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Conceptual Paper

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Role of the state in implementation of strategic investment projects: The SaHo Model for nuclear power

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Abstract: The purpose of the paper is to present an innovative business model, the SaHo Model, designed specifically to enable the Polish government to implement nuclear power development plans, which can be possibly used in other countries and in sectors requiring high capital expenditures. The SaHo Model solves the problems identified in the nuclear energy sector, which are related to high investment risk and high costs of capital at the investment stage, and ensures revenues after connection to the grid. Since the state is the investor at the initial stages, it takes over most of the risk in the short term. Selling the shares before connection to the grid, the state significantly reduces the financial involvement in the long term. From then on, the SaHo Model works similar to the Finnish Mankala or American electric cooperative models, producing and selling energy to their shareholders at production costs. None of the models used so far in nuclear energy provides such opportunities. The SaHo Model allows to enhance the competitiveness of the national industry and to increase public acceptance for nuclear power. Thus, it is not only a business model but also a concept for the functioning of the nuclear industry.

Keywords: business model, nuclear power development JEL Classification: G18, G31, Q48

1 Introduction

Over half a century ago, Milton Friedman – in his letter to the *Time* magazine – wrote this famous sentence: *In one sense, we are all Keynesians now; in another, no one is a Keynesian any longer* [Barro, 2008]. During the financial crisis more than a dozen years ago, Robert Lucas also referred to Keynes: *Well, I guess everyone is a Keynesian in a foxhole, but I don't think we are there yet* [Fox, 2008]. The question is worth asking: are we there now? In the opinion of many economists, politicians, governments, and organizations, we now stand at the threshold of the next economic crisis, possibly the biggest one since the Second World War [*Największy...,* 2020]. Perhaps it is not a foxhole of Lucas anymore, but the black hole of Wheeler [Hawking, 2003]. Being optimistic about the matter, it can be concluded that we are still on the border, on the event horizon. So, there is a chance that, with gargantuan effort, we can escape the crisis force of gravity pulling the economy into the very center of the economic black hole. In such circumstances, actions taken by decision makers should be innovative, brave, and forward-looking. *Dare mighty things* – as Theodore Roosevelt [1899] spoke and as the message encoded on the National Aeronautics and Space Administration (NASA) Mars rover parachute states [*Dare Mighty Things*, 2021].

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The purpose of this paper is to present an innovative business model, the SaHo Model, which – in the strong belief of the Authors – can be used by the Polish government for implementation of Polish nuclear power development plans. The SaHo Model solves the problems identified so far in the nuclear energy sector, which are related to high investment risk and high costs of capital at the investment stage, and also ensures revenues after connecting to the power grid. The SaHo Model is so flexible and universal that it may be used also in other countries and sectors requiring high capital expenditures. The SaHo Model is presented in the final section of the paper.

Section 2 contains an economic literature review on the role of the state in the economy. In this context, in Section 3, the problem of energy security is introduced and the role of nuclear power is discussed. The development of nuclear power is postulated and formalized in documents adopted by the Polish government. In Section 4, obstacles blocking the expansion of nuclear power in the world and models used to solve them are identified. Section 5, as already mentioned, is dedicated to the presentation of the new SaHo Model formulated by the Authors and designed for Polish nuclear power.

2 Role of government in the economy – theoretical approach

Defining the role of the state in the economy is an important issue in the theory and practice of economics. There is a regular feature: acceptance for increasing the role of the state rises in the face of an economic crisis [Madej, 2018]. Keynes demanded government intervention, e.g., in the form of financing investments, arguing that a free market economy cannot function without the support of the state. The government should actively support the economy through fiscal and monetary policies and create proper conditions for the development of enterprises. This is what governments did after the collapse of the financial system in 2008: in line with Keynesian prescriptions, they introduced "stimulus packages" that included "rescuing" banks, issuing money, providing tax breaks and subsidizing private spending, and increasing public spending financed by credit [Skidelsky, 2015].

The role of the state is also to support and protect *infant industries* against foreign competition, e.g., in the form of duties or subsidies [Spałek, 2015]. Tutorial protectionism, despite the social costs that may occur in the short run,¹ has a positive impact on the efficiency and development of the domestic industry in the long run. In addition, after the period of protection, domestic enterprises can successfully compete with foreign ones [Myszczyszyn, 2012]. It seems that the development of new types of economic activities directing the produced goods mainly to the domestic market (e.g., electricity) deserves state protection. The need to support new technologies on the electricity market has been recognized also by the European Commission (EC) [European Economic and Social Committee, 2014].

In three out of five models of the state proposed by Fred Block (macroeconomic stabilization state, developmental state, and public goods state), the authorities are assigned to play an active role in the economy [Morawski, 2001]. The implementation of social and economic goals, which the market and traditional (regulatory and fiscal) tools of economic policy² cannot cope with, may take place with the use of proprietary instruments, e.g., through state-owned enterprises (SOEs). These are enterprises controlled by the state (directly or indirectly), irrespective of the ownership share. Many companies in the world are controlled by the state holding 20%–25% share in the ownership [Bałtowski, 2018]. In the European Union (EU) countries, Japan, and the USA, there are companies controlled by the government through personal ties or by unwritten contracts (phenomenon of overlapping business and politics – "revolving door"). In recent decades, the importance of SOEs has increased, which is referred to in the literature as "the return of state-owned enterprises". In 2004, 14 SOEs from the *Fortune Global 500* list were active in the energy sector; in 2016, there were already 32 such enterprises [Bałtowski, 2018].

¹ This may temporarily reduce the social surplus, but eventually, protection will be removed, and prices will move to a level comparable to that abroad.

² Tools of economic policy such as smoothing business cycles, correcting market failures, stabilizing employment, stimulating aggregate demand through increased investment expenditure – especially during an economic downturn – but also infrastructure investments, especially with a long investment horizon and a high level of risk, and even the production of public goods.

