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Primary Preconditions of Benefits from the Construction of Nuclear Power Plants in Poland

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Abstract:

Purpose: *This paper synthesises the current state of the Polish power engineering sector, the process of developing nuclear power plants (henceforth, "NPPs") and the primary preconditions to consider when formulating contracts for NPP construction projects.*
Design/methodology/approach: *In consideration of future economic growth of the country and its energy security, in 2005 the central government decided to start building NPPs in Poland. However, it was only at the end of 2022 that letters of intent were signed with two contractors for NPP construction (Westinghouse of the USA Korea Hydro & Nuclear Power of South Korea).*
Findings: *The critical conclusions from this paper follow: Poland is stricken by a high degree of decapitalisation of assets in the power engineering sector. Legacy power plants do not only pose a high risk of high failure rates, their performance efficiency is low, which drives the costs and, ultimately, the pricing of electrical power. The Polish government assumes the following breakdown of shares and funding for the NPP projects: 51% with the State Treasury and 49% with a foreign developer.*
Practical implications: *The positive effects on the economy from the construction of NPPs will be achieved if the contracts for NPP projects are properly formulated – limiting the risks that the project developers will want to pass on to the Polish public in the contracts. It will be especially important to establish in the NPP project contracts the conditions that contribute to an increase of NPP construction, protraction of implementation time, and the precise procedure for the NPP construction driving the price of electrical power.*

Keywords: *Government Infrastructures, Nuclear power plants.*

JEL Classification: *H54, P18*

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1. Introduction

Poland's development in the future will require an increase in the supply of electrical power, irrespective of any optimisation of its use generated by parallel increases in economic innovation and energy efficiency. For Poland, securing its own, stable power generation sources is important to national security. (Poland's, 2020, p. 25). Between 2010 and 2019, the energy demand in Poland increased from 70 Mtoe to 75 Mtoe (Poland, 2022, p. 5). Despite a periodic decline in 2020 as a result of the pandemic, the energy demand in Poland is rising again.

Currently, the existing power plants are considerably decapitalised and need to be successively replaced. That is why the state is trying to build new power generation capacities. These are to be based mainly on renewable energy sources (RES), like wind, solar, geothermal and nuclear. This new energy mix for Poland is planned to ensure the stability of the grid by leaning first on NPPs, which will be built by domestic enterprises jointly with project developers from Korea (KHNP) and the USA (Westinghouse). A third consortium could also be established, with a developer from France (EDF) as a party. Ultimately, NPPs could satisfy around 20% of Poland's total electrical power demand around 2050 (Polski sektor, 2017, p. 6).

This paper synthesises the state of the power engineering industry, the history of efforts to build a nuclear power plant in Poland, and the key considerations that should be taken into account when formulating a contract for an NPP construction project with a foreign developer.

2. The State of the Power Engineering Sector in Poland

Polskie Sieci Elektroenergetyczne S.A. (PSE) (Ustawa, 1997) is a corporation tasked with the operational security of the Polish National Power Grid (including balancing, development and maintenance of the wholesale electricity market infrastructure) and cross-border grid connections. PSE operates the high-voltage grid throughout the country, which consists of 246 grid lines with a total length of almost 14,000 km. Virtually 100% of these are overhead, with the exception of a buried grid link on the bottom the Baltic Sea between Poland and Sweden (it is a 245 km long 450 kV line) (PSE obszary, 2023).

Distribution networks rated at 60 to 110 kV are managed by transmission system operators (TSOs). These medium-voltage lines have a total length of about 305,000 km (of which 235,000 km are overhead lines and about 70,000 km are buried lines, mainly located in or near large cities), while low-voltage lines are over 470,000 km (Dolega, 2018; Eneregia Elektryczna, 2023).

Five corporations are critical to electrical power distribution in Poland and have been divested from defunct power distribution businesses. Four of them belong to energy sector capital groups in which the State Treasury controls the corporate governance:

- PGE Dystrybucja S.A. (PGE, 2023).
- Enea Operator Sp. z o.o. (ENEA, 2023).
- Tauron Dystrybucja S.A. (Tauron, 2023).
- Energa-Operator S.A. (Energia, 2023).

The fifth of the corporation is RWE Stoen Operator Sp. z o. o., with its majority privately owned (Stoen, 2023).

