation of the nuclear reactor core and spent fuel pool.
- Determining reactor operating limits based on authorised or licensed fuel operating limits. Compliance with fuel specifications for new fuel. Acceptance and inspection of new fuel. Monitoring and collecting data on the condition of the reactor core during operation.
- Performing calculations to ensure safety (core/reactor cooling system conditions within licensed limits) and performance (neutron flux distribution, core burn rate).
- Ensuring compliance of reactor core operating manoeuvres.
- Fuel load design (fuel movements, location of the fuel assembly in the reactor core/spent fuel pool).
- Modelling and predicting reactor core behaviour under changing operating conditions.
- Supervision of nuclear fuel-related activities during refuelling operations.
- Development of working documents (procedures, programmes, instructions) for reactor start-up.
- Preparation and evaluation of reactor core tests prior to start-up.
- Collecting data and monitoring radiation damage to the reactor core and pressure vessel structures.
- Monitoring, data collection and control of nuclear materials (i.e. fuel assemblies, core monitoring instruments) and other core-related equipment: sources, fuel connections, control rods

Job requirements Knowledge (Cognitive competences) EQF level (1-8)
Reactor physics theory 7 Nuclear safety principles and requirements 6 Safety culture 6 Engineering graphics, drawings and diagrams 6 Radiation protection 6 Nuclear physics 6 Nuclear safety regulations 6 Nuclear engineering 6 Nuclear apparatus in and outside the core (fission chambers, neutron flux monitoring) 6 Numerical methods of reactor design 6 Thermal-hydraulic design and analysis 6 Nuclear fuel (thermal limitations, operating limitations, etc.) 6 Core tests prior to start-up 6 Reactor core operation, limitations and set points 6 Nuclear power plant: reactor fundamentals, reactor and power plant process systems, auxiliary process systems, ionising radiation, heat generation and removal systems, steam supply system, nuclear chemistry, Measurement and control systems, electrical systems 5 National and international codes and standards 5 Industrial safety 5 Operational experience 5 Basic measuring instruments and procedures 5 Visual inspection 5 Materials science and radiation damage 5 Occupational safety and personal protective equipment 4 Quality assurance and control 4 Project management, planning methods and tools 4 Knowledge of information and communication technologies 4 Technical writing 4 Nuclear security 4

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41 *C. Chenel Ramos, Nuclear Job Taxonomy. Final Report, EUR 29126 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-73842-5, doi10.2760/090414, JRC110868*

Skills (technical and functional competences) EQF level (1-8)

Using and interpreting engineering data and technical documentation. 7 Planning, coordinating, implementing and monitoring project activities. 6 Ensuring the implementation of engineering codes and standards. 6 Identifying possible interactions and interactions with other related disciplines. 6 Conducting reactor core analysis and designing fuel configuration. 6 Mapping the location of fuel assemblies in the core and spent fuel pool. 6 Calculating the neutron distribution flux map. 6 Calculating criticality and neutronics. 6 Collect data and monitor core operating conditions. 6 Determine reactor operating limits. 6 Monitor nuclear fuel safety operating parameters. 6 Monitor reactor core performance. 6 Predict/model/analyse reactor core behaviour. 6 Design reactor core operating manoeuvres. 6 Develop core operational manoeuvre procedures. 6 Receive and inspect new fuel. 6 Develop/verify new fuel acceptance and inspection procedures. 6 Collaborate on the development of technical specifications for new fuels. 6 Interpret core monitoring instrument readings. 6 Use and update databases of reactor fuel assemblies, connections, control rods, sources, etc. 6 Design reactor core test procedures, analyse and monitor results. 6 Ensure compliance with statutory regulations and QSE organisational requirements. 5 Create and communicate requirements specifications, technical specifications, procedures and reports. 5 Identify safety requirements. 5 Retrieve technical information using computer-aided techniques. 4 Monitor and maintain a safe working environment. 4 Conduct work analysis, break down activities and assign tasks. 4 Evaluate performance and identify measures and indicators to improve or correct performance. 4 Maintain nuclear materials.

8.7. Nuclear reactor operators

According to the Standard Occupational Classification (SOC)[42] ‘the main tasks in this position are operating or controlling nuclear reactors; moving control rods; starting and stopping equipment, monitoring and adjusting controls, and recording data in logs; implementing emergency procedures when necessary; being able to respond to malfunctions, determine causes and recommend corrective actions. This position is also described as: Nuclear Control Room Operator, Nuclear Reactor Operator, Nuclear Power Plant Operator.

This position can be described in terms of functions, knowledge and skills.

Functions:

- Responsible for all aspects of the safe operation of the reactor facility
- Ensures and controls the safe and trouble-free operation of the reactor facility in accordance with the requirements of technical specifications: (radiation situation, chemical regime, technological limitations and conditions)
- Provides overall supervision of all activities related to the operation of the reactor facility and its auxiliary systems, and directly manipulates the controls of the equipment and systems

42 *Standard Occupational Classification Manual Executive Office of the President; Office of Management and Budget; United States, 2018*

- Monitors and controls the core, reactivity, and systems that may affect reactivity
- Ensures and controls strict compliance with nuclear safety and radiation protection requirements in all activities related to the operation of the reactor facility
- Reports to the unit shift manager on the operational status of the reactor facility and/or any incidents that have occurred
- Coordinates maintenance and testing activities and equipment start-up after maintenance
- Monitors the parameters of assigned equipment during operations and ensures response to system or unit malfunctions, diagnoses the cause, recommends or applies corrective actions, and reports incidents
- Responsible for recording and continuously updating operational records
- During a fuel supply interruption, coordinates and monitors activities in the controlled area
- In the event of an abnormality or emergency, strictly follows the instructions of the Unit Shift Manager in accordance with Emergency Operating Procedures and the internal emergency plan
- Collaborate with other departments within the organisation as part of your responsibilities
- Responsible for implementing operational procedures, such as controlling start-up and shutdown activities, including periodic testing of relevant equipment