Monetarists admit that in times of crisis, the economy may need stabilization measures. However, it should be sufficient to keep interest rates low because it favors investment and allows the control of unemployment [Krugman, 2015]. Keynes, however, perceived a "zero lower bound" of nominal interest rates. Central banks cannot lower the interest rates below this rate; consequently, monetary stimulus tools do not work indefinitely.³ In such conditions, the state should increase public sector expenditures and apply fiscal incentives [Krugman, 2015]. Quantitative easing may not be sufficient as a remedy for an economic crisis because the only visible effect will be an increase in the market value of assets, e.g., shares. In fact, this is the case of the Warsaw Stock Exchange (WSE). Since Poland started implementation of financial support programs for the economy because of Covid-19 pandemic, the value of the Warsaw Stock Exchange WIG Index (WIG) index increased by 56% (March 12, 2020 *vs* March 31, 2021) and the monthly turnover on the stocks from the WIG index increased by 38% (March 2020 vs March 2020).⁴

The economic activity of the state is associated with failures, resulting from limited information and control over private markets and bureaucracy [Stiglitz, 2004]. However, ensuring a level of investment sufficient to maintain full employment may require "socialization" of the investment and taking responsibility for the organization of the investments by the state [Keynes, 2012]. It may also require institutional investors (e.g., pension funds) to be involved in the financing of investments because such investors do not have to maximize profit (at least in the short run). The role of the state is not only to initiate investments but primarily to guarantee successful implementation in difficult socioeconomic conditions [Wilkin, 2018].

Currently, in Poland, several large investment projects have been implemented, e.g., the Vistula Spit canal, financed entirely from the state budget,⁵ and the planned construction of the Central Communication Port in Baranów.⁶ These investments need significant support from the state, and they are associated with the expected long-term economic benefits. The project that meets both of these criteria and still awaits implementation is the *Polish Nuclear Power Program* (PNPP).

3 Energy security in the context of nuclear power

In October 2020, the Council of Ministers adopted the updated PNPP [*Monitor Polski*, 2020, p. 946]. The Program envisages the commissioning of 6–9 GWe of nuclear capacity between the years 2033 and 2043, based on proven large-scale generation III pressurized water reactors. Realization of the Program is justified by the need for maintenance of energy security, protection of climate and environment, and economic factors. In this article, the environmental issues are omitted because the Authors focus attention on energy security and the economic aspects of the problem.

3.1 Selected characteristics of energy security

No single, consistent, and commonly accepted definition of energy security has been developed in the literature so far [Nyga-Łukaszewska, 2019]. Pursuant to the Polish Energy Law Act, energy security means meeting the current and future demand and needs of customers for fuels and energy in a technically and economically justified manner, while maintaining environmental protection requirements. It means the present and future guarantee of the security of raw material supplies on the one hand and the processes of production, transmission, and distribution of energy on the other. This view on the three dimensions of energy security (technical, economic, and environmental) is widespread in the literature [Szablewski and Martin 2011].

³ No matter at what level this "zero" bound is located.

⁴ Own calculations, data from https://www.gpw.pl/statystyki-gpw.

⁵ Dz.U. 2017 p. 820; initially, the costs were estimated at PLN 880 million, but recently, they have been increased to almost PLN 2 billion; see *Przekop Mierzei Wiślanej* [2020].

⁶ Uchwała nr 173/2017 Rady Ministrów; the initial cost analysis assumed the financing of the basic scope with the amount of almost PLN 35 billion, and the Polish Development Fund was mentioned as a potential investor.

Energy security is recognized as one of the public goods that should be delivered by the state [Stiglitz, 2004]. There is a debate whether electricity itself can be considered a public good [Billewicz, 2016]. Undoubtedly, it is one of the scarce resources, with the price always above zero. Electricity is characterized by low price elasticity of demand. The EC emphasized that electricity is an essential basic commodity. Universal access to energy should be at the heart of Europe's energy policy and should be enshrined in the European Treaty. A Member State may establish certain public service obligations to supply electricity in order to eradicate energy poverty [European Economic and Social Committee, 2014].

Electricity itself should be clearly distinguished from the guarantee of its supply, which is the energy security discussed in the article. While electricity may be treated as a commodity, the guarantee of its supply at acceptable prices should be considered as public good and provided by the state to each recipient. In August 2015, because of heat and drought, there was a power deficit in the Polish power system, and "brownouts" were implemented. Economic entities willing to pay the market price for electricity⁷ were forced to reduce the energy consumption from the grid. Therefore, electricity was unavailable even for those who were able to and agreed to pay for it [Billewicz, 2016]. Because of the brownouts, 55.020 MWh of energy was not delivered. The loss in Poland's gross domestic product (GDP) amounted to at least PLN₂₀₁₅ 385 million, and even to PLN₂₀₁₅ 607 million (according to various estimates) [*Wpływ programu...*, 2017].

This situation is an example of the strong connection between energy security and the tragedy of the commons when resources (capacity in energy sector) are insufficient to meet all the needs. There are many possible solutions (e.g., rationing), but the only effective way (in the long run) is ensuring the proper conditions for investors to build new generating units, and even incurring a part of the capital expenditure by the state. The task of the state, however, is not the production and sale of electricity itself.

Investments in energy infrastructure are characterized by long periods of implementation (especially in the case of nuclear projects) and high construction and operating costs. However, these high expenditures are essential to meet current and future demands for electricity, resulting from its projected growth, as well as the need to replace operating units for zero- and low-emission ones. Nuclear power plants (NPPs) can produce huge amounts of energy, affecting the environment in the smallest possible way [*NEEDS...*, 2009]. Thus, nuclear power could be a good response to this growing demand projected and highlighted in the document "Energy Policy of Poland until 2040 (EPP2040)" [*Monitor Polski*, 2021, p. 264].

