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NATIONAL ENERGY AND CLIMATE PLAN: HOW MUCH COAL FOR THE POLISH ENERGY SECTOR BY 2040?

The global economy enters the year 2025 with brand new challenges, related to political tensions and growing economic competition between the US, China and Europe. In February this year, the European Commission announced the *Clean Industrial Deal* program, which declares the continuation of the decarbonization process of the EU economy, but taking into account measures to maintain its global competitiveness at the same time. For the national economy of Poland, exposed to high electricity prices and significant carbon footprint, an effective new energy policy is expected to facilitate the competitiveness with products from global markets. The new National Energy and Climate Plan (NECP), announced in October 2024, presents such proposals for action and, as a result, attempts to define a decarbonized energy mix of Poland in 2040. The primary objective of the paper is a critical analysis of the assumptions adopted in the draft of the NECP. The discussion will focus in particular on the risk associated with meeting the schedule for the introduction of nuclear energy into the national system, and the complete replacement of coal-fired control capacities with new gas sources, in view of the risk of availability and price of the latter fuel. The materialization of the risk of failure to meet the investment schedule means the need for alternative energy supplies to the power system from other sources. The paper is an attempt to identify the possible alternative scenarios for ensuring the capacity and power generation gap.

Keywords: Energy; decarbonization; renewable sources; strategic reserve; energy security

1. Introduction

December 1, 2024 marked the commencement of the term of office of the new European Commission (EC), created as a result of the June elections to the European Parliament. The function of the President of the European Commission was once again entrusted to Ursula von

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der Leyen, which essentially means a continuation of the current European policies and agendas, including the *Green Deal* industrial plan [1]. On January 20, 2025, the office of President of the United States was taken by Donald Trump, who in his pre-election announcements often referred to his previous policy of rebuilding the American economy and continuing the use of fossil fuels. As a result, on the very day of his presidency inauguration, Trump signed a decree withdrawing the U.S. from the Paris Climate Agreement of 2015. The expansion of the Chinese electric automobile industry into the European market, and the consequent introduction of tariffs on them, has led to a deterioration of economic relations between the EU and China, and the suspension of investments in the car batteries manufacturing in some member states. At the beginning of 2025, the European economy was under strong pressure from intersecting American and Chinese interests. In September 2024, Mario Draghi published his *Report* [2] on the competitiveness of the European economy and the risk of its permanent loss. In the area of green transformation of the economy, the report postulates its continuation, but in such a way as to maintain competitiveness on global markets. On 26 February 2025, the European Commission presented a program called the *Clean Industrial Deal* [3], which, on the one hand, announces the continuation of the *Green Deal* policy, and on the other hand, proposes a number of measures to reduce energy prices and rebuild the competitiveness of companies producing for global markets.

Poland took over the presidency of the Council of the EU on January 1, 2025. The role of the presiding state in a given half-year period is to prepare an agenda of work on the most important problems of the Community, to agree on it and to moderate the dialogue in the field of legal framework. According to the Government's declaration [4]: *The aim of our presidency will be to ensure Europe's broadly understood security: primarily military, internal, economic, energy, information, food and health security.* The energy security mentioned in the middle of the list has not been "colored" with green, but it should be assumed that only the pace of transformation, juxtaposed with the paradigm of competitiveness, can be negotiated, but not its overall direction.

On October 10, 2024, the Minister of Climate and Environment presented the *National Energy and Climate Plan* (NECP) [5] for public consultations in Poland. This document is required under the Regulation of the EU Parliament and of the Council on the Governance of the Energy Union of 11 December 2018 [6]. On 30 December 2019, Poland submitted a preliminary national plan containing commitments to achieve European climate goals, but failed to submit the requested adjustments and additions before the end of 2023. Therefore, on March 1, 2024, the new Polish government, under threat of penalties, presented the EC with a version of the revised plan [7], while starting work on a more ambitious proposal. It should be mentioned that the 2019 version did not take into account the climate goals adopted as a result of the Council conclusions of December 2019 (climate neutrality in 2050), written out later in the draft of *FIT for 55* regulation [8]. The 2019 NECP was adopted by the government as a consequence of work on the energy policy of Poland (PEP 2040) [9], which was agreed only on 2 March 2021, but the forecasts, projections for the national energy mix and, consequently, declarations to EU institutions were in fact consistent.

From the perspective of its relevance, the NECP, which was subject to public consultations in October 2024, was prepared on the basis of the assumptions of the European climate neutrality policy and its intermediate goals in terms of emission reduction, the share of RES in gross final energy consumption and energy efficiency. However, from the formal point of view, it is in no way related to the current energy policy of 2021 (still in force). By 15 November 2024, more than 3 thousand comments were submitted to the consulted version of the national plan. It should be expected then that the Ministry of Climate and Environment will make adjustments to the originally presented draft national plan, and next subject it to the formal procedure of adoption by the government in the first half of 2025.

In the paper, the authors attempt to assess the feasibility of the assumptions of the consulted National Energy and Climate Plan, in particular in the context of the schedule for replacing fossil fuels with renewable sources and nuclear energy, as well as temporarily with natural gas. The aim of the analysis is an attempt at estimating the minimum demand for coal fuels in the transition period that can be obtained from domestic mines and to ensure the safe operation of the regulatory units of the national power system.

2. The national power system and coal mining in 2024

Preliminary data on electricity production and demand in 2024 in Poland are presented in TABLE 1. These data are determined on the basis of measurements collected by the Polish transmission system operator PSE [10] during the current operation of the national energy grid and do not take into account, in particular, the self-consumption of energy by prosumers. Therefore, in some cases, they may differ from the final data presented by energy companies for statistical purposes.