Job requirements Knowledge (Cognitive skills) EQF level (1-8) Nuclear engineering: reactor physics, thermal limitations of nuclear fuels, nuclear power plant systems, heat transfer in reactors and fluid flow 6 Occupational safety and personal protective equipment 6 Operational experience 6 Nuclear power plant operation: operation of reactor systems: reactor start-up, normal, transient and emergency operation, measurement of operating parameters, power plant dynamics and control, reactor core operation, instruments and applications 6 Nuclear safety 6 Physics and chemistry theory: thermodynamics, fluid mechanics 5 Applied techniques and engineering: electricity generation, energy conversion, mechanics, electrical engineering, operation of the power system, electrical engineering, energy conversion, sensors, measurements, signal processing, instrumentation and control, pipeline systems, pumps and turbines, hydraulic and pneumatic installations 5 Technical drawings and diagrams 5 Nuclear safety culture 5 Emergency preparedness 5 Nuclear energy science Understanding complex regulations and procedures 5 Industrial chemistry 4 National and international regulations, codes and procedures related to safe operation 4 Radiological protection 4 Human error prevention techniques 4 Corporate procedures 4 Accident analysis and accident modelling 4 Risk assessment 3 Materials science 3

Skills (technical and functional competences) EQF level (1-8)

Maintaining energy equipment in safe and economical operating conditions in accordance with technical specifications and procedures. 6 Recognising abnormal situations in the power plant and reporting them. 6 Monitoring the condition of technical equipment and systems. 6 Predicting the results of actions in systems and components and carrying out any necessary corrective actions. 6 Identifying measures or indicators of system performance and predicting how changes in conditions or actions will affect results. 6 Communicating instructions using safe and effective communication techniques. 6 Executing operational and emergency plans and procedures. 6 Operating and monitoring computer-controlled equipment. 6 Adjusting operating parameters using information from recorders and displays. 6

Reading and interpreting technical drawings and diagrams. 5 Preparing technical reports and operational records. 5 Verifying the condition of equipment using measuring and testing instruments. 5 Correcting abnormal conditions in accordance with standard practice and instructions received. 5 Maintaining and updating repair logs, tracking and reporting systems. 4 Providing data for the preparation of nuclear safety documentation.
4 Monitor and maintain a safe working environment. 4 Perform visual inspections. 4 Comply with statutory regulations and organisational safety requirements. 4 Contribute to the design of requirements specifications. 4 Operate computers using specified software. 4

Based on [(43),]this position can be described as follows:

Entry qualifications: Degree in engineering or a related scientific field and/or rigorous training programmes related to nuclear energy and significant experience.

Job description

The reactor operator is responsible for manipulating the power plant controls, monitoring its operation, directing the direct operation of equipment, and performing licensed activities during start-up, shutdown, power changes, emergency and accident situations, as well as in special configurations. Reactor operators primarily operate the power plant controls from the control room.

Competencies (Technical (T), Regulatory (R), Business (B), Personal (P))

A reactor operator should be able to:

- Manipulate power plant controls in accordance with plant procedures. (T, R)
- Apply theoretical knowledge in practical situations. (T)
- Analyse the operation of power plant equipment and take corrective action for normal and abnormal conditions in accordance with plant procedures and available information. (T, R)
- Use plant procedures and technical specifications to implement appropriate actions under normal, unusual and emergency conditions. (T, R)
- Maintain the power plant in a safe condition in the event of uncertain or unexpected conditions. (T, R)
- Effectively control and coordinate the activities of subordinates and other persons. (R, B)
- Act as an effective member of the shift team in the control room. (B, R)
- Perform duties that support the implementation of the emergency plan. (R, P)
- Take a conservative approach to plant operations. (R, P)
- Cooperate with other groups to solve problems. (P, B)

The reactor operator should understand:

- The concepts, philosophy and responsibilities of the unit operator in the management of reactivity and reactor core safety. (T, R)
- Advanced technical fundamentals, plant design, theory, and interdependencies of systems for which operators are responsible. (T)

43 *Standard Occupational Classification Manual Executive Office of the President; Office of Management and Budget; United States, 2018*

- Relationships between different departments within the plant – quality assurance, engineering, maintenance, training, radiation protection. (T, B)
- Administrative procedures and regulatory requirements for plant management. (T, R)
- Concepts of probabilistic safety assessment and the importance of key components in mitigating the effects of accidents. (T, R)
- Procedures, programmes, company policies, industry guidelines and best practices. (T, R)
- Error prevention techniques and human performance tools. (T, B)
- How to conduct pre- and post-operation briefings. (T, B)
- How to make conservative decisions, with the highest priority given to protecting the health and safety of personnel and the public. (P, T)

*Recommended training/CPD: (*Technical (T), Regulatory (R), Business (B), Personal (P)):

- Advanced technical fundamentals, e.g. plant systems description and reactor operator theory. (T)
- Radiological protection. (T)
- Reactor thermohydraulics. (T)
- Operating licences and technical specifications. (T, R)
- Simulator training: integrated normal plant operations, diagnostics, emergency procedures, responses to accidents and transient operating conditions. (T, R)
- Probabilistic safety assessment. (T, R)
- Safety analysis reporting. (R)
- Advanced transient and accident analysis. (T, R)
- Mitigation of core damage effects. (T, R)
- Error prevention techniques and human performance tools. (T, B)
- Teamwork. (P)
- Conservative decision-making. (T, B)
- Nuclear safety and safety culture. (T, R)
- Operational experience and emergency planning. (T, R)
- Work-related policies and procedures. (T, R, B)

9. Risk analysis regarding the organisation and safety of the modernisation and operation of power units with nuclear reactors (based on the findings of Research Task No. 3, which sets out key requirements and recommendations concerning nuclear safety for selected sites)

9.1. Legal requirements

9.1.1. General requirements for the location of a nuclear power plant

Polish law sets out general requirements for the location of nuclear power plants, aimed at ensuring the safety of both the population and the environment. The key requirements, contained in the Act of 29 November 2000 – Atomic Law, concern the assessment, planning and selection of suitable locations for nuclear power plants.