In Poland, no nuclear unit has been operated so far. In the social memory remains the case of the unfinished construction of the NPP "Żarnowiec", started in 1984 [Jezierski, 2006] and stopped in 1990. Financial losses were evaluated as (at least) USD 2 billion [Melańczuk, 2019]. NPPs operate in 13 EU Member States and in other European countries, including Switzerland, Russia, Ukraine, and Belarus. Poland is a "desert island" on the nuclear map of Europe, importing cheap electricity from nuclear units operating in neighboring countries. It seems that a need to build the first NPP in Poland is justified due to not only energy security and economic, but also image-related, reasons.

Another dimension of energy security is continuity of electricity supply. In Poland, this is endangered due to aging power plants operating in the base load (mainly coal power plants [CPPs]). For the 2030s, numerous shutdowns of these plants are planned. NPPs work best as baseload units; therefore, replacement of CPPs with NPPs seems to be necessary and natural. This will help to both keep deliveries uninterrupted and avoid brownouts. Import of electricity cannot prevent emergencies because no one foreign system operator is able to guarantee future intervention delivery. Additionally, import of electricity does not lower the prices of electricity on the domestic market but leads to reduction in the production delivered by domestic producers. In effect, they lose a fraction of revenues in favor of the electricity importers [Mielczarski, 2020]. Lower revenues and lower profits mean smaller possibilities to finance subsequent projects in the energy sector. Hence, there is a need to create additional mechanisms encouraging entities to undertake new investments (e.g., capacity market) [Mielczarski, 2020]. Import of electricity may only increase energy

⁷ Setting the market price for electricity is a complex topic; it is not covered in this article; more on this can be found in *Wojtkowska-Łodej* [Michalski, Hawranek, 2014].

security in some circumstances, and such a slight "technical" import is allowed in EPP2040. However, the basic assumption is that the Polish economy is self-sufficient. So, energy security requires, first of all, the creation of internal abilities to generate electricity.

Energy security is also a derivative of diversification of fuels and directions of deliveries. In the case of nuclear energy, these conditions can be reached easily. Uranium mines and plants manufacturing nuclear fuel are located in many countries on different continents [*Uranium...*, 2018...]. There is also the possibility of using unconventional uranium resources in Poland. Delivery of fuel assemblies does not require special infrastructure (which is necessary in the case of natural gas and coal), and nuclear fuel may be stored in large quantities for a long time. The prices for uranium on world markets are relatively stable, as is the share of the cost of the fuel in the total cost of electricity production [Appendix no. 5 in the PNPP]. All the circumstances assure the stability of costs of production and prices for consumers. Therefore, it is a key factor for enterprises (especially energy-intensive ones) and the whole economy. Moreover, nuclear energy is resistant to weather conditions, and this is particularly important in the context of development plans for solar and wind energy. It should be underlined that the possibilities for generating renewable energy are inadequate in relation to the forecasted demand for energy in Poland.

Thus, nuclear energy has many advantages in terms of energy security. Therefore, the share of nuclear energy in the energy mix is projected in the PNPP to reach 23% in 2045. The document also assumes NPPs operating at base load of the energy system in Poland.

3.2 Cooperation of the government and private entities in the implementation of investment projects

Since the 1980s, infrastructure investments have been realized in the form of Project Finance. A new entity is established and appointed for the implementation of an investment project, with a separate mode of financing. Most of the equity is provided by the project manager or sponsor. The project company operates with high debt-to-equity ratio (60%). Many investment projects in the energy sector in the USA have been financed this way. In the UK, in the 1990s, the Private Finance Initiative was selected by the government to involve the private sector in the financing and management of infrastructural investments. Financing collected in the private sector reduced the need for public funding and transferred some risk to private entities [Brealey et al., 1999]. In the UK also, the Regulatory Asset Base (RAB) model is applied to finance infrastructural investments. It is based on the prices regulated by the government [RAB Model for Nuclear Projects, 2019]. The government can privatize a public utility that generates and distributes electricity, rather than grant a concession to a private company to generate power sold to the public utility. The project company can retain ownership of the project's assets based on an arrangement and agreement known as "build-own-operate" (BOO). Otherwise, ownership of the project's assets is transferred to the government at the end of the concession period. This is called "build-operate-transfer" project agreement (BOT). For example, ownership of privately financed toll roads and bridges is often transferred to the government [Brealey et al., 1999].

It is extremely important to address (in executive contracts) the different types of investment risks to the entities, which can best evaluate it, control it, and deal with it. Each business entity is exposed to basic types of risk, such as market, credit, operational, and legal risks [Kendall, 2000]. For the company operating in the energy industry, this list grows significantly. There are 24 types of risks mentioned in the literature, including those as specific as weather risk, capacity risk, and risk of terrorist attack [Michalski, 2012; Michalski et al., 2015]. Thought-out distribution of risk between the parties involved (investor, general contractor, and business partners) can reduce both the risk and the related costs. The success of the initial stages of the project will also reduce the risk and lower the cost of financing in subsequent phases. One technology vendor selected for several power units may additionally increase the credibility of the project, obtain economies of scale, especially in terms of construction and operating costs, and – as a result – reduce the financing costs as well. The participation of the State Treasury (ST) as the majority owner serves the same purpose.