TABLE 1

Electricity production and demand from January to December 2024 (*source:* PSE data)

No.	Specification	December			Cumulatively from January to December		
		2023 [GWh]	2024 [GWh]	Dynamics [(b-a)/a*100] [%]	2023 [GWh]	2024 [GWh]	Dynamics [(e-d)/d*100] [%]
		[a]	[b]	[c]	[d]	[e]	[f]
1.	Total Production (1.1+1.2+1.3)	15 626	15 427	–1.27	163 629	166 990	2.05
1.1	System power plants	12 298	12 438	1.13	128 420	124 781	–2.83
1.1.1	hydroelectric power plants	358	191	–46.66	3 592	3 057	–14.89
1.1.2	thermal power plants	11 940	12 247	2.57	124 828	121 724	–2.49
1.1.2.1	hard-coal-fired	7 332	7 157	–2.38	76 607	69 112	–9.78
1.1.2.2	lignite-fired	3 063	3 297	7.64	34 571	35 844	3.68
1.1.2.3	gas-fired	1 545	1 792	16	13 650	16 768	22.84
1.2	RES power plants (other)	208	280	34.95	13 209	17 334	31.23
1.3	Wind power plants	3 120	2 709	–13.18	22 000	24 874	13.07
2.	Foreign exchange balance	–217	–556	156.36	3 889	1 966	–49.46
3.	Domestic electricity consumption	15 409	14 870	–3.49	167 518	168 956	0.86

Compared to 2023, electricity production increased by 2.05% whereas its consumption rose by 0.86%. In the structure of generating energy sources, a decrease in production from hard coal by 9.78% can be observed, in favor of an increase in lignite by 3.68% and gas by 22.84%. Production from wind sources grew dynamically by 13.07% and other renewable (solar) sources by as much as 31.23%. Despite such a large increase in renewable energy in the mix, its share reached 27.10% in 2024 (taking into account the self-consumption of prosumers and industrial auto-producers, the share of RES in the energy mix is expected to reach the level of about 30% in 2024). Last year, less than 2 TWh of energy was imported to the national power system, which means a decrease by half compared to the previous year.

The installed capacity in the national system exceeded 70 GW, of which wind sources accounted for approx. 10 GW and photovoltaic sources for 21 GW. The highest demand for power in the system occurred on 9 January 2024 and amounted to 28,660 MW. On the one hand, the dynamic increase in capacity in weather-dependent sources in the national system allows for an increasing share of renewable energy in the mix, but at the same time makes it necessary to disconnect some units during peak hours, when demand is lower than generation capacity. It is estimated that the amount of renewable energy not fed into the grid in 2024 could amount to approx. 0,7 TWh. The biggest challenge for the coming years will be to gradually increase the flexibility of the national power system so as to maintain the stability of the system's operation, limiting the generation of emission sources in favor of RES.

In 2024, the vast majority of domestic lignite and steam coal was used to produce electricity. Hard coal imports fell to 4.6 million Mg and were a consequence of previously concluded trade agreements. Generating 69 TWh of electricity from hard coal in 2024 means the consumption of about 28 million Mg of this fuel from the power plants' own storages, as well as current domestic and foreign supplies.

TABLE 2 presents preliminary data on domestic extraction, demand, stocks and imports of steam coal and lignite, according to ARP company data [11] and own estimates. Extraction and demand for lignite in 2024 increased slightly, by approx. 2.6% compared to 2023, reaching approx. 41 million Mg. The situation is different on the hard coal market. There was a decrease in both production (by 10.4% y/y) and sales (by 8.5% y/y). The reason was mainly a decrease in demand from domestic power plants and thermal plants, which reduced the production of electricity and heat in favor of an increase in the use of gas.

TABLE 2

Extraction and sale of steam coal and lignite in 2024 (based on ARP data)

	Steam coal		Y/y change	Lignite		Y/y change
[million Mg]	**2023**	**2024**		**2023**	**2024**	
Production	36.4	32.6	–10.4%	40.1	41.0	2.2%
Sales	34.2	31.3	–8.5%	40.1	41.0	
– incl. system power plants	24.2	22.0	–9.1%	N/A	N/A	N/A
– incl. thermal power plants	3.2	2.6	–18.8%	N/A	N/A	N/A
– incl. industrial power generation	1.1	0.9	–18.2%	N/A	N/A	N/A
– incl. others	4.9	4.8	–2.0%	N/A	N/A	N/A
Reserves	3.8	4.9	28.9%	0.6	0.6	0.0%
Import	14.7	4.6		0	0	0

The trend of decreasing use of hard coal for the production of electricity and heat is permanent. Fig. 1 presents a ten-year trend in this area, which only in the period 2020-2022 was flattened due to the disturbances caused by the Covid-19 pandemic and Russia's aggression in Ukraine. A decrease in hard coal production in 2024, compared to the previous year of approx. 5 million Mg, including system power plants generation and heating by approx. 2.8 million Mg, may signify even a deeper decline in the years to come.

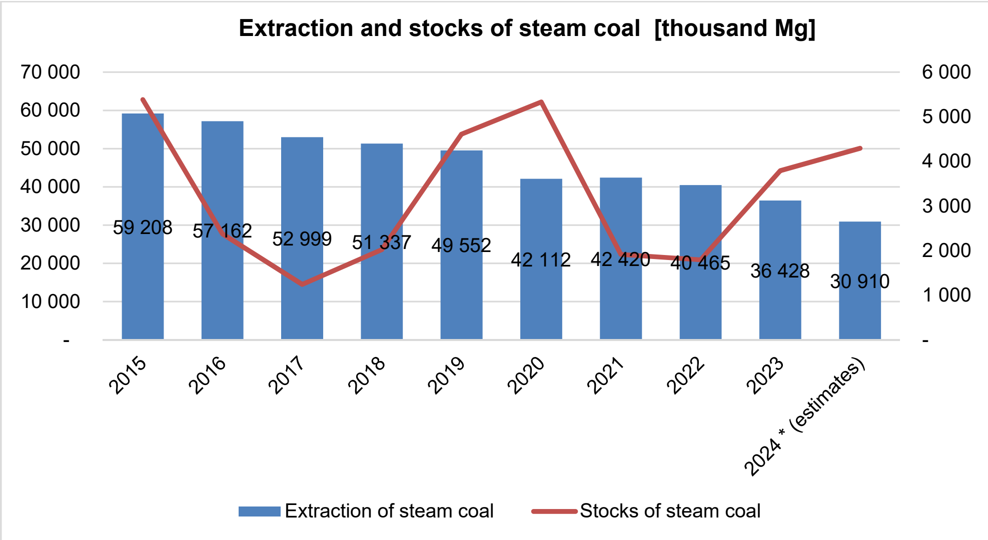

Fig. 1. Hard coal mining in the period 2015-2024.
Data according to ARP energy company and Central Mining Institute (GIG) estimates