9.1.1.1. Radiological safety and health protection of the population

A nuclear power plant must be located in such a way as to ensure maximum safety for the population against the effects of potential accidents, including the release of radioactive materials. The choice of location should take into account the reduction of the risk of radiation exposure to the population and compliance with the requirements for radiological protection specified in national and international regulations.

9.1.1.2. Seismic and geological risk analysis

Atomic law requires that the location of a nuclear power plant take into account all possible geological hazards, such as earthquakes, landslides, flooding or terrain deformation, which could affect the stability and safety of the nuclear facility. A detailed geological and seismic assessment is necessary to minimise the risk associated with the impact of natural forces on the operation and safety of the facility.

9.1.1.3. Environmental protection

The location of a nuclear power plant must meet environmental protection requirements, which means that a comprehensive environmental impact assessment (EIA) must be carried out. This assessment analyses the potential impact of the investment on the air, water, soil, fauna and flora. The EIA process must also take into account the impact on water resources that may be used to cool the reactors, as well as on the local climate and ecosystems.

9.1.1.4. Compliance with spatial development plans

A nuclear power plant must be located in accordance with local spatial development plans. The planning process requires cooperation with local authorities and relevant public administration bodies to ensure that the investment aligns with local conditions. The impact on transport infrastructure, transport accessibility and any possible evacuation needs must also be taken into account.

9.1.1.5. Distance from population centres and critical infrastructure

The location of a nuclear power plant should be sufficiently distant from large population centres and key critical infrastructure. Limiting the impact of potential accidents on the surrounding area is a priority, which is why the location must meet specific standards and regulations regarding the minimum distance from residential areas and strategic facilities.

9.1.1.6. Availability of technical infrastructure

The requirements also apply to the availability of appropriate technical infrastructure necessary for the operation of the power plant, including power connections, access to water sources for reactor cooling, transport infrastructure (road and rail), and emergency and communication infrastructure.

9.1.1.7. Ensuring an adequate level of physical protection

The location of the power plant must allow for adequate physical protection of the facility against external threats, including acts of sabotage, terrorism and air attacks. Regulations impose an obligation to use modern protection and security systems that minimise the risk associated with external factors.

9.1.1.8. Cooperation with the local community and public consultations

Public consultations and information campaigns are required in order to present the impact of the power plant location on the surrounding area and to gather the opinions of residents and interested parties. Such activities are aimed at increasing the transparency of the location process and building public acceptance for the project.

9.1.1.9. Compliance with international regulations and IAEA regulations

As a member of the International Atomic Energy Agency (IAEA), Poland must comply with international standards and guidelines regarding the location and safety of nuclear facilities. In this context, best practices in risk assessment, emergency management and environmental protection are taken into account.

In summary, the selection of a location for a nuclear power plant in Poland is subject to detailed analysis in accordance with the requirements of the Atomic Energy Act, aimed at ensuring maximum safety, minimising environmental impact and guaranteeing an adequate level of public health and safety.

9.1.2. General requirements for the design of nuclear reactor and nuclear power plants

The Regulation of the Council of Ministers of 31 August 2012 on nuclear safety and radiation protection requirements (Journal of Laws 2012, item 1048 - *Dz.U. 2012, poz. 104*8) specifies detailed requirements for the design, construction and operation of nuclear facilities, including nuclear reactors, in Poland. The purpose of these requirements is to ensure the maximum level of nuclear safety and radiological protection for the public, personnel and the environment.

9.1.2.1. Basic principles of nuclear safety

- Defence in depth: The design of the reactor and the entire power plant must be developed in accordance with the principle of defence-in-depth, which means the use of multiple physical and organisational barriers to prevent the release of radioactive substances. This requires the existence of systems to prevent, detect and mitigate the effects of possible accidents.
- Protection against accidents: The design must minimise the risk of accidents and ensure that the possible consequences of accidents are controlled and limited in order to prevent serious consequences for the population and the environment.

9.1.2.2. Safety system design

- System reliability: All safety systems, including reactor cooling systems, must be highly reliable. Redundancy (duplication of key components) and technical diversity are required to prevent failures resulting from a single point of failure.
- Passive and active systems: Safety systems must be capable of operating both passively (without the need for electrical power) and actively in order to ensure the highest possible level of safety.
- Ability to shut down safely: The design must take into account the possibility of safely and immediately shutting down the reactor in an emergency and ensuring long-term heat removal after shutdown.

9.1.2.3. Protection against external and internal hazards

- Resistance to external factors: The nuclear facility must be designed to withstand various external factors, such as earthquakes, floods, extreme weather conditions, fires and aircraft crashes.
- Internal hazards: The design must take into account protection against internal hazards such as system failures, internal fires, explosions, and possible human error.

9.1.2.4. Radiological protection

- Minimisation of radiation exposure: The design must ensure that radiation exposure for staff and the public is minimised through the use of physical barriers, appropriate radiation protection and monitoring systems.
- Ventilation systems: Ventilation systems must be designed with the capability of filtering air contaminants and controlled release of radioactive substances into the atmosphere, in accordance with applicable standards.

9.1.2.5. Facility monitoring and control

- Monitoring systems: The power plant design must include advanced systems for monitoring and controlling reactor operating parameters, including systems for detecting failures and safety breaches.
- Automated control systems: It is recommended to use automated control systems that allow for quick detection of irregularities and taking appropriate corrective or preventive measures.

9.1.2.6. Physical security and facility protection

- Physical protection: The facility design must provide an adequate level of protection against unauthorised access, sabotage or external attacks.
- Integrated security systems: This includes monitoring, alarm systems and access control to prevent deliberate actions that could threaten the security of the facility.

9.1.2.7. Procedures for accidents and emergencies

- Emergency response plans: The power plant design must include detailed plans for responding to both internal and external emergencies and provide for the possibility of rescue operations involving external services.
- Evacuation and personnel safety systems: Consideration of evacuation routes, personnel protection procedures and other elements to minimise the effects of a potential accident.

