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STANISŁAW TOKARSKI[1], ANTONI TAJDUŚ[2*]

CHALLENGES FACING THE POLISH ENERGY SECTOR IN 2024 AND UPCOMING YEARS

The paper discusses a variety of serious challenges facing the Polish energy sector until 2040. These challenging tasks largely result from intensive works in the European Union on the finalisation of measures implementing a zero-carbon economy, as well as social (Covid-19), political and military events, both global and regional (war in Ukraine). After analysing the present condition of the energy sector, the authors proposed a modification of Poland's energy policy, pointing out that the transformation of the national electricity system towards zero-carbon energy requires, on the one hand, speeding up investments in renewable sources, but on the other hand, insuring this process by own controllable generation sources. The paper also defines the conditions that should be met to achieve the highest possible share of non-carbon energy in the national energy mix by 2040.

Keywords: energy policy; energy sector; Covid 19

1. Introduction

By the end of 2023, intensive work was underway in EU bodies to finalise the negotiation process and reach an agreement on the final targets, actions and legal tools for the implementation of the Green Deal [1]. Have all the elements implementing the zero-carbon economy contained in the Fit for 55 proposals of July 2021 [2] been finalised, together with the changes resulting from RepowerEU [3]? The first half of 2024 will be the last implementation phase of the Green Deal regulations before the forthcoming European Parliament elections in June 2024. Is any significant change in economic policy priorities to be expected after the European Parliament

[1] CENTRAL MINING INSTITUTE, PLAC GWARKÓW 1, 40-166 KATOWICE, POLAND
[2] AGH UNIVERSITY OF KRAKÓW, AL. MICKIEWICZA 30, 30-059 KRAKÓW, POLAND
* Corresponding author: tajdus@agh.edu.pl

elections? It seems very likely. There have already been announcements suggesting an increase in the scale of emission reductions by 2040 by the future EU authorities. Also, addressing issues such as water quality, the circular economy and 'sustainable' food policy is to be expected.

Europe plays an important role in the global economy, but its economic policies are strongly affected by political and military events, both global and regional. The EU, while still attempting to restore its economy after the COVID-19 pandemic, had to fend off the effects of the commodity crisis resulting from Russia's February 2022 assault on Ukraine. It turned out that energy raw materials still exerted a huge impact on the European economy. The world, including the EU, began to address the issue of energy security and sovereignty again. These events (Covid 19, the war in Ukraine) have significantly changed the world's priorities and understanding of the notions of economic and military security. The country's own resources, technologies, know-how and goods production chains are gaining importance, in addition to cooperation within economic blocs such as EU-US. Own independence and sovereignty returned to favour. The fact is that the EU does not have significant resources of energy raw materials or elements critical to the energy transition. In the technological race, it has been overtaken by China and the US. So the question is, where does Europe look for opportunities now? Does it still have a chance to regain its leadership in the economy of the future by completely transitioning, as the very first economy in the world, to carbon-free technologies?

Seemingly, the only good solution is to become independent of the missing energy resources by resorting to our own renewable sources. It is important to adjust the pace of transformation to allow for the rebuilding of our own production chains, such as photovoltaic panels, batteries, and electrolyzers. This process must be ensured by the available raw materials found within European countries. It also seems necessary, as much as possible, to become independent of the transport of liquefied gas or oil from distant uncertain directions, which can be blocked by military actions.

In the domestic economy, de-carbonisation of the energy sector and the overall economy is expected to accelerate significantly in early 2024. For this purpose, at the end of 2023, Poland received the first funds from the EU, i.e. €5 billion as part of the implementation of projects covered by the RepowerEU program. These funds should be used primarily to support investments in renewable energy sources and electricity grids. However, this is only the first step. The government must revise its energy policy and the country's commitments to contribute to European reduction targets. What seems inherent in the debate about the economy in the near future are the issues of increasing the assimilation of renewable energy from weather-depended sources by the national system, a realistic date for the construction of the first nuclear power plant, and estimating the volume of coal and gas needed in the transition period.