Due to the high dynamics of electricity production from renewable sources in 2024 and the continuation of this trend at the beginning of 2025, a decrease in demand for carbon fuels should be expected in the coming years. This means that it is necessary to make adjustments to the mining plans presented in the application for notification of state aid for the mining industry, as well as to undertake more radical reforms of the coal mining sector itself.

3. National Energy and Climate Plan (NECP): The perspective of electricity and heat

The National Energy and Climate Plan [5] consists of a basic document and six annexes:

Annex 1. WAM (i.e. with additional measures) scenario – active transformation scenario;

Annex 2. WEM (i.e. with existing measures) scenario – a scenario of transformation in a path similar to "business as usual";

Annex 3. Analytical assumptions and forecasting methodology (for both scenarios mentioned above);

Annex 4. Description of energy efficiency and Primary Energy Factor (PEF) improvement measures in the electricity grid (describes the measures to achieve the required end-use energy savings referred to in Article 8(1) of Directive 2023/1791 and the value of PEF for Poland, pursuant to Article 31 of Directive 2023/1791);

Annex 5. Financing the climate and energy transition (including a description of investment needs);

Annex 6. Reference of the European Commission's recommendations to the draft NECP of 29 February 2024.

The baseline document and Annex 1, i.e. the scenario of an ambitious transformation, as well as Annex 3, describing the methodology and analytical assumptions, are of key importance for further analysis. Without going into the details of modeling and construction of the tools themselves, according to the authors, the results of the energy mix simulation were most influenced by the assumptions and the politically expected final result.

TABLES 4 and 5 present forecasts of electricity and district heating production. These figures are given as gross, i.e. including the power plant's own demand and grid losses. Attention should be paid to the expected value of electricity production, especially its increase in the period 2035-2040 by approx. 80 TWh. Compared to the forecasts contained in PSE's documents: *Development Plan for Meeting Current and Future Electricity Demand for 2025-2034* (PRSP) [12] and *Resource Adequacy Assessment at the National Level 2025-2040* [13], net electricity demand in 2040, in the dynamic transformation scenario, will amount to approx. 235 TWh, compared to 308 TWh in the NECP. In the baseline scenario, the demand is estimated at 215 TWh net. Attention should be paid to the difference between the net and gross values, adopted differently in PSE's planning and in the work on the NECP, which causes some difficulties in interpretation and comparison.

TABLE 4

Gross production of electricity and heat forecast in NECP.
Data based on NECP

	2005	2010	2015	2020	2025	2030	2035	2040
Electrical energy [GWh]	157 295	158 186	165 128	158 247	180 213	192 604	228 257	307 923
District heating [TJ]	336 292	335 831	274 357	285 870	280 425	251 724	229 116	221 327

The estimated structure of the expected energy mix is presented in TABLE 5. In 2030, it is assumed that 56.1% of electricity from renewable sources will be reached. At the same time, the share of hard coal and lignite will fall to 19%. For 2040, the assumed levels amount to 76% and 1.3%, respectively. In addition, a new category of electricity source has been created referred to as "Storage (Batteries)", which can mean excess energy that could be stored instead of being reduced and utilized in periods of higher demand. But it is also possible to interpret the category similarly to the one for energy from water pumped in pumped-storage power plants, in which case it is not additional energy, but produced in other sources and used through the storage.

For district and individual heating, the target for the share of renewable energy in 2030 has been set at 35.4%, assuming an increase of 0.8-1.1% year-on-year.

TABLE 6 present a forecast of the installed capacity mix in the national system, depending on the primary energy source. In 2030, coal-fired and gas-fired power plants, which mainly perform regulatory and reserve functions for renewable energy sources, are planned with capacities of 15.7 GW and 6 GW, respectively. In the period 2025-2030, the decommissioned hard coal units are to be replaced by gas-fired power plants (the total capacity of gas-fired power plants and combined heat and power plants is to reach 11 GW in 2030). In 2040, hard coal and lignite-based capacities will fall to 4.5 and 0.7 GW respectively (the latest units in Kozienice, Opole, Jaworzno and Turów), and the capacity of gas-fired units are expected to slightly increase to 6.7 GW. In 2035, production from the first block of the nuclear power plant (capacity of 1.2 GW) and the modular SMR power plant (capacity of 0.6 GW) is assumed. In 2040, nuclear power with a total capacity of 7.4 GW is an important component of the system's power and energy mix.