9.1.2.8. Requirements for radioactive waste management

- Safe waste storage: The design must include systems for the safe collection, storage and management of radioactive waste generated during the operation of the power plant.
- Waste minimisation: Efforts should be made to minimise the amount of radioactive waste and to store and process it appropriately in accordance with regulations.

9.1.2.9. Technical qualification of components and materials

- Compliance with norms and standards: All elements and components must be designed and manufactured in accordance with international norms and standards for nuclear safety.
- Certification and testing: Appropriate testing, certification and quality verification of the materials and equipment used are required.

The Regulation of 31 August 2012 (*Rozporządzenie z 31 sierpnia 2012 r.*) imposes a wide range of technical requirements on the design of nuclear facilities to ensure the highest level of safety, radiation protection and resistance to various hazards. Each design must be developed in a comprehensive manner, taking into account the specific technological characteristics, radiological safety, hazard protection and emergency management.

9.2. Dolna Odra Power Plant

9.2.1. General description of the property

The Dolna Odra Power Plant is an energy complex located in Nowy Czarnów near Gryfino, in the West Pomeranian Province. It is one of the largest system power plants in Poland, which for years has played a key role in the national power system. The Dolna Odra Power Plant is currently part of the PGE Polska Grupa Energetyczna group. For many years, the power plant relied on hard coal-fired units, but in recent years it has undergone a modernisation process involving the expansion of natural gas-based capacity. The power plant was launched in 1974.

Following modernisation and the construction of new gas-steam units, the total installed capacity is approximately 1,366 MW. The Dolna Odra power plant originally consisted of eight coal-fired units, each with a capacity of approximately 200 MW. As part of the modernisation programme, some of the old units were decommissioned, while others were left in reserve. In 2021, two modern gas-steam units were commissioned: unit 9 and unit 10 with a total capacity of 1,367 MW. These are natural gas-fired units, which significantly improve energy efficiency and reduce CO_2 emissions compared to traditional coal-fired units.

PGE plans to further develop and modernise the infrastructure in Dolna Odra, including a possible increase in the share of lower-emission technologies and the development of energy storage capacity, which is part of the implementation of the national energy transition policy.

In the context of the DEsire project, the Dolna Odra power plant ranked high in the nuclear retrofit readiness ranking.

9.2.2. Safety assessment related to nuclear retrofitting

This analysis assumes the replacement of the coal-fired units at the Dolna Odra power plant with an EPR (European Pressurised Reactor) pressurised water nuclear reactor. A summary of the most important elements of the safety assessment for such a transformation is presented below.

9.2.2.1. Technological safety of the EPR reactor

The EPR reactor is an advanced Generation III+ pressurised water reactor (PWR) designed to meet very high safety standards. Its design incorporates passive safety systems and redundant and independent active systems, which increase reliability. The EPR reactor is equipped with a double safety enclosure, which minimises the risk of radioactive material release in the event of a serious accident, and protects the facility from external threats such as terrorist attacks or aircraft impacts. The design provides for additional solutions in the event of so-called beyond design basis accidents. One of the most important systems in this regard is the so-called core catcher: in the event of a core meltdown, the EPR reactor has a system for capturing and controlled cooling of the molten core, which minimises the possibility of radioactive substances escaping outside the facility.

9.2.2.2. Location security

The Dolna Odra power plant is located in a region with relatively low seismic activity, which is a favourable factor from the point of view of nuclear power plant construction. However, detailed geological and hydrological studies would need to be carried out to ensure that the site meets nuclear safety requirements. The EPR reactor requires large amounts of water for cooling. The location on the Odra River provides access to water sources, but the risks associated with possible changes in water levels or droughts that could affect cooling must be assessed.

9.2.2.3. Radiological safety aspects

The transition to nuclear technology requires the development of detailed radiation protection plans. The power plant must meet strict radiation standards and its operation should be continuously monitored to ensure that radioactivity emissions do not exceed permissible levels.

In the case of a nuclear power plant, protection zones must be designated around the facility, where additional restrictions apply. This may require adapting the infrastructure around Dolna Odra and ensuring appropriate evacuation plans and emergency response procedures.

9.2.2.4. Emergency planning zones

Emergency planning zones for a nuclear power plant with an EPR reactor, which would be launched at the site of the Dolna Odra power plant, should be defined based on the recommendations of the International Atomic Energy Agency (IAEA) and Polish law. The key emergency planning zones are the Precautionary Action Zone (PAZ) and the Urgent Protective Action Planning Zone (UPZ), which are designed to protect the population in the event of an accident.

9.2.2.5. Precautionary Action Zone (PAZ)

Objective: The PAZ zone aims to provide immediate protection to the population through the rapid implementation of preventive measures such as evacuation, sheltering indoors or the distribution of potassium iodide tablets.

Zone radius: Usually ranges from 3 to 5 km around a nuclear power plant. According to IAEA guidelines, the PAZ zone should be designed to respond quickly to emergencies and minimise potential effects on the population and the environment. Assuming a radius of 3 km for this zone, the situation is illustrated in the figure.

It is important to note that the town of Gryfino lies on the border of this zone, which also extends into Germany.

9.2.2.6. UPZ - Urgent Protective Action Planning Zone

Purpose: The UPZ zone covers an area where further protective measures can be taken in the event of a radiation hazard, such as temporary shielding, access control, radiation monitoring or preparation for evacuation, if necessary.

Zone radius: For EPR reactors and in accordance with IAEA recommendations, the typical radius of the LPZ is between 15 and 30 km around the power plant. The exact radius depends on risk analysis and terrain characteristics (e.g. population density, terrain, hydrological and meteorological conditions).

9.2.2.7. Long-Term Protective Action Planning Zone (LPZ)

Purpose: Covers an area where long-term protective actions, such as population resettlement or long-term environmental monitoring, may be taken.

Zone radius: May cover an area within a radius of 30 to 100 km from the power plant, depending on the specific location, the anticipated accident scenario and the assessment of potential environmental and health impacts.

9.2.2.8. Specific comments on the designation of zones in the case of Dolna Odra

Given the specific characteristics of the Lower Oder region, it is important to take into account the population density around Gryfino and Szczecin, the hydrological conditions associated with the River Oder, and the proximity of the Polish-German border.