3.3 Costs of electricity produced – the state's perspective

An NPP does not emit greenhouse gases (GHGs); therefore, it does not need CO_2 emission allowances (EU Allowances [EUA]). The price of the allowances on the primary market of the European Energy Exchange has changed almost sevenfold during the past 5 years: from 6.94 EUR/EUA on the last auction in April 2016 to 48 EUR/EUA on the last auction in April 2021 [*Handel emisjami CO*₂...]. The EC forecasts the price to be between 50 and 100 EUR/EUA in 2050. Accordingly, the expected strengthening of the upward trend in the coming years means a huge increase in production costs and electricity prices for customers in Poland because our energy sector is mainly based on coal and gas. NPPs are not only insensitive to changes in the EUA prices and in the context of EU climate and energy policy, they, in fact, enable achievement of climate neutrality.

Appendix no. 5 to the PNPP presents the analyses performed using the Total Cost Methodology (TCM). The main overarching objective of the study is to minimize the total cost incurred by the economy and society for power generation, considering the indirect operating costs of the power sector, the energy mix, and energy security. The indirect operating costs of the system consist of side effects (emission of pollutants and system imbalancing) and external costs, which include system costs (power reserve, networks, and balancing), environmental costs (health and ecosystem), and macroeconomic costs (security, import–export balance, and employment). Therefore, TCM differs significantly from the investor's point of view. It allows the capture of the viewpoint of the state and the economy. The analyses indicate that nuclear energy is the cheapest source of energy when the full cost calculation (including investor, system, and environmental costs) is considered. Among the variants of the future energy mix examined, the scenarios involving nuclear power are characterized by the lowest energy generation costs. Nuclear energy has the greatest potential to reduce CO_2 emissions in the power generation sector. The lack of nuclear power in the energy mix means the highest external costs and their tendency to grow.

Nuclear power is characterized by the lowest average total cost among all energy sources if the weighted average cost of capital (WACC) is <6%. However, as the WACC increases, the average total cost increases the fastest. This shows how important it is to lower the WACC in nuclear projects and to prepare a precise financial and business model. A similar dependence occurs if the sensitivity of the total cost to the length of the investment period is examined: it grows the most for NPPs. The sensitivity of the total cost to changes in the amount of investment expenditures is also the highest.

4 Financing of NPP projects

NPPs, although requiring high capital expenditures at the investment stage, operate for a very long time, generating positive cash flows in the perspective of at least 60 years.⁸ However, this has a negative impact on the assessment of the project when the Net Present Value (NPV) approach is used.

NPV is the commonly used method of capital budgeting. It is assumed that investment projects with a positive NPV exist; one just needs to find them. Consequently, emphasis is placed on estimating and discounting cash flows. Projects with positive NPV are accepted, while those with negative NPV are rejected. However, in perfectly competitive markets, it is impossible to find and implement an investment project with a positive NPV (especially in the long run!). Assets are properly valued on such a market and the profit possible to be earned covers only the economic costs equal to the market remuneration for the factors of production used. Thus, in a perfectly competitive market, the NPV for investment projects should be neutral. Only the imperfections existing on the market provide a chance to find investment projects with a positive NPV [Shapiro, 1999]. Therefore, the following question arises: should we look for NPV>0 when analyzing investment projects in the energy generation sector, which are to be built in the EU? After all, for many years, the EU has put a lot of effort into building competition in the energy sector. It seems that it is enough for investment projects to achieve NPV equal to zero. In this context, if additional

⁸ Approximately 60–80, and perhaps, even 100 years [United States Nuclear Regulatory Commission].

features defined by the state are met, it appears appropriate to allow even projects with a negative NPV to be implemented.

The NPV method discriminates against long-term projects, even if the period of generating positive cash flows is correspondingly longer. This means that each NPP receives a worse rating than a coal or gas unit. This is not due to the financial characteristics of these projects but due to the quality of the evaluation method itself.

There is also an inconsistency in the analysis when inflation is considered: even if it is correctly included when estimating the discount rate, the future cash flows are usually underestimated. This makes long-term investment projects worse in the NPV assessment. Discount rates are also sometimes overestimated because a project perceived as risky receives a higher discount rate. This rate is not lowered when the initial stages are successful and the project can be assigned a lower level of risk and discount rate [Myers, 1999].

Moreover, if the operation of a nuclear unit lasts twice or three times longer than the operation of, e.g., a gas unit, the full comparative financial analysis should include the cash flows related to the closure of obsolete, depreciated gas power plant and the construction and operation of the new one, built as replacement. This problem is usually ignored in comparative analyses of different energy sources.

Undertaking an investment project with a negative NPV may be justified also by the need to build a foundation, e.g., on a new market, in a "young" sector, or in modern technology. The second step, the second project, may already have a positive NPV. If there is time dependence between the successive stages and one cannot start with the second step, then the negative NPV at the beginning should not preclude the start of the entire investment project [Myers, 1999]. On the contrary, the state should engage in the implementation of the first stage with increased commitment, thus supporting the *infant industry* in the economy.

In the PNPP, capital expenditure is estimated at approximately PLN 20 billion/GWe from 2025 to 2045 [Appendix no. 5 in the PNPP, Table 1]. The financial and business models are presented generally and fragmentarily. It assumes the acquisition of PGE EJ1 by the ST and then the inclusion of one strategic coinvestor related to the selected reactor vendor. Originally, it was assumed that Polska Grupa Energetyczna S.A. (PGE) would take on the role of the investor. However, PGE is listed on the WSE and therefore is focused on meeting the short-term expectations of shareholders (which is typical for developed capital markets) [Horbaczewska, 2019]. Together with the short terms of office of the management boards, this reduces the incentives to invest in fixed capital and long-term growth of the company's value. It is in nobody's interest to implement a new, long-term project that requires enormous investment expenditures and is burdened with high risk. This may explain the reluctance of management boards to undertake such projects, especially capital-intensive and risky investments such as the construction of an NPP. The funds generated in business activities are not used to finance such ventures but are allocated to shareholders (e.g., as dividends), because this keeps share prices and capitalization high in the short term [Horbaczewska, 2012]. Managers, usually economics graduates, attach importance to financial analysis rather than building technology, products, and markets [Myers, 1999]. But, in most cases, the method of financing the investment is of secondary importance. Investment decisions are the most important. Focusing on discounted cash flows changes the future of enterprises; in fact, this shortens their future [Hayes and Garvin, 1982].