TSOs are required to maintain distribution lines (with operation and repairs), expand their tier of the grid and manage correct flow of electrical power (PSE usługi, 2023). The four largest TSOs are part of energy holding groups, although operate under the ownership unbundling formula, as a result of regulations introduced at European Union level (With the exceptions provided for, among others, by the so-called Third EU Energy Package).

Unbundling is primarily concerned with the independent management of all aspects from daily operations (including the development of policies, procedures, internal regulations, or remuneration and incentive systems for employees), through projects and the shaping of the structure of assets and liabilities, to the evaluation of results (as these cannot be linked to the group's standing). The biggest problem with electrical power distribution networks their age and density. For the most part, the distribution system lines were built as part of a different system (to transmit energy from large generators to consumers) and are decades old.

They are characterised by high failure rates and incompatibility with RES, which are dispersed in nature and require power import and export. Considering the issue of distribution system density, there are 41 km of network per 1,000 km2 in Poland, while there are 161 km in Switzerland, about 120 km in Greece, 100 km in Germany, 90 km in France, and 80 km in the Netherlands. Jankiewicz, 2018).

Electrical power in Poland is mainly generated by power plants fired with hard coal and lignite. Approximately 80% of the energy generated comes from these sources (Poland, 2022, s.5). Like TSOs, most of the coal power plants is owned by energy holdings and have significantly decapitalised assets. More than 67% of power plants by installed capacity are more than 30 years old, and more than one half are 50+ years old (Statystyka, 2012, p. 78; Ponad, 2021, p. 7-9).

Because of their age and systematically increased stringency of environmental protection regulations, the power units will have to be decommissioned. By 2030, power generation sources with a capacity of around several thousand megawatts will need to be shut down. This means that there should be power generating units built to replace the phased-out ones. New power plants must provide a higher capacity than those being phased out, which is dictated by the forecasts of economic growth. The obsolete power plants in Poland have caused domestic issues with meeting demand for electrical power and maintaining it in compliance with specifications, especially in small towns far from power plants (See e.g., ARE, 2023).

Considering the situation in the power engineering industry and with a view to Poland's long-term economic growth, domestic power generation capacity needs to be increased rapidly. If relevant projects are not launched within 1-2 years, there will be issues with continued availability of electricity, as NIK (Najwyższa Izba Kontroli, Poland's Supreme Audit Office) already pointed out in its 2013 report (Funkcjonowanie, 2013).

Externalities (like the objective of climate neutrality) (See e.g. European Green Deal, 2023) and internal conditions (which include international agreements to abandon fossil fuels while improving environmental awareness and concern for the health of the population) mean that the power plants to be built must be RES. According to the Polish government, the foundation of grid stability will be NPPs. (Polityka, 2012) NPPs facilitate a stable output of electrical power that is impervious to weather, a considerable advantage over other RES (like photovoltaics or wind farms).

3. The State of Nuclear Power Engineering in the World

Many countries wish to continue operating nuclear power plants and even plan to build new NPPs, despite the various concerns raised. For the European Union, a total of 106 nuclear reactors were in operation in 2019, generating 765,337 GWh of energy, which was 26% of the Community's total electrical power output. France had the largest share of generation from nuclear power in these years (with nearly 400,000 GWh, 52.1% of the EU total), followed by Germany (75,000 GWh or nearly 10%), Sweden (66,000 GWh or 8.6%) and Spain (58,000 GWh or approximately 8%). Statista, 2023; World Nuclear News, 2023).

Despite the large share of NPP output, it was 25% lower in 2020 than 15 years earlier. This is a consequence of phasing out NPP reactors, first in Germany (with an NPP output loss of 60%), followed by Slovakia, Bulgaria, France, Belgium, Spain, Sweden, and Lithuania (the latter of which shut down its reactors already in 2009). However, this is not a one-way trend. Between 2006 and 2019, there has been an increase in nuclear power generation in Romania (by over 100%), the Netherlands (by nearly 13%), the Czech Republic (about 16%), Slovenia (nearly 5%), Finland (about 4%) and Hungary (about 21%), among others.