2. Revision of Polish energy policy

The document Poland's Energy Policy until 2040 [4], adopted in February 2021, quickly became obsolete. In December 2020, the European Council adopted the Green Deal and the 2050 climate neutrality target, with an intermediate target of a 55% reduction in greenhouse gas emissions by 2030 (relative to 1990 emissions), while the 2040 PEP assumed a 40% reduction and the National Energy and Climate Plan (KPEiK) [5] assumed only a 30% reduction. The situation changed dramatically after Russia's assault on Ukraine in February 2022 and the resulting commodity crisis. Natural gas, which, according to PEP 2040, was supposed to act as a transitional fuel for power and heating, turned out to be too risky in availability and price. In view of the above

and assessing the progress of investment projects in offshore wind farms and nuclear power, the Government decided in April 2022 to adjust the energy policy. In mid-2023, the considered so-called scenario No. 3 was unofficially revealed, which set energy mix targets for 2040, assuming that 73% of electricity would come from renewable sources, corresponding to 74% of the share of renewable capacity installed in the national system [6]. When we compare the simulations of the current policy (high allowance price scenario) with scenario No. 3, we notice a significant difference in the amount of capacity of the NPS in 2040. The capacity increases by over 100%, from 60 GW to almost 130 GW, as shown in Fig. 1.

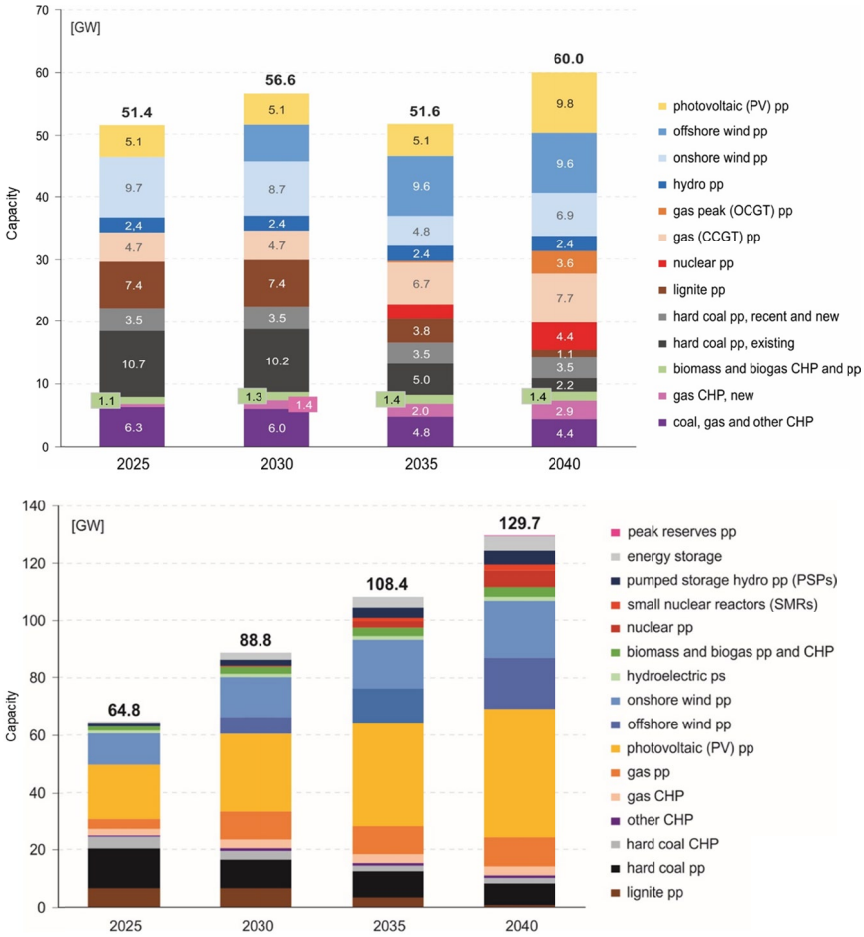

Fig. 1. Projection of capacity and structure of NPS power in 2040 according to the current PEP 2040 policy of 2021 and scenario No. 3

The situation is similar in relation to the forecast of electricity consumption. In the current policy, the volume of domestic consumption in 2040 is assumed at the level of 204 TWh, whereas in scenario No.3, it is 244 TWh. (Fig. 2)