4.1 Specific features of investments in nuclear power

NPPs have many features discouraging managers from investing. They are characterized by relatively high investment costs (Figure 1), high fixed operations and maintenance (O&M) costs, high investment risk (long construction period, complicated administrative procedures and licensing, risk of construction delays, and cost overruns), and long return on investment [*Projected Costs...*, 2020].

High investment risk is rooted also in social and political aversion to nuclear energy, caused by excessive phobia to the radiation and exaggeration of the effects of past accidents and incidents. Low public acceptance has forced decision makers and regulatory authorities to impose very restrictive safety standards on the nuclear industry. These standards increase the following:



Figure 1. Median of investment costs for various electricity sources (USD'2019, millions). *Source*: Own elaboration based on [*Projected Costs...*, 2020, pp. 43–44]. CCGT – Combined Cycle Gas Turbine; mln, million; PV - Photovoltaics.



Figure 2. Predevelopment costs for various electricity sources in the UK (GBP'2018/MWh). *Source*: Own elaboration based on *Electricity generation costs* [2020, p. 26]. CCGT – Combined Cycle Gas Turbine; PV - Photovoltaics.

- predevelopment costs of the project, including site selection costs (Figure 2)
- licensing costs
- engineering, procurement, and construction (EPC) costs
- all other costs related directly to the construction of the nuclear plant

Financial institutions perceive NPPs as risky investments. In addition, these projects need a long time to get returns on the invested capital (typically 20–35 years). Together with a lack of long-term and credible national energy policy, it creates too much uncertainty for potential investors. This uncertainty manifests in high expected risk premium, which means high costs of capital: debt as well as equity.

Due to the high construction costs, moderate O&M costs, and long payback period, nuclear power investment projects need a stable and reliable stream of revenues. Today's electricity markets are based on marginal cost price signals and do not generate incentives for new investments, especially for units with high fixed costs. Renewable energy sources (RES) are exempted from these rules – they benefit from dedicated direct or indirect subsidies, or other forms of economic privileges against non-RES. Increasing the inflows of subsidized renewable electricity distorts market signals and even leads to negative electricity prices. Long-term price predictions are very uncertain. In these circumstances, any nonsubsidized project based on revenue from the electricity market is completely unprofitable.

4.2 Business models in the power sector in the EU and the USA - a brief review

There are many different methods used by governments to generate incentives for the construction of new power units or to keep running the existing ones on the electricity market. The most common are as follows:

- Feed-in tarrifs (FiT)
- Feed-in premium (FiP)
- Power Purchase Agreements (PPAs)
- Regulatory Asset Base (RAB)
- Contract for Difference (CfD)
- Carbon Emissions Avoidance Credits (CEAC)
- Production Tax Credit (PTC)
- Various capacity mechanisms (CMs)
- Zero Emission Credits (ZEC)
- Clean Energy Standard (CES)
- Tradable certificates of origin, e.g., green certificates
- Carbon Tax/EU Emissions Trading System (ETS)

All these methods can be divided into four types. The first six belong to Type 1, which basically ensures stable revenues guaranteed and regulated by the state. The next two methods form Type 2. Here, the electricity producer receives a fixed amount of extra revenues in addition to normal sales revenues (and capacity remuneration in CMs) or a tax exemption that effectively equals additional revenue (e.g., in PTC). Total revenues are as volatile as wholesale electricity prices but always sufficient to cover the fixed costs of the plants. Type 3 consists of the subsequent three methods. This is similar to Type 2, but the extra revenues are variable – either based on a dedicated market (e.g., green certificates, CES) or on periodic decisions made by the energy market regulator (e.g., ZEC). The last type is made of parafiscal taxes imposed on electricity generators who use highly GHG-emitting power units. It is intended to deteriorate the profitability of those units and to force the operators to close the plants. The tax rate is determined either by the government or by the dedicated market (e.g., EU ETS) with possible regulatory interventions (EC).

There are some business models operating outside of the electricity markets and enabling the sale of the electricity produced, as follows:

- Exeltium
- Cooperatives (co-ops)
- Industrial power (autoproducers)
- Energy clusters

The *Exeltium* model is used in the Flamanville-3 nuclear project in France. It works as follows: a group of large electricity consumers sets up a company trading in a wholesale electricity market, which buys large volumes of electricity for their owners from Electricité de France's (EDF) existing nuclear plants with upfront payments [Sawicki and Horbaczewska, 2018]. This model has only been used in this project so far.

The three other models are based on autoproduction. They are used for nuclear power only in Finland and the USA. In Finland, they are known as *Mankala* [Sawicki and Horbaczewska, 2019a, b]. However, from the legal point of view, they are not cooperatives but joint stock or limited liability companies, unlike in the USA, where they are essentially cooperatives [Sawicki, 2021]. The electricity generated in the co-op's power plants is directly sold to its owners, not to the market. In principle, the price equals the production costs, so these plants do not make profit. This is similar to the industrial power (autoproducer) model used in Poland, but here, the power plant is owned by one or more companies and the energy is consumed on site, with no long-distance transmission like in *Mankala* or in American co-ops. The energy clusters are made up of autoproducers and consumers of electricity located in a limited area. They have to selfbalance, i.e., produce the same amount of energy as they consume. This is not the case in *Mankala* and in US cooperatives, which can consume more than produce and *vice versa*.

The models described above are used also to finance new nuclear investment projects. Of course, for every single project, local conditions have to be taken into account. For example, in the case of EU Member States, compliance with state aid rules and EC acceptance are necessary. So, from the European nuclear investor perspective, all these business models have advantages and disadvantages, as presented in Table 1.