At present, NPPs are critical in the national energy mix of France (70.6%), Slovakia (53.1%), Ukraine (51.2%), Hungary (48%), and Bulgaria (40.8%) (Eurostat, 2023; NucNet, 2023; World Nuclear Association 2023). The same is true for countries outside the European Community. In 2021, there were 440 nuclear reactors operating in 33 countries worldwide, seven more than the year before, yet 23 less than in 2002 and two less than in 2011 (Energetyka, 2021). Globally, the United States of America is the largest producer of nuclear energy (almost 31%), followed by China and France (more than 13% each), Russia (around 8%) and South Korea (approximately 6%) (World Nuclear Association, 2023; World Nuclear News, 2023; NucNet, 2023; Power Reactor Information System, 2023).

Just 15 countries in the world account for 91% of global nuclear power generation. The average age of nuclear reactors is 31 years, and one in five has been in operation for more than 41 years. In 2020, nuclear power plants were commissioned in Belarus and the United Arab Emirates, with some 53 units under construction (half of which were in China and India). The largest number (20) of NPPs has been commissioned in China in recent years, with another 18 under construction. China is planning to have 150 new nuclear reactors in operation by 2035, which is an investment of $440 billion (IAEA, 2023; International Renewable Energy Agency, 2023).

However, of the 33 countries operating nuclear reactors in 2021, only 14 were actively implementing nuclear power generation. The remainder operating NPPs has been holding the development of nuclear power generation, while continuing to operate the legacy reactors or even decommissioning them (in 2021, there were 26 nuclear reactors in long-term cold shutdown compared to just 5 in 2011) (The World Nuclear Industry, 2021).

Table 1. *Number and capacity of nuclear reactors with the output and share of nuclear power in global power generation, years 2000-2021*

	Reactors in operation	**Net installed capacity (GWe)**	**Energy output (TWh)**	**Share (%)**
2005	441	368.12	2626.34	16
2006	435	369.58	2660.85	16
2007	439	371.71	2608.18	15
2008	438	371.56	2597.81	15
2009	437	370.70	2558.06	14
2010	441	375.28	2629.82	13.8
2011	435	368.92	2517.98	13.5
2012	437	373.24	2346.19	11
2013	434	371.78	2358.86	11
2014	438	376.26	2410.37	11
2015	441	382.81	2441.34	11.5
2016	447	390.49	2477.30	10.6
2017	448	391.72	2502.82	10.3
2018	450	396.62	2562.76	10.3
2019	443	392.10	2657.16	10.1
2020	442	392.45	2553.21	10.2
2021	441	393.25		

Source: *Proprietary, based on resources from the International Atomic Energy Agency and Power Reactor Information System.*

According to the data in the table above, the share of electrical power generated in NPPs in the global energy mix is steadily declining, from 16% in 2005 to 10% in 2021. This trend is more likely to continue over the next few years, as the cost of building and maintaining NPPs is steadily increasing (they have risen by a third in the last decade), with the same costs for photovoltaic and wind installations decreasing (by 90% and 70% respectively over the same period) and an increase in their efficiency (Gram, 2023) Furthermore, some countries, such as the Federal Republic of Germany, explicitly prefer other types of RES for non-commercial reasons as well.

Despite major uncertainties relating to the high capex and the performance of safety solutions in nuclear power engineering, nuclear reactors are still being built around the world. This is driven by the need for energy security and increasing pressure to reduce greenhouse gas emissions.

4. Progress in the Construction of NPPs in Poland

In Poland, efforts to build an NPP began in early 2005, when the Council of Ministers adopted the "Energy Policy of Poland for 2025". (Polityka, 2005[3]). In January 2007, the Parliamentary Nuclear Power Committee was established Polskie Sieci Elektroenergetyczne S.A. (now PGE S.A.) began an analysis to qualify potential locations for the NPP construction.

However, it was not until 13 January 2009 that the Council of Ministers adopted a resolution to begin work on the Polish Nuclear Power Engineering Program. A Government Plenipotentiary for Polish Nuclear Energy was appointed in May 2009 and a framework schedule of activities was published in July 2009. The guidelines in the Polish Nuclear Power Engineering Program included:

- Passing the legislation required for the development and functioning of nuclear power engineering;
- Development of feasibility studies for the NPP construction project;
- Definition of the method of and securing the NPP construction funding
- Selection of the NPP location and conclusion of the NPP construction project contract;
- Development of the technical plans and specifications, with securing of the coordination and permits required by law
- Securing of the construction permit and actual construction of an NPP reactor unit rated at approx. 3000 MWe, ultimately complemented with a second, same-rated NPP reactor unit, with the capacity of 21 TWh/annum of each unit (See e.g., Program, 2010).