TABLE 5

Gross electricity production forecast in NECP classified by primary energy sources.
Data based on NECP

	2005	2010	2015	2020	2025	2030	2035	2040
Lignite	54.8	48.7	52.8	38.1	31.2	11.4	3.0	0.0
Hard coal*	88.5	89.3	79.4	70.7	64.6	31.9	16.5	4.1
Gaseous fuels**	5.2	5.1	6.4	17.4	23.4	30.8	26.9	9.9
Heating oil	2.7	2.6	2.1	1.7	1.8	1.4	1.2	0.9
Nuclear energy	0.0	0.0	0.0	0.0	0.0	0.0	9.5	58.1
Biomass	1.4	5.9	9.0	6.9	6.8	7.9	7.4	7.5
Biogas/biomethane	0.1	0.4	0.9	1.2	2.2	3.2	3.5	4.8
Water power	2.2	2.9	1.8	2.1	2.6	2.9	3.0	3.0
From pumped water	1.6	0.6	0.6	0.8	1.2	3.9	3.9	6.6
Onshore wind energy	0.1	1.7	10.9	15.8	28.6	47.4	59.2	69.5
Offshore wind energy	0.0	0.0	0.0	0.0	0.0	21.7	45.5	67.4
Solar energy	0.0	0.0	0.1	2.0	15.3	24.6	33.9	43.1
Geothermal energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	6.9	17.8
Other***	0.7	1.1	1.0	1.5	2.5	2.4	2.2	1.8
Storages (batteries)	0.0	0.0	0.0	0.0	0.0	3.1	5.7	13.5
Total	**157.3**	**158.2**	**165.1**	**158.2**	**180.2**	**192.6**	**228.3**	**307.9**

* Including coke oven and blast furnace gas,
** High-methane and nitrogen-rich natural gas, gas from mine methane drainage, oil associated gas,
*** Inorganic industrial and municipal waste.
Source: Own elaboration of ARE S.A. (MESSAGE-PL) commissioned by the Ministry of Climate and Environment, EUROSTAT

The reduction of the level of controllable coal and gas capacities in the national system means that the control functions have been shifted to energy storage facilities (pumped-storage power plants and chemical storage) and, to some extent, to nuclear units.

TABLE 6

The capacity in national power system estimated in NECP, classified by primary energy sources.
Data based on NECP

	2005	2010	2015	2020	2025	2030	2035	2040
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Lignite-fired power plants	8 197	8 145	8 643	7 445	6 566	6 566	3 344	683
Coal-fired power plants	14 613	14 655	13 617	15 889	14 465	9 136	5 847	4 572
Gas/hydrogen-fired power plants	0	0	0	0	1 332	5 957	5 957	6 703
System nuclear power plants	0	0	0	0	0	0	1 170	6 225
SMR nuclear power plants	0	0	0	0	0	0	600	1 200
Hydropower plants	914	935	964	987	1 008	1 118	1 148	1 178
Pumped storage power plants	1 679	1 679	1 705	1 705	1 767	2 510	2 510	4 235
Autoproducer CHP plants	6 140	6 126	1 605	1 945	1 814	1 755	1 608	1 110
Coal-fired CHP plants			4 968	5 226	4 578	3 757	2 403	19

TABLE 6. Continued

1	2	3	4	5	6	7	8	9
Gas/hydrogen CHP plants	760	807	928	2 688	3 515	5 071	4 581	4 760
Biomass power plants and CHP plants	102	140	513	534	669	983	1 116	1 145
Biogas/bio-methane CHP plants			216	241	362	509	526	519
Bio-energy with carbon capture and storage (BECCS)	0	0	0	0	0	0	0	0
On-shore wind power plants	121	1 108	4 886	6 499	11 996	19 028	23 042	25 816
Off-shore wind power plants	0	0	0	0	0	5 927	12 233	17 883
Geothermal power plants	0	0	0	0	0	0	0	0
Photovoltaic installations	0	0	108	1 229	19 726	28 976	37 901	46 293
Hydrogen/gas turbine power plants	0	0	0	0	0	0	0	805
Energy storage	0	0	0	0	50	1 975	3 690	8 706
DSR/Power import	0	0	150	615	1 788	2 864	3 524	3 874
Total	**32 526**	**33 594**	**33 118**	**39 535**	**69 634**	**96 131**	**111 201**	**135 724**

A comparison of the assumptions of the current energy policy, PSE's planning documents, and planning data of the NECP project, in terms of electricity demand, forecasts of source capacity and mix structure shows huge differences that definitely require explanation and commentary. In fact, PEP 2040 forecasts electricity demand at the level of 204 TWh in 2040, whilst in PSE's scenarios there are two forecasts, 210 or 235 TWh (depending on the dynamics of electrification of the economy). The NECP project assumes gross production of 308 TWh.

4. Critical analysis of the assumptions of the National Energy and Climate Plan (NECP)

The feasibility of achieving the climate goals declared in the NECP project in 2030 requires a critical look at the following assumptions of the plan:

1. The current energy policy assumes electricity production in 2040 in the amount of 204 TWh, with the installed capacity in the national grid of 60 GW. The draft NECP assumes 307.9 TWh and 135.7 GW of capacity, respectively. What is the reason for such a tremendous difference in forecasts?
2. Is it possible to launch the first nuclear units before 2035?
3. Construction of 25 GW of new weather-dependent RES capacity by 2030. Is it possible to implement?
4. Shutdown of 6 GW of controllable coal capacity by 2030. What instead?
5. If 30-35 TWh of electricity from gas is assumed (in the period 2030-2040), do we need more gas-fired units? What about peak power: from coal or gas?
6. Will 2 million Mg of coal (4 TWh of electricity) in 2040 ensure energy security and sovereignty?
7. What is the alternative scenario if the deadlines for investments in offshore wind farms and nuclear energy are postponed by 5 years?