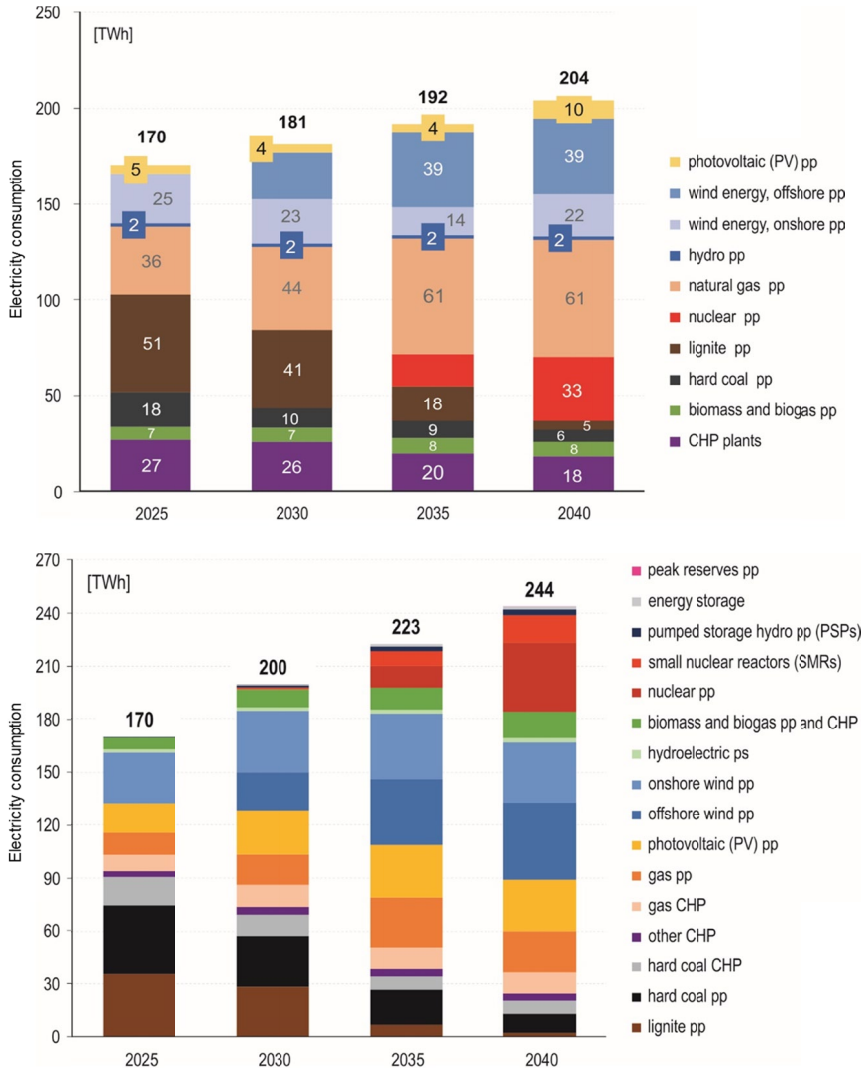

Fig. 2. Electricity consumption forecast and its structure until 2040, according to the current PEP 2040 policy and scenario No. 3

Assuming even a far-reaching electrification of heating, transportation and other sectors of the economy by 2040, a significant 20% increase in consumption in the projections prepared only two years apart clearly indicates that the policy requires an urgent revision.

An attempt at redefining the country's energy mix will certainly require a serious "feasibility study" of the ability to rebuild generation sources and the electricity transmission and distribution system in order to define realistic Polish climate targets. The European 2030 emission reduction target for the ETS sector is 62%, relative to the reference year (2005). If this target were to be translated directly into the domestic energy sector, emissions would have to be reduced

by almost 30 million tons in the 2024-2030 period. Hence, a new energy policy prepared in an exceptionally thoughtful manner should take into account both the changing external conditions, including the experience of the Ukrainian conflict, as well as the reality of the pace of its implementation.

3. What about the National Energy Security Agency (NABE)?

The transformation of the country's electricity system towards non-carbon energy requires, on the one hand, accelerating investment in renewable sources, but on the other hand, ensuring this process by own controllable generation sources. In the perspective of 2030, the latter can be achieved by almost exclusively coal-fired power plants. Domestic power companies (PGE, Tauron, Enea, Energa), which have decided to implement, among others, large wind projects, have encountered, on the part of the banking sector, a barrier to financing new investments due to the possession of coal-fired power plants in their assets. As a condition for obtaining further investment financing in the European market, it became necessary to separate coal assets from the energy companies. In 2022, the government adopted the document pertaining to the transformation of the electric power sector in Poland [7], which envisaged the creation of the National Energy Security Agency (NABE). NABE became tasked with taking over all coal-fired power plants and lignite mines from state-owned companies.