[3] This document was then updated several times, the current version from 2019 is called "Energy Policy of Poland until 2040"

A special purpose vehicle, called EJ1 sp. z o.o. (a limited liability), was incorporated on 28 January 2010 to build the NPP with the slated commissioning of the first reactor unit for operation in 2022. The schedule of the NPP project was unrealistic, as no project location or developer was selected until 2015.

The Polish NPP construction was revisited and saw effective work at the end of 2022, when the Polish Nuclear Power Engineering Program was updated. The update provided for cooperation with two to three foreign developers (Uchwała, 2020). The first NPP is to be built by a U.S. corporation, namely Westinghouse, with the project site near Lubiatowo in the Pomeranian region. The planned capacity is approximately 6.7 GW and the project cost varies from $31 billion (as estimated by the Polish government) to $40 billion (according to the estimates from Westinghouse) (Sawicki, 2023).

The Polish government plans to split the funding for the first NPP project into 51% for and from the State Treasury and 49% for and from the foreign developer. Unfortunately, the foreign developer does not want to own such a large share and declares a maximum of 10%. The final structure of shares will be established in the final contract for the project. Construction is expected to start on the NPP project in 2026, with the NPP units commissioned for operation between 2033 and 2034.

A second nuclear power plant will be built near Konin by a South Korean company (Korea Hydro & Nuclear Power) together with domestic corporations, ZE PAK S.A. and PGE S.A. Four reactor units of 5.6 GW are planned to be built by this project consortium. As with U.S. developers, the share held by Korean partners is expected to be 49%. The schedule of the NPP construction is not known yet, although it is most likely similar to the NPP project to be delivered with the U.S. developers (Ministerstwo Aktywów Panstwowych, 2023). In both NPP projects for Poland, letters of intent were signed at the end of 2022, and the contract provisions are now being drafted.

The French government and French corporations have undertaken diplomatic and lobbying efforts for the construction of a Polish NPP. Another project site is therefore possible, probably in the vicinity of Bełchatów, and the capacity of the NPPs in Poland will eventually be increased.

5. Basic Preconditions of Benefits from the Construction of NPPs in Poland

The situation in the domestic energy industry necessitates building more generation capacity. It may be difficult to complete all the planned NPP with the Polish funding at 51% of the total project cost. Power engineering corporations do not have sufficient capital to finance the projects alone or to secure the required funding from the financial markets (as the EBITDA is too low and the projects are encumbered with a prohibitively high risk). In turn, the State Treasury, due to the constitutional limit on the public debt level, may also find it difficult to raise funds on the capital market. It is why contracts with the NPP technology providers should require the developers as the contractual parties to assume the duty and seek funding for the entire project with preferential pricing. Indeed, the level of interest rates on the capital being raised is important for the profitability of NPPs. This was addressed in the Polish Nuclear Power Engineering Program (Program, 2020, p. 50).

Another potential issue is compliance with the preset project schedule and construction budget. There is no prior experience in the field of NPP projects in Poland and potential foreign nuclear power project developers have not operated in our country before, so they may have difficulties with various obstacles (like the official authorities issuing NPP permits and licenses for the first time in history, which may generate various risks). It is especially so as the construction of an NPP is a complex task both in terms of official procedure and actual execution.

Practice shows that even countries that already had experience in NPP construction would face certain difficulties in the process. An example is Finland, which built its first two NPP units on the island of Olkiluoto back in the 1970s. In 2005, the construction of a third NPP unit began, which was to be model in terms of safety and low construction and operating costs.

Unfortunately, the technical problems encountered during the project significantly extended the commissioning date. Originally planned for 2009, it was postponed to 2011, and rescheduled once again to 2012. Finally, it was not until January 2016 that operational testing of the reactor systems began. The initial cost of €3 billion rose to an estimated €8.5 billion (Power, 2023). Delays and cost increases have been reported in other ongoing projects in countries that already have had built and operated NPPs. This even applies to corporations that want to develop nuclear power projects in Poland.