A critical analysis of the above assumptions, at the expert level, indicates a high risk related to achieving the assumed progress in the electrification of heating, transport and industrial processes, as well as the feasibility of meeting the schedules for the implementation of investments in new capacities, especially nuclear ones. Below there are arguments supporting these concerns:

1. In 2024, the national grid operator PSE initially measured electricity demand at 169 TWh, and domestic production at 167 TWh (TABLE 1). The latter volume should be made more realistic by adding the production of prosumers, which is directly consumed, in the amount of about 3-4 TWh. The data in TABLE 5 assume gross production in 2025 at the level of 180.2 TWh. In fact, there is a certain difficulty in estimating the own needs of sources in the changing mix in subsequent years (for new coal-fired power plants, own needs account for about 10% of gross production). Grid and other losses also depend on the structure of the network and the distance over which electricity is transmitted. If we assume that the demand/production in 2025 will remain at the level of the previous year, or increase slightly, then the difference between the gross and net value could be estimated at the level of 12-14 TWh. The WAM version of the NECP assumes an increase in production/demand in the decade 2025-2035 by 35.7 TWh, while in the decade 2015-2025 it was 15 TWh, i.e. twice less. In the five-year period 2035-2040, this growth doubles again, reaching as much as 79.6 TWh (gross electricity production 307.9 TWh in 2040). In the development plan elaborated in 2024 by PSE grid operator, electricity demand in 2040 ranging 210-235 TWh is assumed (depending on whether the decarbonization/electrification of the economy is more or less dynamic). The expert assessment indicates too high demand for electricity adopted in the NECP. Such an excessive assumption in the NECP must be followed by expenditures on new sources of generation, which will not be needed in the case of lower demand. According to the authors, electricity demand in 2040 should be estimated at the level of the dynamic scenario of PSE, i.e. 235 TWh.
2. At the beginning of 2025, the advancement of the first nuclear project, assuming the construction of three AP 1000 nuclear units by Westinghouse, fails to indicate both the technical and organizational feasibility of meeting the deadline for the commissioning of the first nuclear unit planned in the current energy policy, i.e. 2033. According to the upcoming update of the Polish Nuclear Power Program (PPEJ) [14], it is assumed that the first unit will start commercial operation in 2036, and the following ones in 2037 and 2038, respectively. The construction site is to be handed over to the contractor in 2025 (!), and the actual work on the nuclear power plant is to commence in 2028. It is worthwhile to point out here that currently in relation to the project of the first nuclear power plant in Choczewo-Lubiatowo, intensive work is underway on the financing model, and in particular on the scope of public aid. Polish authorities submitted proposals to the European Commission for the capital participation of Poland in the project at the level of 30%, i.e. PLN 60 billion according to the current budget estimate, the State guarantee for other expenditures obtained from the capital market, and the formula of a contract for difference for electricity purchase. The EC is currently examining the legitimacy and proportionality of the scope of the requested state aid. Earlier domestic experience in the construction of large power units in coal technologies in the previous decade indicates an approx. 10-year construction cycle, starting with the decision to launch the tender

procedure. Even more important here are the experiences from the construction of the recent nuclear power plants in Olkiluoto in Finland, Flamanville in France, or Hinkley Point C in the UK. In the latter case, the two units with a total capacity of 3,200 MW, built by the French EdF, according to the contractor's announcements [15] from early 2025, may be delayed by about 5 years in relation to the original schedule, and the budget may exceed GBP 40 billion (the first unit was originally assumed to be commissioned in 2025, and the budget in total was GBP 18 billion). Taking into account the above, expert estimates of the date of commissioning the first unit of a nuclear power plant in Poland assume that it is possible around 2040.

3. Between 2025 and 2030, an increase in renewable capacity of 25 GW is assumed. The largest increase, by 9.3 GW, is to take place in photovoltaic power plants, followed by onshore wind farms – 7 GW, and offshore plants in the Baltic Sea – 5.9 GW. The remaining capacities are to be covered by energy storage, assuming that they effectively store surplus renewable energy that would otherwise be lost. Investments in photovoltaic power plants are not complicated, but from the point of view of ensuring that the electricity they produce is fed into the grid, the issue seems to be far more serious. Currently, these are not commercially preferred solutions, unless considered together with large-scale storage facilities. The cheapest electricity can be produced in onshore wind farms. Unfortunately, the development of investments in this segment has stagnated and there is no indication that a sensible compromise will soon be reached on the so-called ”distance act” [16], enabling new locations for these power plants. A retrofit of older wind turbines with lower towers and powers, and thus lower efficiency and number of operating hours, should also be expected soon. Therefore, there appears a serious risk of the feasibility of increasing the capacity of this technology by 1.5 GW annually. Offshore wind farms are slowly entering the implementation period. The largest Polish projects of Orlen, PGE and Polenergia are implemented in collaboration with foreign partners. In January 2025, PGE announced the commencement of a joint investment with Denmark's Oerstede in the Baltica 2 wind farm with a capacity of PLN 1.5 GW and a budget of PLN 30 billion. Noteworthy, this project is covered by a contract for difference, with a price guarantee, and it should be expected that this price will exceed PLN 500 per MWh. While regulatory risk seems most significant in the case of investments in onshore wind farms, in the case of offshore wind farms, there will be primarily technological risk involved. Only the first works on the foundations and installation of turbines will allow to assess the actual risk of meeting the schedule for the installation of turbine towers and power evacuation. From the experts' point of view, it should be assumed that the implementation of any new technology is associated with both technological and budget risk, as well as the occurrence of the so-called ”teething troubles”. According to the authors, there is a high risk of postponing the date of commissioning offshore wind farms on the assumed date.
4. The draft of the NECP assumes a rapid reduction of coal capacity in the national mix. It was assumed that as a result of the discontinuation of capacity market support for power plants emitting more than 550 kg of carbon dioxide per MWh, most of these units will be shut down from mid-2025. Currently, work is underway to extend the support until 2028, but the formula of annual auctions proposed in the amendment to the act means that units that fail to obtain support for 2026, apparently will not be willing to wait for the auction for 2027, bringing losses to the operator in the meantime. The analyses car-

ried out in PSE's Development Plan indicate that if the 6 GW of controllable coal-fired capacity planned in the NECP is shut down by 2030, despite the commissioning of new gas-fired units, the balance of supply and growing demand for controllable power in the system clearly seems unfavorable. The risk of interruptions in the supply of electricity to final consumers beyond the ERAA standards grows significantly. In the expert assessment for the period 2025-2030, it seems absolutely necessary for the operator of the national power system (PSE) to prepare an analysis of the demand for controllable power in the grid, in specific locations, capacity levels and availability dates. If excess capacities are identified as a result of such an analysis, they should be permanently discontinued. For units necessary from the point of view of the system operator, financing should be provided in the strategic/balance reserve formula, above the existing capacity market and regardless of the planned capacity market after 2030. According to the authors, by 2030 it is necessary to maintain most of the existing reserves in 200MW-class power units as sources of controllable power.