The main purpose of creating NABE should be raised again from the outset. Is it:

- creating a reserve of steerable power for the NPS during the transition?
- freeing power companies from their coal assets?
- establishing a company tasked with power plant restructuring and decommissioning?
- re-nationalisation of generation assets (increasing energy sovereignty)?

According to the authors, the primary purpose of establishing the NABE agency should be to create a reserve of regulatory power for the NPS for the transition and additionally to relieve energy companies from coal assets. If this is the case, a critical re-examination of the assumptions of the NABE project and the consequences that may result from its implementation is necessary. The creation of NABE carries the following risks:

- Market – excessive concentration (more than 70% of the domestic market),
- Financial – decline in the ability to operate independently due to rapid loss of revenue,
- Management – centralisation, excessive management concentration,
- Organisational – hierarchical, multi-level organisational structures,
- Logistical – unjustified separation of hard coal supply chains,
- Developmental – limited modernisation and investment capacity,
- Political – the need for State Treasury guarantees for the creation of a giant,
- Sociological – the prospect of liquidation of the company discourages new employees,

It is imperative that politicians tackle the fundamental questions at hand: Is the minister in charge of energy to take over responsibility for decommissioning old power plants from the existing owners, or is NABE a return to the pre-1989 Energy and Lignite Community?

Then, what is NABE supposed to be?

Supposing that the primary purpose of the new NABE agency is to stand as a regulatory power reserve for the NPS during the transition period, which seems reasonable, then the following underlying assumptions should be made:

- NABE should have power units that will be activated outside the energy market by PSE (e.g., along the lines of the cold reserve intervention mechanism) and not participate in the market (too high costs and limited operation time),
- NABE should be financed from funds for the strategic reserve (fixed costs) and revenues from energy sales (variable costs),
- The decision to transfer specific units to NABE should be made by energy groups without a transfer fee (if the unit is not efficient in the energy market),
- NABE, in agreement with PSE on the need to maintain a given capacity in the NPS, takes over the specified unit, and the unit not taken over is decommissioned in the corporation,
- Mines that are associated with power plants have the potential to be transferred to NABE,
- The NABE program is synchronised with the program to prepare a regulatory power reserve for the NPS after the end of support from the power market (notification may be necessary).

Adjustment of the NABE project, according to the assumptions specified above, may result in a significant reduction of the State's financial involvement in the process (the size of the Treasury guarantee at the level of PLN 70 billion in the first year, according to the current draft). Payments for the transfer of coal assets between State Treasury companies are also not envisaged. Adjusted to actual needs, the size of NABE will also reduce the need for working capital, including covering the purchase of emission allowances.

4. How to increase the assimilation of energy from weather-dependent sources?

The dynamics of investment in renewable sources, especially in distributed photovoltaic installations, led for the first time to a situation where the system operator, to ensure the safety of its operation, decided in April 2023 to limit the generation of solar farms. The supply of electricity from domestic sources was higher than the demand for it by consumers, including foreign ones. In such scenarios, a reduction in supply is necessary, and that's what occurred. Since we all agree that as much renewable energy as possible is desirable in the energy mix, the question is what opportunities exist for increasing its assimilation by the NPS. Therefore, it is crucial to take into account the following actions and their corresponding limitations:

- **Energy storage**

As of today, the most effective, large-scale storage of electricity can be achieved through pumped-storage hydropower plants (PSHs). Poland's electricity system has about 1.9 GW of installed PSH capacity and the capacity to store about 9 GWh of electricity (energy produced, for example, by a 1 GW wind farm in 9 hours). The government plans to build about 2.5 GW of pumped-storage capacity, mainly in three locations: Młoty, Tolkmicko, and Rożnów. These storage facilities can realistically be built after 2030. Thus, the PSH energy storage capacity will remain rather minor until then.

Large-scale battery storage of energy appeared for the first time last year in the main auction for 2027, in a token amount of only 165 MW, with the possibility of storing less than 0.7 GWh.

The price was at a record high of more than PLN 406/kW/year. For the 2028 main auction, held in 2023, more than 16 GW of energy storage was submitted, and a price obtained (according to PSE's announcement) was PLN 244.90/kW/year, 40% less than a year before. The auction ultimately resulted in the contracting of 1.7 GW of energy storage capacity, which is a good result. The potential increase in the volume of renewable energy in the daily balance is less than 7 GWh.