Model	Advantages	Disadvantages
Electricity market	Compliance with EU state aid rules	No offtake High price volatility, negative prices High investment risk
PPA	Offtake Stable selling prices	No compliance with EU state aid rules
CfD, CEAC	Stable selling prices State loan guarantees	No offtake EC acceptance required case by case
CfD (Czech version)	Offtake Stable selling prices State loan guarantees	Model waiting for EC acceptance
RAB	Stable selling prices Charging consumers from the beginning of construction State loan guarantees	No compliance with EU state aid rules (probably) No offtake
PTC	Fixed state subsidy for every megawatt hour (MWh) of electricity generated Regulatory risk insurance State (federal) loan guarantees	No offtake High price volatility, negative prices No compliance with EU state aid rules
ZEC	Relatively stable selling prices	No offtake No compliance with EU state aid rules
CES	A subsidy in market revenue	No offtake No compliance with EU state aid rules Subsidy value is set by (dynamic) market
СМ	Covering of fixed production costs	No offtake (for energy) High price volatility, negative prices EC acceptance required case by case Short-term auctions Unfavorable to units with high fixed costs
Carbon tax/ ETS	Increasing of costs for coal- and gas-based competitors Compliance with EU state aid rules	No offtake High price volatility, negative prices
Exeltium	Offtake Contracted sales of large electricity volume at relatively stable (indexed) price	Price volatility in the long term, dependent on the wholesale market price index Offtakers have a right to withdraw EC acceptance required case by case (probably)
Mankala	Offtake Selling price covers all production costs Compliance with EU state aid rules	High risk before and during construction The model requires a perfect cooperation of dozens of shareholders

Table 1. Advantages and disadvantages of business models – the EU investor's perspective

Source: Own elaboration.

CM, Capacity Mechanism; CEAC, Carbon Emissions Avoidance Credit; CES, Clean Energy Standard; CfD, Contract for Difference; EC, European Commission; ETS, Emissions Trading System; EU, European Union; PPA, Power Purchase Agreement; PTC, Production Tax Credit; RAB, Regulatory Asset Base; ZEC, Zero Emission Credit. Most of these models have been designed for specific local projects; hence, they may be difficult or even impossible to apply in other countries, or they may generate too much financial burden to the electricity consumers and taxpayers. A good example is the British version of CfD designed for Hinkley Point C NPP. The so-called *strike price* negotiated by the investor and the government is widely criticized as being too high [*Hinkley Point…*, 2017]. The revealed structure of costs (per megawatt hour) indicates that the nuclear risk premium stands at almost one-third of the strike price (GBP 36.0 out of GBP 92.5/MWh), while the nominal after-tax WACC is 9.2% [*Nuclear Sector Deal…*, 2020]. The CfD model allowed the cutting of capital costs only slightly [*Discount rates…*, 2011], and they still remain too high.

A significant drawback of the models mentioned above is the necessity to obtain acceptance from the EC for every nuclear project (state aid investigation). This generates additional risk for the project development phase and delays its implementation. From the end-user perspective, none of these models is able to noticeably decrease the cost of electricity, either because of high capital costs and/or because of additional costs to the process of electricity generation (e.g., generator's profit margin).

5 The SaHo Model as an innovative business model for nuclear power

Taking into account the above-mentioned issues, in the Authors' opinion, there is a necessity to find a fresh business solution for nuclear power, specifically to design an entirely new business model. The new model, although dedicated for the PNPP, should be universal and applicable to various nuclear projects in many countries. The most important criteria which – in the Authors' view – should be met by a perfect business model are listed below:

- 1) Compliance with existing and expected EU regulations and policies (applicable to the EU Member States);
- 2) Electricity offtake;
- 3) Stability of revenues for the NPP company;
- 4) Low electricity costs for consumers;
- 5) Financing of investment with low-cost capital;
- 6) Public acceptability;
- 7) Possibility to implement it in a fast and easy way (i.e., using existing regulations);
- 8) Transferring part of the risk to the state in the short term;
- 9) Limiting of the financial burden to the state budget and public finances in the long term;
- 10) Business flexibility from the investor's point of view;
- 11) Long-term state engagement in nuclear power development; and
- 12) Applicability to various nuclear projects in different legal systems.

All the criteria listed above are met by a new and innovative business model designed by the Authors, namely, the SaHo Model.

5.1 The SaHo Model

The name of the model is derived from the Authors' surnames. Designing the model, the Authors analyzed a various business solutions used so far in nuclear projects across the world and applied their own expertise in the energy industry (including the nuclear sector), economy and finance, as well as knowledge of the legal and regulatory issues of Poland and the EU. As a result of their efforts, a comprehensive, consistent, and – at the same time – simple concept was created. The SaHo Model makes use of the elements of proven models, and it is possible to implement it in a short time because it is compatible with Polish and EU laws, regulations, and energy strategies, both existing and expected. The Authors focus on the Polish power sector, but the SaHo Model can be easily applied to finance nuclear investment projects in other EU countries as well as in the USA and Canada. The SaHo Model not only enables the building of an NPP efficiently and

cheaply but also allows both enhancement of the competitiveness of the national industry and increase in public acceptance for nuclear power. Thus, it is not only a business model but also a concept for the functioning of the nuclear industry. It can be considered a breakthrough concept, changing the way of thinking about nuclear power and bringing it closer to citizens.

5.2 Description of the SaHo Model

As mentioned before, the construction of an NPP requires high expenditure spread over a long investment period. For a private investor, it means a significant investment risk and high capital costs, usually putting into question the profitability of the project. At the same time, it is commonly known that the lowest-cost capital is usually available to the state (government). It is also the state that can best manage risks arising in the first stage of the investment (e.g., political risk, legal risk, and regulatory risk). State involvement reduces such risk and encourages private financial institutions to provide financing at the lowest possible interest rate. This lowers the WACC, which is a key parameter in the NPV method.