The expansion of the Virgil C. Summer Nuclear Power Station in Jenkinsville, USA with two new generating units from Westinghouse required increasing the budget more than 2.5 times, and the Flamanville NPP (EDF) in France saw a nearly quadruple budget overrun (according to unofficial data, even 5 times). The Koreans were also not spared from increasing the budget for the expansion of their Kori NPP (owned by KHNP - a co-developer in the NPP project to be built near Konin). The estimated budget overrun in this project is currently at ‘only’ ten-odd to several dozen percent.

The same is true of the completion time, which is also exceeded in nuclear power plant construction projects. Nine recently completed NPP projects with technology from Westinghouse, KHNP and EDF experienced an average delay of more than four years against pre-development assumptions (Oettingen, 2021). For this reason, in addition to a fixed deadline for the commissioning of the NPP, the contracts signed with project developers should specify precisely the conditions that may cause the developer to be in delay. An unjustified extension of a project deadline should result in considerable liquidated damages.

This is important not only because of the mere fact that the connection of the required capacities to the Polish grid is postponed, but also because of the final cost of the supplied electrical power. The Polish Nuclear Power program specifies that protracting the construction time of an NPP by 5 years increases the cost of the generated energy by 20%, while the same extension for a gas-fired power plant increases this cost by 5% only (Program, 2010). Similar restrictions on the project contractor should apply to construction budget overrun, as this affects the price of electrical power for Polish consumers.

NPPS could – assuming timely project development and that the current production costs are maintained, which are lower than in conventional power plant projects – have a positive impact on future price of electrical power. The lack of competitiveness in the domestic market facilitates shifting the commercial risks from developers to consumers. It is important because the ROI period of an NPP is long (and up to decades long), and if other RES are developed, the NPP owners could declare bankruptcy, with their creditors never recovering their outlay.

This was the case, for example, in the UK, where competition emerging in the energy market made British Energy insolvent, becoming de facto bankrupt in 2002 due to excessive costs, and with the creditors forced to swap a large share of their receivables for shares, while existing shareholders retained only 2.5% of the shares in the company that emerged from restructuring British Energy.

In seeking to maximise profits, businesses operating in an oligopolistic market tend to inflate prices and unjustifiably increase profit margins (See e.g, Jankiewicz, 2017). To secure such objective, project developers may establish provisions in the contracts signed with government principals that regulate the minimum price and output of power to be sold (and with the consumers charged additionally for capacity readiness, should the demand sink). In doing so, developers make sure that their risks are mitigated.

If the generation of electricity from NPPs becomes more expensive than from other energy sources then, according to the principle that the minimum price is set by the power plant that is most expensive in production and connected to the grid, an actual increase of electrical power prices can be expected in Poland. In practice, this means that the society will have to suffer higher costs, which will reduce Poland's economic growth and quality of life. To provide a safeguard from this risk, it is necessary to negotiate with the foreign developers the lowest possible volume of energy that the consumers are committed to consume from the NPPs.

This is because the NPP developers should compete with other sources on the free market. In addition, the price and margin construction procedure should be precisely defined in the contract, plus facilities for analysing each cost item by experts in the government. This last provision is important because multinationals (and this is what Poland will be dealing with when investing in nuclear power generation) can pass on costs from other business operations to the NPP-related operations in Poland, and thus enjoy an excuse for their high prices.

6. Conclusions

The power generation potential presented above shows that Poland will suffer from issues with the supply of electrical power in the coming decade. Economic development, which heavily relies on electricity supply, could be negatively affected. This means that if Poland does not increase capital investment in power generation capacity, the country's energy security will be at risk.

Poland should focus on the development of innovative electricity generation technologies (like RES) and the retrofitting of the domestic power grids, which will significantly reduce grid losses. This would allow outrunning these pitfalls, increase the level of innovation and, with less expensive electricity available, spur a faster growth of the economy. For reasons of energy production stability, new large power generating units should run on nuclear fuel.

The Polish electrical power market remains concentrated, a feature which makes it attractive to prospective NPP developers. However, when negotiating an NPP construction contract, commercial aspects should be focused on that are relevant to the construction deadline and costs, and the contract price.

Failure to do so will expose the Polish nuclear power projects to multiple risks, including schedule and budget overruns, lower electricity supply on the domestic market, a necessary and increased dependency on imported electrical capacity, lower competitiveness on the domestic market, and high prices of electricity.

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