Prosumer energy storage facilities are not popular in the domestic market due to high costs. It is estimated that there may be about 10,000 of them, with a capacity of about 100 MW. The main reason for the low popularity is the principle of mandatory balancing by the system of energy injected by the prosumer until 2023 (net metering principle). The change of this rule to net billing in 2023, as well as subsidies for the purchase of energy storage under the next „My Electricity" program, may change prosumers' approach to investing in their storage [8,9]. According to the authors, such a distributed system can, without significant grid investments, considerably flatten the daily curve of electricity demand in the system. If 1 million prosumers install home storage, it is possible to achieve a storage capacity of up to several GWh of energy. Smart programming of energy storage charging cycles and the use of their capacity by individual or group consumers will both increase the amount of renewable energy in the grid and reduce energy consumption during peak hours.

What may become an important way to store energy is the production of hydrogen using electrolysis, using excess electricity from renewable sources. This method has a serious potential to be used for energy storage in the future, even though the efficiency of the process is still relatively low. Hydrogen produced from renewable sources is called „green hydrogen". Renewable-powered electrolysers with a capacity of more than 6 GW are expected to be installed in Europe by the end of 2024, with the capacity expected to reach as much as 40 GW by 2030. According to the delegated regulation of the European Commission of February 2023 [10], the principle of simultaneity of energy production from renewable sources with the electrolysis process, which produces hydrogen, has been introduced as a target. It was assumed that these sources could not be older than three years from the date of production of the first kilogram of hydrogen. This restriction means that hydrogen produced with renewable energy excess from older sources is not treated as 'green'.

In summary, the potential for electricity storage in the national energy system is insufficient and is not expected to increase significantly in the perspective of 2030. Currently, the best solution is to create conditions for rapid expansion of energy storage capacity in prosumer installations. Energy storage in the form of heat, especially seasonally, remains a separate issue.

- **Demand elasticity – dynamic tariffs – local balancing**

Flexible demand, which means using electricity during periods of excess and lower prices, can increase the volume of renewable energy in the national system. The July 28, 2023 amendment to the Energy Law, which came into force on September 7 [11], introduces a demand flexibility service, which can be contractually concluded between the local distribution network operator and the client. The customer may give up part of its power (flexible power), and the supplier will be entitled to exercise such right of curtailment during peak hours. The detailed rules and method of remuneration for giving up part of the power, and consequently the energy supplied to the plant or household, has not been defined, but, following the example of the US market, the right of the local operator to turn off, for example, air conditioning or heating for a certain period may be associated with a discount in the electricity bill.

Beginning August 24, 2024, electricity sellers will be required to offer dynamic tariffs to their customers. Dynamic tariff means offering electricity at a price that changes depending

on the changing availability of energy in the national system over time. Consumers will be able to decide to increase their consumption when there is availability and a lower price and reduce it during peak hours with high prices. Making dynamic tariffs available to residential consumers requires the installation of real-time metering metres at the consumer's site and the construction of a central information system (CSIRE) and systems that actively manage consumption.

Local generation and consumption of renewable energy is the most effective way to increase renewable energy in the structure of the national energy mix. Supporting the creation of local power generation communities with its storage and efficient use can significantly reduce the need for investment in distribution networks. It is technically and economically inefficient to transform energy from the low-voltage level to send it to even a not-so-distant point in the system at medium voltage.

Failure to synchronise the growth of weather-dependent renewable capacity in the national system with the capacity to assimilate the energy it generates can lead to overinvestment and consequent stranded costs. This is the worst possible scenario, for which all consumers will inevitably pay. It is also an inefficient expenditure of resources on the transformation.

5. Nuclear power: When realistically the first power plant?

In the second half of 2023, a decision was made to locate the first two large nuclear power plants in Lubiatów-Kopalin and Konin. The issuance of a localisation decision means that the investment is in line with the public interest and state policy. It begins the arduous process of obtaining the necessary further approvals and decisions, construction permits and the start of construction itself. According to media reports, construction of the Lubiatów-Kopalin power plant is expected to commence in 2026 (Westinghouse and Polskie Elektrownie Jądrowe). In Poland's energy policy until 2040, the first nuclear unit is set to be commissioned by 2033. Based on the actual realisation cycle of 1,000 MW class coal-fired units in Poland in the previous decade, the time from the start of the bidding process, with the assurance of the ability to finance the project, to the production of the first MWh, was about 10 years. In addition to determining the location and identifying the technology, there is no financing model, including a support mechanism (e.g., a contract for difference), the capital structure of the implementation company, and the procurement formula (tender, direct supply from the technology supplier). This raises the question of a realistic timeframe for commissioning the first nuclear power plant and producing the first MWh of electricity. According to the authors, the date of synchronisation with the grid of the first nuclear unit should be expected to be postponed for several years, and a significant share of nuclear energy in the energy mix may occur around 2040.