5. The NECP assumes that in 2030 natural gas fired power plants and combined heat and power plants (CHP), and after 2035 with an admixture of renewable gaseous fuels, will generate 30.8 TWh of electricity. The maximum production from gas by 2035 will not exceed 35 TWh. The key issue here is, however, the mode of operation of the planned gas-fired power plants and their role in the national grid of Poland. If we assume that in 2030 there will be 6 GW of gas-fired capacity in the system, they will be more than able to supply the grid with even more than the expected 35 TWh of electricity. However, if it is assumed that the gas-fired units will function as the control power units, then an analysis should be made of the appropriate proportion of coal-fired (existing) and new gas-fired (to be built) capacities to ensure the lowest cost of balancing the system for consumers. According to the authors, in order to mitigate the risk of availability and prices of natural gas, it is necessary to maintain coal and gas capacities in optimal proportion. In addition, gas-fired units operating only in an open cycle can be considered as peak power supply. Investments in new units with combined cycle gas turbines (CCGT) will not ensure the profitability of these units and hence seem unjustified.
6. The NECP assumes practically a departure from coal in the energy sector in 2040. The assumed production of 4.1 TWh of electricity means a demand for 2 million Mg of hard coal, which will inevitably result in an accelerated liquidation of domestic production. Although the WEM version of the plan assumes a scenario with demand for hard coal in 2040 at the level of 10 million Mg, which corresponds to the social agreement signed by the Polish government with the representatives of the mining industry, achieving the declared climate goals is practically possible only if the ambitious scenario is implemented. Reducing the emissions of electricity production is largely expected by the domestic industry. According to the authors, all activities aimed at increasing RES in the energy mix should be treated as a priority, but with the principles of operational stability and security of the national system. Expert research conducted at the Central Mining Institute (GIG) indicates that the demand for thermal coal in 2040 will be at the level of 10-12 million Mg (Fig. 2). The presented chart contains forecasts resulting from the current energy policy (19.1 million Mg of steam coal in 2040) and the draft NECP (2 million Mg). In the scenario assuming high prices of emission allowances and scenario 3, of June 2023, which was not adopted, the demand oscillates between 10-11 million

Mg in 2040. The main reason for the differences in demand lies in the risk of delays in investments in nuclear energy and offshore wind farms. If the realistic date of commissioning of the first nuclear unit should be estimated at around 2040, then the question of filling the raw material shortage and power generation gap between 2035 and 2045 will remain open and unsolved.

7. Experts [17-20] estimate that there is a high risk of postponing the schedule for the implementation of the nuclear energy program by about 5 years. Therefore, if instead of the 58.1 TWh of electricity production in nuclear power plants assumed in the NECP in 2040, the amount is only 9.5 TWh (as assumed in 2035), then it should be decided from which source the missing power can be effectively supplied. The situation is similar in the offshore wind energy segment. The materialization of the risk of delaying the implementation of the multi-directional investment program in this segment may result in the failure to supply the national grid in 2040 with approx. 21.9 TWh (the difference between the assumed production of 67.4 TWh in 2040 and 45.5 TWh in 2035). In total, the volume will increase, along with the last decommissioned coal-fired power plants, to approx. 70 TWh by 2040. It is therefore necessary to analyze what sources of primary energy will be available in the period 2035-2040, and what investments should be made to provide alternative sources of power to the national system. From the point of view of the availability of domestic raw materials, the availability of domestic hard coal and remaining lignite resources in the region of Turów should be assumed with great certainty. Poland has relatively small deposits of natural gas and the volume of production available in the country will not increase significantly (production amounted to 3.4 billion m^3 in 2023). The grid infrastructure and the availability of gaseous fuel from Norwegian fields, as well as the liquefied gas import capacity, fully meet the needs of the domestic economy, including the energy sector. If we ignore the risk of conflicts in the region and the related certainty of supply, and the resulting risk of high price volatility, gas could be considered a fuel for the transition period, and therefore also for the alternative scenario. Both gas and coal, from the point of view of climate policy, are considered transitional fuels, and due to their emissions, they are recommended for rapid phase-out. It is also worth mentioning the marginal costs of electricity generated with their use, which are heavily burdened with a fee for carbon dioxide emissions. Poland does not have water energy resources. Also a significant availability of biomass and biogas, due to their intended use for other branches of the economy, cannot be considered as a significant potential for an increase in the amount of electricity for the alternative scenario. Significant capacity surplus occurs however in the onshore wind energy and solar energy sectors. In the case of the former, the NECP assumed the installed capacity of 25 GW in 2040, with a production of 69.5 TWh, whereas in the case of photovoltaic: 46.3 GW of capacity and 43.1 TWh of production, respectively. A large excess of installed capacity over the needs of the national system means that these sources, especially PV, are switched off by the system operator during the hours of the highest insolation or high winds. The amount of electricity not fed into the grid, in both of these technologies, can be estimated at approx. 10 TWh in 2040. Assuming the import and export neutrality of the domestic system and the future availability of existing coal-fired power plants, including those with built-in CCS installations [21], and the availability of additional imported gas, the provision of electricity in the period 2035-2040 in alternative variants should be considered.