Therefore, the first step is to establish a Special Purpose Vehicle (SPV) or to take over an existing one (e.g., PGE EJ 1 in Poland). Its statutory objective is to build, own, and operate an NPP and sell the electricity produced to its owners.⁹ In the Authors' opinion, the most transparent legal form of the entity is a joint stock company; hence, the SaHo Model was conceived within this legal framework (other solutions are also possible). The sole owner of the company at the very first stage is the state, or an institution designated by the government, e.g., the Polish Development Fund Group. This is the *initial investor*. Such an *initial investor* is best able to perform the role of an efficient, strong, reliable, and credible project organizer and developer. The state takes over most of the business risk and facilitates the process of obtaining the lowest-cost financing (the crucial element for project profitability). It also guarantees efficient project implementation by setting a high priority for the project in all government institutions involved (e.g., regulatory authorities¹⁰) and effective coordination of project tasks.

Then, in the period between the establishment of the project company and connection to the grid, the *initial investor* gradually sells its shares to electricity consumers – let us call them *final investors* (Figure 3). The sale of shares may be organized in the form of tenders, auctions, or bilaterally negotiated contracts. Finally, at the time of grid connection (i.e., the end of construction and start of operation), the *initial investor* should possess no shares. Here, the SaHo Model starts to function in a similar way as the Polish industrial power (autoproducer), the American public power and co-ops, the Finnish Mankala, or even a German renewable co-op model. Electricity is produced only to satisfy the needs of the owners (shareholders). The offtake is the right and the duty of the shareholders. The offtake is proportional to their share in the ownership and based on the cost-price formula since a profit is not an objective of the company. The statutory goal of the company is to produce and sell energy to its shareholders at the lowest possible price covering the total production costs.

The shareholders may be electricity consumers of various types:

- Manufacturing industry (various sectors)
- Transportation (e.g., railways)
- Entities controlled by local governments (e.g., subways), including host communities
- National government institutions (e.g., government agencies, health care, and so on)
- Households (through dedicated energy cooperatives)
- Other types of investors

The shares can be bought by the *final investor* from the *initial investor* at any time between SPV establishment and connection to the grid (see Figure 4). The later a *final investor* buys them, the higher is

⁹ And other products such as heat, hydrogen, and industrial radioisotopes, if available.

¹⁰ While respecting their independence, as required by international treaties.



Figure 3. Changes in the ownership structure in the SaHo Model at subsequent stages of the project (basic scheme). *Source*: Own elaboration. SPV, Special Purpose Vehicle.





the price because the investment risk and the time needed to complete the project are reduced. On the other hand, the certainty of project completion is increasing. No wonder that the share price will increase along with the implementation of subsequent stages of the investment. But the price still should be attractive to potential investors. The reasons for this approach and assumptions are the following:

- 1) Project development is effective owing to a reliable state *initial investor*.
- 2) When the project approaches its final stages, the risk (and its cost) is much lower than at the beginning of construction.
- 3) Capital costs are low during the entire project execution (the discount rate may be variable but always relatively low).

Acquiring an electricity offtake at production cost in the completed NPP will undoubtedly be a good investment opportunity for electricity consumers, even if they use the NPV method for economic evaluation of the investments.

5.3 Advantages of the SaHo Model

A significant advantage of the SaHo Model is the strong commitment of the state in the initial stages of the investment project. The state is able to collect the necessary financing at a low interest rate as well as manage the most challenging kinds of risk specific to the initial phases of the project. The distinguishing feature is gradual reduction of state involvement at subsequent stages of the investment.

Another advantage is the compliance with Polish and EU laws and policies, both current and expected ones. It has many features of the European industrial power model and energy cooperatives, which are very perspective in the context of EU energy and climate policy.

According to the Polish Commercial Companies Law, a company is obliged to realize its objective determined by the shareholders. In the case of an NPP company operating within the framework of the SaHo Model (the SaHo-NPP), the objective is not making profit but the production of energy (primarily electricity) and its delivery¹¹ to shareholders at production costs. Similar objectives are embedded in the Polish industrial power model, Mankala, and American co-ops and public power companies.

The cost of electricity production in the SaHo-NPP would be approximatley USD 20/MWh (total operation cost or operating expense [OPEX]).¹² Of course, earlier, a shareholder would have to buy shares of the SaHo-NPP company, but this would be a long-term investment, not the element of the cost of electricity. Thus, the shareholder-consumer practically buys (almost) a guarantee of stable and nonintermittent supply of cheap electricity.

In the Authors' opinion, assuming the political determination for nuclear power development and an active state participation in the early stages, the SaHo Model has no defects. It meets all the criteria of a perfect (nuclear) business model, listed above in this article:

- Ad. 1. The SaHo Model is based on Polish and EU laws, regulations, and long-term strategies.
- Ad. 2. Offtake right and obligation is written in the company agreement or the statute.
- Ad. 3. According to the company agreement or the statute, shareholders are obligated to cover all fixed and variable operating costs of the SaHo-NPP company.
- Ad. 4. Shareholders of the SaHo-NPP company receive electricity at production cost (plus transmission and distribution costs), with no margin for the electricity generator, out of the electricity market, and with no capacity payments to the power companies. The total cost (price) is lower than in the case of the electricity market or purchase based on bilateral agreements.
- Ad. 5. Project development and construction costs are initially financed by the state-owned *initial investor*, ensuring the lowest possible cost of capital. Then, shares are gradually sold to electricity consumers, who take the responsibility of financing the SaHo-NPP operation costs. For the *initial investor*, it is certainly an investment with high expected rate of return as compensation for the risks taken in the early stages of construction. The *final investors* are guaranteed quick and safe return on capital, merely several years after the investment, which is unique in nuclear business models (a typical period lasts at least 20–35 years). Lenders benefit from safe repayment. This allows to further decrease the cost of capital and to finance subsequent SaHo-NPPs with mostly the same funds. It also helps to avoid an increase of public debt, which is important during the ongoing crisis.
- Ad. 6. The SaHo Model provides end-users an almost guaranteed 24/7 (weather-independent) access to electricity at the lowest possible cost. The SaHo-NPP shares are purchased voluntarily. Consumers are not forced to finance the SaHo-NPP, as in the CfD or RAB models. The possibility to purchase the SaHo-NPP shares by individuals (through co-ops) can increase public acceptance for nuclear power and create a large citizen-based pronuclear society, similar to the renewable co-op lobby groups in Germany.

¹¹ Not including transmission and distribution.

¹² The Authors assumed OPEX for Generation III NPPs with 1,100 MWe capacity in USA, according to data from the NEA-OECD [*Projected Costs of Generating Electricity*, 2020]. For depreciated Generation II NPPs in Europe, these costs are mostly at EUR 12–30 per MWh.

- Ad. 7. The SaHo Model is completely compliant with Polish and EU regulations. It is based on existing solutions and models already in use in Poland and other countries.
- Ad. 8. The SaHo-NPP company is 100% owned by the state at the beginning and remains under government control at later stages of the project (though it is not mandatory). It takes a "nuclear" risk, specific to the first stages of the project, which is significantly related to the activities of state agencies (e.g., nuclear and environmental regulatory authorities).
- Ad. 9. The burden on the state budget is carried only in the early phases of the project. The sale of the SaHo-NPP company shares will be an additional income for state institutions.
- Ad. 10. The *initial investor* has a statutory right to sell its shares to any investor-consumer; the new owners *final investors* have also a right to resell the shares. Freedom to trade in shares means flexibility and liquidity for the investors.
- Ad. 11. Together with the sale of shares and the commissioning of the SaHo-NPP, the state may indirectly control it through state-owned shareholders, the right of veto, the golden share, proper laws and regulations, and/or due to the provisions in the company's statute. Using the SaHo Model to implement subsequent NPPs (or units), the state may be engaged in the development of nuclear power in the long term.
- Ad. 12. The SaHo Model can be applied to each new build NPP, in both Poland and other EU countries, as well as outside the EU. The co-op models are allowed in most countries.

Here comes the question of whether the electricity consumers, primarily industrial companies, will be interested in buying shares of the SaHo-NPP? But do they have a cheaper option of electricity supply? In the case of companies operating in the EU economic environment, there are no viable alternatives. The cheapest one could be probably a mix of own RES and capacity market based on gas units. But the total cost of this solution is way above the total cost of electricity possible to be obtained from the SaHo-NPP for the reasons mentioned in this chapter. Certainly, before the implementation of this model, the government should carry out consultations with end-user organizations (e.g., national industrial associations) to make sure that the benefits of the SaHo Model are well understood and there is a real interest among them to buy SaHo-NPP shares.

Therefore, the SaHo Model is beneficial to all stakeholders of the nuclear power program: the government, capital providers, electricity consumers, and the society in general. Among the benefits for the government are the following: successful implementation of a nuclear power program, building a decarbonized baseload capacity to the power system, providing the national economy with cheap and stable electricity (increasing energy security), GDP increase, and reduction of inflation and unemployment, thus, resulting in an increase of social wealth. This facilitates the dynamic development of the national economy and an increase of its competitiveness on international markets. Electricity consumers have 24/7 weather-independent access to cheap electricity. Low electricity costs for industrial plants lead to (at least partially) low manufacturing costs.

6 Summary

Implementation of the PNPP is essential to ensure energy security in Poland in the coming decades, as well for the decarbonization of the energy sector and a decrease of electricity costs. This energy technology is available in almost all neighboring countries, along with plans of new build. In fact, Poland already imports electricity from nuclear plants abroad. But in this situation, profits are gained by neighboring states that have NPPs at their disposal.

The delay in the construction and commissioning of an NPP may result in high costs for the economy of our country. The Supreme Audit Office estimated the costs in 2018 at PLN 1.5 billion to PLN 2.6 billion annually [*NIK o realizacji...*, 2018]. Now, they are several times higher – in 2019, domestic commercial power plants spent PLN 9.55 billion on the purchase of EUAs, and in the period 2013–2019, a total of PLN 20.4 billion,¹³ which corresponds to the cost of building one nuclear unit with a capacity of approximately 1,000 MWe.

¹³ Own calculation based on Statystyki Elektroenergetyki Polskiej [2014-2019].

The construction of an NPP requires high expenditure, but it is spread over several years of the investment process (6–8 years). The experience of recent years has shown that there are no business entities in Poland that would be willing to finance a project based on large reactors. There is a similar problem in other countries. Therefore, many different financing and business models have been invented to support investors in the early stages and to provide electricity offtake after the start of electricity production. However, the financial costs are still very high. Despite subsidies for nuclear energy producers, the price of energy for consumers is still high, which is especially troublesome for the electricity-intensive industries. Therefore, it seems that the only solution is the active participation of the state in the implementation of nuclear power programs in many countries.

The state's support for large innovative investment projects is particularly important now, when we are most likely at the beginning of the next economic crisis. Such actions are considered appropriate and desirable in difficult times in economic literature. They promote economic stability, prevent the decline of economic activity (especially deindustrialization), and prevent energy poverty, and help contain inflation. The innovative SaHo Model proposed by the Authors in the article is worth serious consideration by the Polish government, as well as the governments in other countries.

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