There are high hopes for the use of small modular reactors (SMRs) on a wider scale in the power industry. SMR technology has been known since the mid-1950s. To date, SMRs have been used as power generation in submarines, US radar and Arctic stations, among others. Despite its advantages, such as compactness, passivity, the possibility of mass production and delivery to the site in full, built-in safety systems, and the possibility of scaling output power (reducing investment costs), it has so far failed to gain popularity in the power industry. The most advanced project of the US company NuScale, whose construction began in Idaho, was unexpectedly halted in the second half of 2023. Lack of economic efficiency was cited as the reason. In Poland, cooperation with NuScale was undertaken by KGHM, but after the decision to discontinue the investment in Idaho, the company began looking for other SMR suppliers. Competing with the NuScale project

was GE Hitachi's BWRX 300 reactor project, which is currently under construction in Ontario, Canada, with a plan to be operational in 2030. In Poland, the BWRX 300 construction contract was signed by Orlen Synthos Green Energy. In December 2023. The Minister of Climate and Environment issued in-principle location decisions for six projects in urban centres across the country, prompting a discussion of site considerations, technological issues and safety. However, a serious problem appeared in this respect, as BWR technology is not indicated in the current program for nuclear power and is not being developed in Europe. Meanwhile, the Polish Nuclear Power Program of 2020 assumes only the construction of reactors that have already been installed in another country, and there exists experience of their operation. Currently, in the world, there is no commercially implemented first civilian SMR, [12-15]. Hence, the conclusion is that the commissioning of the first SMRs in Poland may take place after 2035.

In summary, nuclear power can play a key role in decarbonising the country's energy mix, however, this will not happen until around 2040.

6. Coal in the national energy mix: How much and until when?

In 2022, as much as 76.9% of electricity (147.6 TWh) was produced from coal: 50.1% hard coal and 26.8% lignite. More than 29.7 million Mg of hard coal was used for this purpose. Power plants, combined heat and power plants and heating plants in 2022 together consumed 44.8 million Mg of hard coal. The Polish mining industry mined 42.1 million Mg of thermal coal and imported more than 17 million Mg. The year 2022 was special in the world economy. After Russia attacked Ukraine in February 2022, the spectre of underheated housing and industrial shutdowns loomed, resulting in intensified efforts directed at importing coal from various possible directions. The shortages were mainly in so-called "coarse coal." A considerable amount of coal was imported without regard to price. After sifting out the coarse assortments (which account for 5 to 8% by weight of coal) needed for households, stocks estimated at 8 million Mg of expensive thermal coal, suitable only for burning in power plants, were left in the spring of 2023.

In 2023, PSE's preliminary figures show a decline in production to 163.6 TWh (down 6.58%) and electricity consumption to 167.5 TWh (down 3.44%) in Poland. Coal-fired power generation also fell to a 68% share of the mix, with hard coal accounting for 76.6 TWh. Thermal coal output in 2023 was about 37 million Mg, and imports approx. 18 million Mg.

There is a consensus on the need to reduce the share of coal in the energy mix. On the other hand, it should also be understood that in the national balance during the winter period, in the absence of solar generation, approx. 20 GW of thermal power plant capacity is necessary to ensure system balancing.

The key question, then, is how much and for how long the capacity is needed in conventional units, i.e. the necessary production of electricity from them during the transition period. In an expert study conducted in 2021 at the Central Mining Institute (GIG) [16], the researchers obtained a demand curve for hard coal until 2040 (Fig. 3). Hard coal consumption for electricity generation, according to the study, will fall to about 15.8 million Mg in 2040, a value slightly higher than the PEP 2040 forecast, the high allowance price scenario, i.e. 11.1 million Mg. In Scenario 3, from mid-2023, demand for lignite is projected to fall to virtually zero in 2040, and for hard coal to 10 million Mg (Fig.4). In turn, Figure 5 shows the projection of natural gas use for electricity

generation until 2040, adopted in scenario No.3. The maximum consumption of natural gas for electricity generation is projected for the year 2035, at the level of 7.6 bcm. In 2030, 5.9 bcm of natural gas is expected to be consumed, to produce about 30 TWh of electricity.