Assumptions of the alternative scenario:

1. The average annual gap in electricity generation in 2035-2040 is estimated at 60 TWh (maximum 70 TWh in 2040).
2. The available capacity of coal-fired power plants in 2040 (Kozienice, Opole, Jaworzno and Turów) – 4.5 GW. In addition, some 200MW-class units, in particular the Połaniec Power Plant, approx. -1 GW. Since the construction of new coal-fired units is not planned, there is a capacity to generate approx. 35 TWh of electricity per year.
3. Expenditure on carbon dioxide capture installations is estimated at EUR 1.2 billion/1 GW.
4. Energy storage facilities for storing excess RES energy that cannot be fed into the national grid – approx. 2.5 GW, in four-hour chemical storage, or in the case of building pumped-storage capacity, in three locations: Młoty, Tolkmicko, Rożnów, also approx. 2.5 GW.
5. Expenditure on chemical energy storage is estimated at approx. EUR 1 billion/1 GW, in four-hour storage,
6. Capital investments in new large-scale CCGT gas units are estimated at approx. EUR 1.1 billion/1 GW
7. The price of emission allowances will increase in the years 2035-2040 from EUR 120 to EUR 250 (in accordance with the assumptions of the NECP), on average EUR 185 per allowance per year.

Three variants of filling the gap of power generation in the period 2035-2040 were analyzed:

1. Gas scenario with surplus RES energy storage,
2. Coal scenario with surplus RES energy storage,
3. Coal scenario with CCS and surplus RES energy storage.

In the gas scenario, it is necessary to build an additional 7 GW of gas capacity, which will generate about 50 TWh of electricity per year and, together with energy storage facilities (10 TWh), will fill the gap for the alternative scenario. In the coal scenario, the capacity of the available coal-fired power plants will amount to approx. 5.5 GW, which should provide the possibility of generating approx. 35 TWh of electricity. Together with the stored energy, this solution offers a potential of about 45 TWh per year. In the case of a scenario with the existing new coal-fired power plants (without 200 MW-class units) being equipped with carbon capture and storage (CCS) installations, the capacity to cover the shortage of generation potential will be reduced to approx. 25 TWh, due to the decrease in efficiency related to the needs of the capture installations.

Comparing alternative scenarios, the following conclusions can be drawn:

1. In the event of a generation gap in the period 2035-2040 amounting to about 60 TWh on average per year, only the gas scenario with the storage of surplus energy from RES provides the possibility of fully covering it,
2. Coal scenarios, assuming only the necessary upgrades, including the development of CCS installations for new units, will not provide sufficient generation to cover the gap,
3. With the assumed price expansion path for emission allowances, investments in CCS installations are profitable and can ensure the lowest emission of the energy produced. The critical path is to prepare the national infrastructure for the transport and storage of carbon dioxide,
4. The smallest expenditures on investments and upgrades are required in the coal scenario without CCS, but leave the highest carbon footprint,

5. If the coal scenario is chosen, with or without CCS, it will be necessary to fill the generation gap with gaseous fuel, including the construction of new gas-fired power plants,
6. Filling the generation gap with energy from chemical energy storage, in the long-term storage formula, may turn out to be unprofitable and significantly increase the cost of energy,
7. Maintaining energy security and independence indicates the necessity, at least in part, to implement one of the coal scenarios, in combination with the gas scenario.

4. Conclusions: How much coal for the power industry?

Taking into account the beginning of the new term of office of the European Commission, as well as the Polish presidency in the European Union, whose task will embrace, among others, preparation of legislative initiatives for the recovery of the European economy, and in particular its competitiveness, it seems absolutely necessary to pay attention to the following conditions of the presented National Energy and Climate Plan:

- **First, the new Energy Policy, then the National Energy and Climate Plan (NECP).** Elaboration on a new NECP (WAM) is currently under way, in a more ambitious version than the one formally submitted to the EC in 2019, with a subsequent revision of February 2024 (WEM). The launch of these activities was necessary due to delays in delivering this document to Brussels in the required timeframe. Nevertheless, Poland's external obligations towards European institutions should be primarily based on national policies, taking into account the holistic impact of the declarations made on the entire economy and the well-being of citizens. The current document of the Polish Energy Policy until 2040 was adopted in February 2021 and was based on assumptions that do not take into account the European *Green Deal*, as well as the actions resulting from Russia's invasion of Ukraine (*RepowerEU*). There is a need for closer coordination of strategic documents in the area of industry and energy, among others, the adoption of appropriate gradation and chronology of strategic documents. Economic policy should come first, followed by energy policy subordinated to it, for which the priority will be to ensure a continuous supply of electricity with a low carbon footprint and a competitive price. National energy policy, due to the cost of energy in household budgets and potential energy poverty, is of particular importance for the overall standard of living. **According to the authors, the new national plan, as Poland's obligations towards EU institutions, should be presented only after the adoption of the energy policy**.
- **The ambitious transformation of the national energy and heating sector towards renewable and low-emission sources is beyond any discussions as to its direction. Its pace is important.** In mid-2024, the capacity of weather-dependent renewable sources installed in the national power system (KSE) exceeded 28 GW (18 GW in photovoltaic sources and 10 GW in onshore wind farms), which means that at certain hours of the day they provide capacity exceeding domestic demand and possibilities of exporting surplus energy. This allowed Poland to cover almost 30% of electricity production during this period. The preliminary assumptions of the NECP for 2030 (WAM scenario) are almost 57GW (59% of installed capacity) and 56% of electricity production from renewable sources. The key to the pace of development of renewable energy is the ability to introduce

the electricity it can produce into the national power system (KSE). Already in 2024, it should be expected that about 0.7 TWh of electricity that can be produced will not be fed into the grid due to exceeding domestic demand and export possibilities. This problem can be solved in the short-term (daily) sequence, currently only through chemical energy storage. Unfortunately, current plans to develop new energy storage facilities may only allow for less than 10% of the storage capacity (several dozen GWh) of electricity that can be produced by weather-dependent renewable sources. Increasing the amount of renewable energy from weather-dependent sources introduced into the national system is partly possible by improving the flexibility of the KSE grid by making demand more flexible, increasing storage capacity, including heat storage, electrification of certain sectors of the economy (sector coupling), as well as increasing the regulatory capacity of existing conventional units. **It is necessary to synchronize the pace of increasing the flexibility of the KSE national grid (including long-term storage) with the implementation of planned investments in renewable sources, so that it is possible to make maximum advantage of the production of newly built sources.**