This may affect the details of emergency planning. The designation of emergency planning zones must comply with the provisions of the Polish Atomic Law and the recommendations of the IAEA. It is necessary to take into account cross-border communication procedures with the German authorities, as any emergency measures may affect border areas.

9.2.2.9. Preparatory steps in emergency planning

Developing a crisis response plan: PAZ, UPZ and LPZ zones must be covered by a crisis response plan that specifies appropriate protective procedures and countermeasures. It is necessary to implement rapid warning systems, public information systems and coordination of activities between emergency services and public administration. It is also necessary to organise simulation exercises to prepare local communities and services to respond appropriately in the event of an accident.

9.2.3. Radioactive waste management

The introduction of the EPR nuclear reactor involves the generation of radioactive waste, which requires appropriate storage and management. The construction of specialised waste storage facilities may be necessary, and planning for their long-term operation must take into account high safety standards. Radioactive waste differs from conventional pollution from coal-fired power plants, which poses a new challenge for safety and responsibility related to its storage.

9.2.4. Responding to emergencies

Nuclear power plants such as EPR require extensive crisis management procedures. In the case of Dolna Odra, new emergency management plans would need to be prepared, taking into account cooperation with local authorities, the fire brigade, the police and civil protection services. The transition to nuclear technology requires training power plant employees in nuclear reactor operation and safety procedures, which may pose a challenge for the existing team.

9.2.5. Cyber security

EPR nuclear reactors, like other modern nuclear units, use advanced control and automation systems. It is therefore necessary to ensure a high level of cyber security to counter potential threats from cyber attacks.

9.2.6. Social and political aspects of security

The construction of a nuclear reactor at the site of the existing Dolna Odra power plant may be met with a variety of public reactions, ranging from approval to opposition. It is crucial to ensure adequate communication with the local community, informing them about the plans and the benefits and risks associated with the nuclear power plant. Involving the local community and developing mechanisms for dialogue can have a positive impact on public acceptance and the safe operation of such a facility.

9.2.7. Nuclear material transport security

The transition to nuclear technology requires the safe transport of nuclear fuel and radioactive waste. Logistics systems and transport procedures must be developed to prevent any risks associated with the transport of hazardous materials.

9.3. Summary

In summary, replacing the coal-fired units at the Dolna Odra power plant with an EPR nuclear reactor poses many safety challenges, but also creates the potential for a transition to less carbon-intensive and modern energy sources. The EPR reactor, due to its advanced safety systems, is one of the safest available on the market, but requires a comprehensive approach to planning and implementation to ensure full technological, environmental and social safety.

From a purely safety perspective, the choice of reactor and its location are feasible. There is a high risk associated with the cross-border consultation process.

10. Diagnosis of legal and legislative barriers to the investment process

The implementation of coal-to-nuclear investments (i.e. replacing coal sources in the area of electricity generation with nuclear energy), despite their potential benefits, may encounter numerous legal and legislative barriers. The complexity of administrative procedures and the inadequacy of existing regulations to the requirements of such projects can significantly hinder their implementation. An important element of the preliminary feasibility study for a coal-to-nuclear investment is understanding the procedural path required to obtain a construction permit and identifying key legal and legislative barriers.

10.1. Description of the procedural path for obtaining a building permit for a nuclear facility

A building permit for a nuclear facility is a key document enabling the commencement and conduct of construction works. Before submitting an application for its issuance, the investor must prepare design documentation in accordance with legal requirements and obtain a number of formal documents and administrative decisions. In the case of nuclear facilities, this process includes both the standard construction procedure and an additional path that takes into account the specific requirements related to nuclear proceedings.

The standard construction procedure is based on the Act of 7 July 1994 – Construction Law (Journal of Laws 2024, item 725 - *Ustawie z dnia 7 lipca 1994 r. Prawo budowlane (Dz. U. 2024 poz. 725)*, hereinafter referred to as the Construction Law. This legal act regulates the construction process, including investment preparation, obtaining a building permit, construction works, commissioning of facilities and their maintenance in proper technical condition. The Act specifies the rights and obligations of participants in the investment process, indicates facilities requiring a building/demolition permit or notification, describes the procedures for obtaining them and the rules of operation of public administration bodies. It also sets out the requirements regarding design documentation and the formalities necessary for the construction process.

The technical documentation required when applying for a building permit consists of three elements: two parts of the construction design — the land development design and the architectural and construction design. The third part, i.e., the technical design, must be prepared and kept on the construction site before work begins. All elements of the construction design must be signed by engineers with the appropriate qualifications, in accordance with the scope of the documentation.

The nuclear procedure and the additional requirements and simplifications applicable therein are set out in the Atomic Law Act of 29 November 2000 (Journal of Laws 2024.1277 - *Ustawy z dnia 29 listopada 2000 r. Prawo atomowe (Dz.U.2024.1277)*, hereinafter referred to as the Atomic Law, and the Act of 29 June 2011 on the preparation and implementation of investments in nuclear energy facilities and accompanying investments (Journal of Laws 2024, item 1410 - *Ustawy z dnia 29 czerwca 2011 r. o przygotowaniu i realizacji inwestycji w zakresie obiektów energetyki jądrowej oraz inwestycji towarzyszących (Dz. U. 2024 poz. 1410)*, hereinafter referred to as the Special Act. The body responsible for issuing decisions within the nuclear path is the National Atomic Energy Agency (*Państwowa Agencja Atomistyki* - PAA), represented by the President of the PAA.

The first and one of the most important decisions in the process of constructing a nuclear facility is **the fundamental decision** issued by the minister responsible for energy at the request of the investor. This document specifies the permitted parameters of the investment related to the construction of a nuclear power plant. It also constitutes the basis for applying for further administrative decisions, including the decision on determining the location of the investment in the construction of a nuclear power plant and other permits necessary for the preparation, implementation and use of the facility. The purpose of the fundamental decision is to protect the public interest, in particular in the context of implementing state policy objectives, such as energy policy, and ensuring national security (Article 3a of the Special Act).