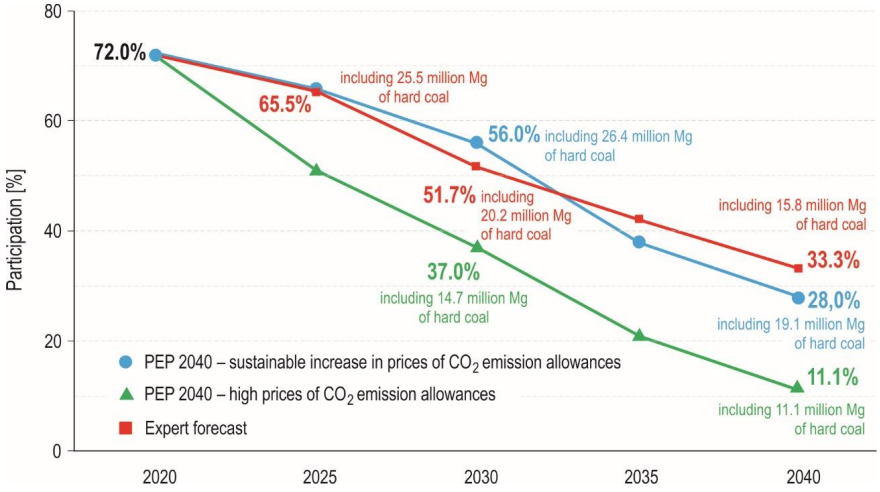

Fig. 3. Expected share of hard coal in the national energy mix. PEP 2040 and results of expert studies, GIG 2021

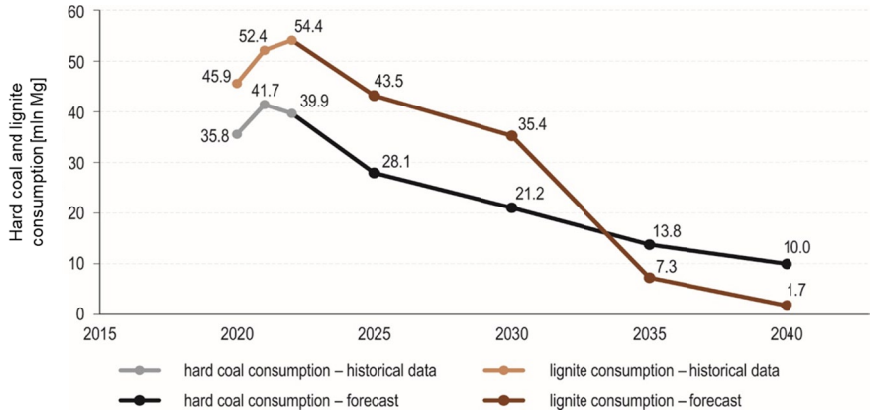

Fig. 4. Expected share of hard coal and lignite in the national energy mix. Scenario No. 3 of the proposed mid-2023 energy policy revision

As a result of the outcome of past capacity market auctions, some 5.8 GW of new gas-fired capacity was contracted with a delivery date of 2027. No new gas-generated capacity was contracted during the December 2023 auction. As a result, the total installed capacity based on gaseous fuels will exceed 11 GW by 2030. With a cost-effective and dependable supply of gas fuel, it would be possible to produce up to 60 TWh of electricity.