- **Existing coal-fired units are the cheapest reserve of the KSE national grid during the transformation period.** Throughout the entire technological transformation of the energy sector, it is always necessary to ensure **every momentary balance between the demand for energy and the energy supplied to the power grid**. The possibilities of increasing demand are limited. By 2030, the controllable reserve of the KSE system will embrace conventional sources, mainly coal, and after that time also newly built gas-fired power plants (a total of about 11 GW in 2030). A significant change in this area will take place only after the first nuclear capacities are launched (it should be assumed that this is feasible around 2040). The condition for the stable operation of the national grid for the next 10-15 years is to maintain a sufficient amount of controllable capacity running on fossil fuels. For this group of units, whose revenues do not cover the costs (too short operating time), it is necessary to develop financial mechanisms that guarantee the coverage of fixed costs (balance/strategic reserve). For new low-emission controllable sources (gas and other technologies), it is necessary to continue the capacity market mechanisms. Otherwise, after 2025, there is a real threat of shutting down about half of the controllable capacity necessary at the level of the system operator (PSE). With regard to new controllable sources, particular attention should be paid to assessing the amount of gas actually necessary to produce electricity after 2030. The risk of the availability of this imported raw material, as well as its prices, remain valid in the context of the experience of 2022. **It is necessary to maintain the controllable reserve of the national power grid, mainly based on the existing coal-fired power plants and gas sources built so far (the cost and emissions of the fuel are not of significant importance in peak operation).**
- **Synchronization of the program to reduce coal production with the needs of the power generation industry for the transition period is needed.** Until the planned nuclear power potential is built, it is necessary to plan the demand for capacity and energy resources (2025-45). The indication of the controllable conventional capacities necessary in time and location by the national system operator (PSE) will enable the construction of non-oversized financial mechanisms for their maintenance (cold reserve or other type of off-market balance/strategic reserve) and will accelerate the decision to decommission

redundant units. This will also allow for the preparation of a plan for the commissioning of individual coal-fired units, taking into account technological, economic and other conditions to optimize the costs of maintaining the necessary capacity. The capacity in the national grid planned in this way should be also matched with the clear specification of the expected volume of production and necessary energy resources, including coal from domestic mines (according to the cost and quality ranking). **The energy security and sovereignty of the State requires the protection of minimum domestic raw material and generation resources in the event of external threats. According to the authors, it is necessary to reconsider the demand for coal for energy purposes in 2040 (about 2 million tons were assumed in the NECP).**

- **Distributed generation and local use of electricity.** The reversal of the future direction of energy transmission in Poland (from north to south) causes a huge increase in capital expenditures on the reconstruction/expansion of transmission networks. The same applies to increasing the flexibility of the distribution system. The most efficient solution is to generate and use energy locally. In the energy policy of the NECP and support mechanisms, this area should be given special attention. **Previous initiatives to build clusters and local energy communities have proven ineffective. It is necessary to develop effective mechanisms in this area to reward local energy generation and consumption.**
- **Alternative scenario in the event of delay in the implementation of investment programs**. The risk of postponing the schedule for the implementation of the first nuclear power plant should be estimated as high. To ensure the continuity of operation of the national power system, it will be necessary to supply energy from alternative sources. The analysis of fuel availability and generation capacity in the period 2035-2040 indicates the availability of the latest coal-fired sources, the need to increase the capacity of gas-fired power plants and the use of stored, surplus energy from renewable sources. Filling the generation gap, estimated at 60 TWh on average per year, requires the use of both existing

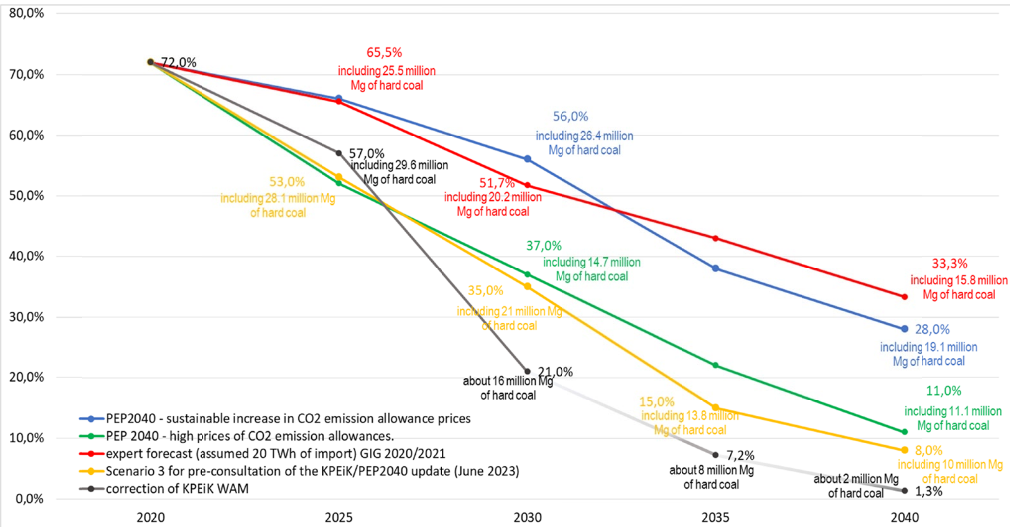

Fig. 2. Demand for coal in the national mix. Central Mining Institute (GIG) research, own study

coal-fired capacities (including CCS) and the construction of gas-fired units. **According to the authors, in this case, the demand for hard coal to fill the power generation gap should be estimated at about 20 million Mg in 2040.**

It seems necessary to re-evaluate some of the assumptions of the proposed NECP in connection with the above-mentioned risks. External commitments to the EU institutions should be undertaken only after a particularly careful and in-depth assessment of the impact on the national economy and social issues. According to the authors, the adoption of the NECP should be preceded by an update of the energy policy of Poland and making its assumptions consistent with the national industrial policy.

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