The fundamental decision enables the investor, among other things, to submit an application for **a decision on environmental conditions** (*decyzji środowiskowych uwarunkowaniach* **-** abbreviated as DoŚU), which is necessary in the further process of obtaining a building permit for a nuclear facility. DoŚU is issued for projects that may always have a significant impact on the environment and for projects that may potentially have a significant impact on the environment. The rules for issuing it are regulated by the Act of 3 October 2008 on access to information on the environment and its protection, public participation in environmental protection and environmental impact assessments (Journal of Laws 2024.1112 - *Udziale społeczeństwa w ochronie środowiska oraz o ocenach oddziaływania na środowisko (Dz.U.2024.1112)*. The EIA is intended to ensure that the planned investment has the least possible negative impact on the environment. If the investment may have a significant impact on the environment, an environmental impact assessment is carried out before a decision on environmental conditions is issued. The assessment is based on an environmental impact report prepared by the applicant. This report presents data on the impact of the investment on the environment, covering both the methods of construction and the operational phase, taking into account aspects such as noise, emissions and the impact on residents.

For energy facilities classified in the third geotechnical category, such as nuclear power plants, it is also necessary to prepare **geological and engineering documentation** (*dokumentacji geologiczno-inżynierskiej* **-** abbreviated as DGI), which is attached to the construction design as part of the technical design. The requirement to prepare DGI stems from the Act of 9 June 2011 Geological and Mining Law (Journal of Laws 2024, item 1290 - *ustawy z dnia 9 czerwca 2011 r. Prawo geologiczne i gornicze (Dz.U. 2024 poz. 1290)*) and the implementing acts to this Act, including the Regulation of the Minister of the Environment of 18 November 2016 on hydrogeological documentation and geological and engineering documentation (Journal of Laws 2016, item 2033) and the Regulation of the Minister of Transport, Construction and Maritime Economy of 25 April 2012 on determining the geotechnical conditions for the foundation of buildings (Journal of Laws 2012, item 463).

Geological and engineering documentation (DGI) should be prepared independently of the obligation to prepare a geotechnical opinion, ground investigation documentation and a geotechnical design. In accordance with the provisions of the Geological and Mining Law, DGI requires approval by the competent authorities. The process begins with the development of a Geological Works Project, which is agreed upon and approved in the form of an administrative decision. After its approval and notification of the intention to commence field work, the planned geological works (at the earliest 2 weeks after approval), laboratory tests and analyses necessary for the preparation of the DGI are carried out. Once the documentation is complete, an application for its approval must be submitted. The decision in this matter is issued by the district administrator (assisted by the district geologist) or the provincial governor (with the assistance of the provincial geologist).

The next step in the investment process is to obtain **a decision on the location of the investment for the construction of a nuclear power plant**, which is issued by the locally competent provincial governor. Pursuant to Article 15(6) of the Special Act, this decision replaces the decision on development conditions required in the standard procedure (for non-nuclear investments) in the absence of a current Local Spatial Development Plan. The decision on the location of the investment grants the right to use the land necessary for its implementation. It includes, among other things, the designation of the property covered by the project, requirements for the protection of third party interests and conditions for the implementation of the investment, such as technical, environmental, conservation and fire safety requirements. The application for this decision must be supplemented by a number of opinions from other authorities, as specified in Article 5 of the Special Act.

A prerequisite for issuing a decision on determining the location of a nuclear energy facility investment is obtaining a prior decision on environmental conditions. It is worth noting that this decision may be submitted by the Investor in the course of proceedings for issuing a decision on determining the location of a nuclear energy facility investment.

In addition to the fundamental decision and the decision on the location, the investor should also obtain **a permit to carry out activities involving exposure related to the construction of a nuclear facility** (hereinafter referred to as a nuclear facility construction permit). One of the conditions for obtaining a permit for the construction of a nuclear facility is compliance with requirements concerning nuclear safety, radiological protection, physical protection and security of nuclear materials. In addition, the investor must ensure adequate financial resources for the completion of construction and maintenance of the safety of the nuclear facility (Article 38g(1) of the Atomic Law). The licence is issued by the President of the PAA within 24 months of the date of submission of the application together with the required documents. The application should include, among other things, a preliminary safety report, a location report, a design for the physical protection system for the nuclear facility and nuclear materials, a decision on environmental conditions, an opinion of the European Commission issued pursuant to Article 43 of the Treaty establishing the European Atomic Energy Community, as well as other documents specified in the Regulation of the Council of Ministers of 30 August 2021 on documents required when submitting an application for a licence to perform activities involving exposure to ionising radiation or when notifying the performance of such activities (Journal of Laws 2021.1667). The application must also be accompanied by **water law permits and notifications**, if required (Article 388(5) of the Water Law Act of 20 July 2017, Journal of Laws 2024.1087).

Upon receiving an application for a licence to construct a nuclear facility, the President of the PAA enables public participation in the proceedings by publishing the content of the application together with a summary safety report in the Public Information Bulletin. All interested parties may submit comments and motions, as well as participate in the administrative hearing (Article 39d of the Atomic Energy Act).

Pursuant to Article 39e of the Atomic Energy Act, when considering an application for a licence, the President of the PAA has the right to carry out inspections at the site where the activity covered by the application is planned. To this end, he may use the services of authorised laboratories and expert organisations, as well as require tests or expert opinions to be carried out in order to verify compliance with nuclear safety and radiation protection conditions.

Pursuant to Article 39f of the Atomic Energy Act, before issuing a licence, the President of the PAA submits a request to the Council for Nuclear Safety and Radiological Protection for an opinion on the draft licence. After obtaining this opinion, the draft is forwarded to the applicant, who has one month to submit comments. After considering these comments, the President of the PAA issues a decision on the granting of a licence for the construction of a nuclear facility. This decision, together with the content of the application and a summary safety report, is made public.

A licence for the construction of a nuclear facility specifies the conditions for carrying out the activities covered by the licence, including, inter alia, design requirements, the obligations of the organisational unit with regard to the safety of the nuclear facility, equipment, employees, the public and the environment, including radiation protection, emergency planning and procedures, nuclear facility management, and operating limits and conditions (Article 39g of the Atomic Law).