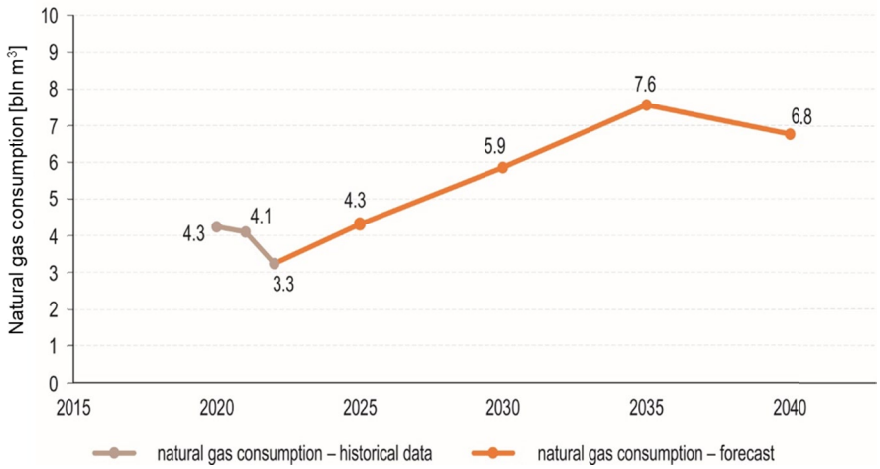

Fig. 5. Expected share of natural gas in the national energy mix.
Scenario No. 3 of the proposed mid-2023 energy policy revision

The question that needs to be resolved is which fuel in the transformation period will play a transitional role: coal or natural gas [17-19]? After 2030, the capacity installed on natural gas can virtually cover the demand curve of the national system for most of the year. Does this mean that coal units of the 200 MW class can be permanently set aside, after 2030?

According to the authors, given the risk of stability of supply and the fluctuation of prices of gaseous fuel on world markets, while natural gas should be treated as a desirable fuel in the mix of generated energy, it still fails to provide a guarantee of security in periods of escalation of military conflicts in the world. This leads us to the conclusion that during the transition period, it seems necessary to maintain a capacity reserve of about 10-12 GW in coal units, including the 200 MW class. The decision to permanently decommission every unit must be taken after a careful and in-depth analysis of the need for its existence at a given point in the system by PSE. Coal-fired units whose existence is necessary for operational stability should operate outside the energy market and be disposed of by the system operator (new NABE). To reduce the carbon footprint in the national mix, generation from renewable sources, natural gas, and ultimately, nuclear power plants should be used consistently.

7. Conclusions

Politicians, the national economy and the energy sector face new challenging tasks in designing a green transition. Significant financial allocations and adequate human resources are needed in this complex process. Poland cannot afford to deviate significantly from the pace of the European transformation, but it certainly has the right to receive some recognition for its historical circumstances. Thus, in 2024:

1. It is necessary to revise Poland's energy policy until 2040 to meet European aspirations to reduce emissions, taking into account national circumstances (revision of National

Energy and Climate Plan). According to the authors, the energy policy adjustment should be preceded by a reliable „feasibility study" that identifies the benefits and costs from the point of view of the national economy.

2. The transformation of the national energy mix away from fossil fuels to renewable energy is not disputed by anyone. To ensure the security of this complex and long-term process, it is necessary to base it on existing energy and generation resources during the transition period. During the transition period, a national power system reserve is required. It should be organised in a "new NABE".
3. Investment in renewable sources, including prosumers energy, should be accelerated at the most reasonable pace. The key issue remains to increase the scope of assimilation of energy from weather-dependent sources by the national system, taking into account aspects of storage and flexible demand. Excessive investments, from which energy will not be used, can become a source of stranded costs, for which all energy consumers will inevitably pay.
4. Nuclear power is desirable in the Polish reality to ensure a non-carbon energy mix. In the energy policy of Poland until 2040, which was adopted for implementation, the date of commissioning of the first nuclear unit was set for 2033. Meanwhile, taking into account global experience, as well as domestic conditions, obtaining electricity from the first nuclear power plant is possible only closer to 2040. It is also unlikely that before 2040 small modular reactors (SMRs) will commence their operation.
5. By 2030, efficient coal-fired power plants will determine the operational security of the national system, as well as the volume of electricity generated. Gradually, after 2030, electricity from offshore wind farms and gas-fired power plants will change the mix structure. Coal-fired power plants will act as a power supplier and function mostly outside the energy market. However, a market play between gas fuel and coal is possible.
6. Given the numerous variables, it is extremely difficult to design a national energy mix for particular years that would be still valid from a few years perspective. It should be assumed that in 2040, virtually one hundred percent of non-carbon energy is feasible in the national energy mix, in technologies that will compete with each other, outlining a "real" power and capacity curve in controllable technologies disposable by the system operator (coal, natural gas). These resources will insure the system and generate energy only during critical periods.
7. In 2040, to ensure energy security, the mining industry should output approximately 10-12 million Mg of hard coal. This volume of coal will constitute a strategic reserve. While designing the coal mining transformation path, it should be assumed that such mining capacity should be maintained. In the event of a decline in demand, excess coal can be exported and, in the event of its shortage, imported.

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