Obtaining a permit for the construction of a nuclear facility is a prerequisite for issuing a building permit. It may be submitted by the investor in the course of proceedings for the issuance of a building permit. The content of the permit, together with the decision on the location of the investment, is binding on the provincial governor who issues the building permit (Article 15(2) of the Special Act).

The final stage of the procedural path for obtaining a building permit for a nuclear facility is to submit an application for **a building permit** together with the construction design and all necessary formal attachments. The entire application is reviewed by the competent administrative authority for compliance with the regulations. The first step in the verification process is to assess the completeness of the application (formal verification), which the authority is required to carry out within 14 days of its submission, in accordance with Article 33(6) of the Building Law. If the application contains formal deficiencies, the authority calls on the applicant to remedy them within a specified period. If the applicant is unable to remedy the deficiencies within the specified time, they have the right to submit a request for an extension of the proceedings. In such a situation, the administrative authority may postpone the procedure in accordance with Article 64 of the Code of Administrative Procedure (Journal of Laws 2024.572). After the applicant has made any corrections and the authority has accepted the application as valid, the office notifies the interested parties of the initiation of administrative proceedings. The next step is a substantive verification, during which the content of the application and attachments is analysed. Also at this stage, the architectural and construction authority has the right to request the applicant to correct any irregularities in the application, setting a deadline for their correction. The applicant may then supplement the documentation, provide additional explanations regarding the solutions used, or request the legal basis for the authority's request. After the design has been corrected/clarified, the authority may close the case by issuing a decision.

Once the building permit has been obtained, a construction log is issued, a site manager is appointed, construction documentation is prepared, and then work can begin, starting with preparatory work and then moving on to the actual construction activities.

Apart from the main decisions described in this chapter, and depending on the scope and complexity of the investment, other decisions and agreements may be required under separate regulations (e.g. permission to cut down trees, permission to access a public road if the investment is located on a national or provincial road, etc.). Most often, these decisions are attached to the building permit application.

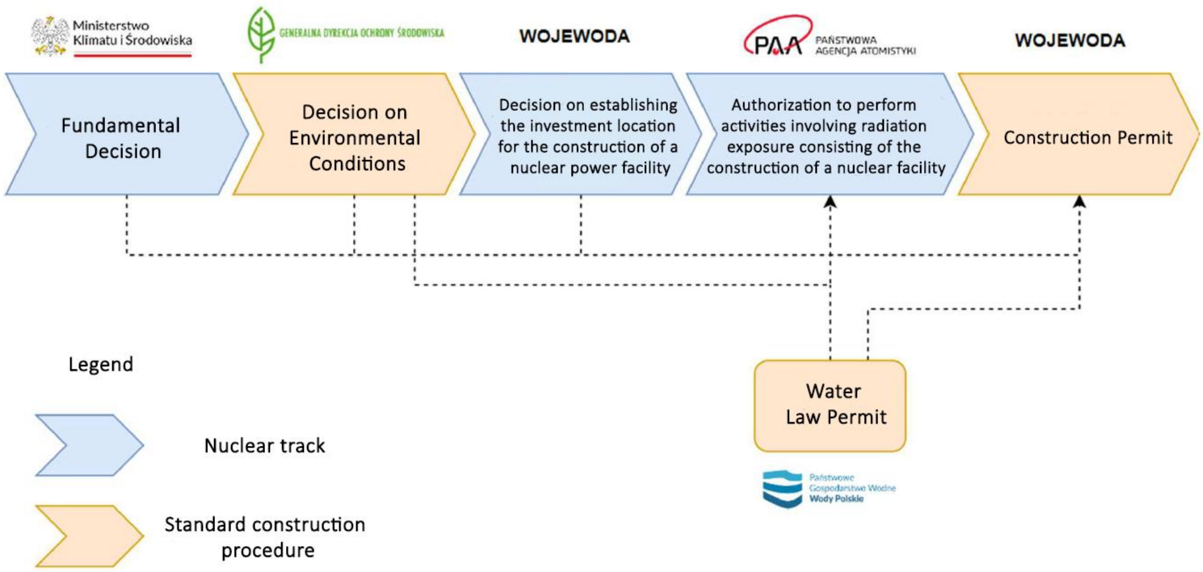

Figure 46 Simplified diagram showing the process of obtaining a building permit for a nuclear facility.

10.2. Legal and legislative barriers to the investment process

Obtaining a permit to build a nuclear power plant in Poland is a complex process that faces numerous legal barriers. An analysis of the Atomic Law, the Construction Law and the Special Act indicates the following obstacles:

10.2.1. Scattered and imprecise regulations

The regulations governing the process of obtaining a building permit for a nuclear facility are scattered across numerous legal acts, which makes them difficult to interpret and apply. The Atomic Energy Act and the Special Act introduce certain simplifications, but they do not eliminate all barriers. In addition, the applicable legal regulations contain provisions that are sometimes unclear and leave room for interpretation.

10.2.2. Lack of experience of the administrative bodies involved in issuing decisions in the process of obtaining the necessary permits and authorisations

One of the significant barriers to obtaining a permit for the construction of nuclear power plants in Poland is the lack of experience of administrative authorities. To date, no such investment has been carried out in Poland, which means that officials and institutions responsible for project assessment do not have sufficient practical experience in the specific requirements of this type of undertaking.

The process of obtaining permits for the construction of a nuclear power plant is complex and requires consideration of many legal, technical, environmental and construction aspects. Of particular importance is the precise application of regulations concerning nuclear safety and radiological protection, as well as compliance with national technical and construction standards.

A lack of prior experience in assessing this type of investment may lead to a lengthy decision-making process and ambiguous interpretation of regulations. In addition, administrative authorities may adopt an overly cautious approach in an effort to avoid potential errors, which may result in additional requirements and delays in project implementation.

10.2.3. Two separate paths for assessing nuclear power plant construction projects and the lack of a separate derogation procedure for nuclear facilities

In the Polish legal system, the construction of a nuclear power plant is subject to assessment by two separate authorities: the President of the PAA and the provincial governor. The problem stems from the different assessment criteria adopted by these authorities. The President of the PAA focuses on nuclear safety and radiological protection, allowing solutions based on foreign norms and standards if they are confirmed by international certificates. This system allows for a certain degree of flexibility in the approach to projects, especially in the case of "standard plant" projects, which are based on proven solutions used worldwide and which can be adapted to Polish conditions. The provincial governor, on the other hand, must strictly apply Polish technical and construction regulations.

In practice, this means that standard plant designs, although based on recognised foreign standards, must be adapted to the requirements of Polish construction law. The special act does not provide for exemption from the requirement to comply with national technical and construction regulations, which means that standard plant designs often require modifications or exemptions. In the case of derogations, there is no separate procedure for nuclear facilities, which means that the President of the PAA does not participate in the process of granting derogations. As a result, a situation may arise in which a design meets nuclear safety requirements but is not approved by the provincial governor due to non-compliance with local building regulations, or vice versa.

10.2.4. No pathway for adapting existing facilities

One of the significant legal barriers in the process of implementing investments related to the construction of nuclear power plants is the lack of regulations concerning the adaptation of existing facilities, installations or infrastructure to the requirements of such projects. Facilities originally designed and used for other purposes may not meet the technical and formal standards necessary for operation within a nuclear power plant.

Current regulations do not provide for a dedicated procedural path that would allow for the conversion and adaptation of existing buildings, installations or infrastructure elements in a manner consistent with the requirements for radiological protection and nuclear safety in the construction of a nuclear power plant. There are also no guidelines specifying the scope and type of technical documentation that would need to be submitted in the event of such adaptation in order to document compliance with nuclear safety requirements.

10.2.5. Recommendations:

- Developing and implementing detailed legal provisions enabling the conversion of facilities originally designed for other purposes in a manner consistent with the requirements for nuclear power plants.
- Preparation of detailed guidelines specifying the technical standards that adapted facilities must meet in order to be eligible for use as part of a nuclear power plant infrastructure. These guidelines should also cover the type and scope of technical documentation required to demonstrate compliance with safety standards.
- Introduction of a procedure enabling the assessment of the compliance of adapted facilities with technical requirements and requirements concerning radiological protection and nuclear safety. This process could be carried out by supervisory authorities such as the National Atomic Energy Agency.

11. Investment schedule

Assuming that the project begins in 2026 and ends in 2045, it will span a total of 20 years of intensive investment, administrative and technical activities. The schedule has been divided into several major stages, the sequence and interdependencies of which are crucial for the successful implementation of the project.

In the first year, i.e. 2026, a feasibility study is planned to be developed, which will serve as the basis for assessing the project's implementation possibilities and for further strategic decisions. At the beginning of 2027, the investor, having decided to continue with the project, will begin the long-term process of obtaining the necessary administrative decisions, such as the Environmental and Location Decisions. This stage will last until 2032.

From 2032 to 2034, work will be carried out to obtain the necessary building permits, including the development of the Construction Design, which will begin in 2033 and be completed a year later. The permit to commence preparatory work will be issued in 2032, while the building permit is planned for the end of 2034, marking the boundary between the formal phase and the commencement of actual work on site.

The design phase begins in 2034 and lasts until 2042. In the meantime, from 2036 onwards, components and equipment will be ordered and delivered. These two processes are carried out in parallel, which allows for a reduction in time.

Intensive preparatory work on the construction site will also begin in 2033. The actual construction of the reactor will start in 2034 and continue until 2042. The crucial moment – the start of reactor construction – will take place in 2035.

After completion of construction in 2041, testing of all systems will commence. At the same time, from the end of 2041, activities related to obtaining a start-up permit will be carried out. The commissioning itself will take two years. Finally, from mid-2044 to early 2045, the process of obtaining an operating licence will be carried out, which will complete the entire investment.

It is also worth noting that the existing coal-fired units are scheduled to be decommissioned in 2032.

The entire schedule is an example of the highly complex, long-term planning characteristic of nuclear projects. It indicates a very long preparatory period, which includes almost a decade of analyses and administrative procedures before actual construction begins. Key schedule risks include potential delays in obtaining environmental and location decisions, a protracted design and procurement process that may be susceptible to market changes, and the length of the testing and commissioning phase, which reflects the stringent safety and precision requirements.

The schedule is based on clearly defined, multi-year stages, in which some activities overlap in a controlled manner. This allows for optimisation of the implementation time, but also requires precise coordination of design, execution and formal processes. Due to the length and complexity of the individual phases, risk management, legal stability and the availability of qualified staff and technology suppliers will be crucial.

The project is ambitious, but its structure complies with international standards for nuclear investments and takes into account both formal requirements and real technological, logistical and social needs.

12. SWOT analysis

Table 24 SWOT analysis

	POSITIVE	NEGATIVE
INTERNAL	**STRENGTHS** • Increased energy security • Restoration of generation capacity (approx. 1600 MW) • Possibility of utilising local human resources and local companies • Reduction in the carbon intensity of electricity generation compared to coal-fired power plants	**WEAKNESSES** • Limited possibility of using the existing technical infrastructure of the analysed facility • Need to release the entire area of existing 200-class units and their external facilities • Adjustment of the investment schedule to the decommissioning of coal-fired power units • High investment costs compared to other technologies
EXTERNAL	**OPPORTUNITIES** • Implementation of plans to decarbonise the Polish energy sector in line with the Coal-to-Nuclear concept • Local development – the power plant remains in its current location. • Preservation/increase in jobs and reducing the adverse impact on the local aquatic environment of the Odra River, which may translate into better cooperation with environmental organisations	**THREATS** • Construction of a nuclear reactor on the site of a former coal-fired power plant • Financing – difficulty with financial arrangements • Adaptation of regulations to the Coal-to-Nuclear approach • Accumulation of nuclear investments at one time • Risk of not obtaining adequate financial support at the operational level (contract for difference)