GOSPODARKA SUROWCAMI MINERALNYMI – MINERAL RESOURCES MANAGEMENT

2025 Volume 41 Issue 2 Pages 55–71

DOI: 10.24425/gsm.2025.154550

PRZEMYSŁAW KASZYŃSKI[1]

The impact of the capacity remuneration mechanism on the decarbonisation of the energy sector in Poland in the context of the future demand for natural gas for electricity production

Introduction

Natural gas plays a key role in the energy transition of economies historically dependent on fossil fuels, in particular hard coal and lignite (Popescu et al. 2020). Poland is an example of such a country, where gradual decarbonization is focused on replacing coal-based power plants and combined heat and power plants with natural gas-based power generation units. This trend is observed not only in energy policy and strategic documents but also in the investment and refurbishment processes of numerous energy companies (Fuksa 2021).

In 2023, the capacity installed in natural gas-based thermal power plants was 4,732 MW (7.8% of the total capacity installed in the Polish power system). In comparison, the capacity

✉ Corresponding Author: Przemysław Kaszyński; e-mail: kaszynski@min-pan.krakow.pl
[1] Mineral and Energy Economy Research Institute, Polish Academy of Sciences, Kraków, Poland; ORCID iD; 0000-0002-0600-4374; Scopus ID: 55875297600; Researcher ID: F-7582-2019; e-mail: kaszynski@min-pan.krakow.pl

installed in 2010 was 934 MW (80.2% less compared to 2023 and 2.6% of the total capacity installed in Poland). Considering electricity generation, natural gas-based power plants produced 13,650 GWh in 2023 (8.3% of the total electricity production in Poland). In 2010, 390 GWh was produced in natural gas-based units (97.0% less compared to 2023, and 2.09% of the total electricity production in Poland (PSE 2011; PSE 2024). The total consumption of natural gas by public power plants and combined heat and power plants (CHPs) in 2023 amounted to approximately 2.45 billion m^3, of which over 1.5 billion m^3 was used only for electricity production (ARE 2024).

New investments in natural gas-fired power generation units may be subsidized by incentives and support mechanisms in Poland, including the capacity market (Dz.U. 2018 poz. 9) and individual cogeneration premium (only for CHPs; Dz.U. 2019 poz. 42). The capacity market is a remuneration mechanism designed to provide financial support for ensuring capacity availability to the system on the call of the Transmission System Operator (TSO). This market includes TSO and capacity market units as key participants. It is a single-buyer model in which TSO purchases the capacity obligations. The auctions are descending clock auctions in which the prices are set in the Pay-As-Clear system (Komorowska et al. 2022). The mechanism of the individual cogeneration premium provides support to new high-efficiency cogeneration units with a capacity installed of at least 50 MWe. The comparison and detailed analysis of those two mechanisms are presented by Zamasz et al. (2020). Although the analysis did not present an unequivocal answer to the absolute advantage of any of the solutions, the study presented significant problems and challenges related to their practical implications.

The present study focuses on the impact of the results of the capacity auctions on natural gas demand in Poland from a long-range perspective. The results will provide valuable information that should be included in planning processes in periods of dynamic fluctuations in the international fuel markets. The capacity market has been in Poland since 2018. To date, nine capacity auctions have been conducted. In 2018, three capacity auctions were held (for 2021, 2022, and 2023 delivery years). In each next year, one capacity auction was conducted (in 2019 for the 2024 delivery year, in 2020 for the 2025 delivery year, in 2021 for the 2026 delivery year, in 2022 for the 2027 delivery year, in 2023 for the 2028 delivery year and in 2024 for the 2029). In December 2025, the last (according to the existing scheme/framework) capacity auction for the 2030 delivery years is expected.

1. Literature review and study contribution

The mechanism of the capacity market introduced in Poland is thoroughly described in the literature. Komorowska et al. (2020) presented the key assumptions of the market and analyzed the potential economic consequences before its implementation. Kaszyński et al. (2021) examined the results of the capacity auctions for 2021–2025 delivery years to address the issues of the new investments within this mechanism. The study showed that the profits of the capacity markets are gathered mainly by existing coal-based power generation units.

Tucki et al. (2019) conducted a survey to examine the consequences of capacity market implementation in Poland, pointing out the potential to increase the energy security of the power system. Komorowska (2020) analysed the capacity market and decarbonization process, concluding that the mechanism delays the decarbonisation of the power system and has a negative impact on carbon neutrality. The results showed that Even if obsolete coal-fired power plants are phased out, they are mainly replaced by natural gas-fired ones.

Although the capacity market has been analyzed in numerous studies, there is a gap in the literature about the impact of capacity auction results on natural gas consumption in the coming years. Then, the objective of the study is to investigate the capacity auction results with regard to the existing, refurbished, and new natural gas-based capacity market units. Then, considering the profile of electricity generation and trends in the Polish power system, the consumption of natural gas will be examined. The results of this study contribute to the existing literature in the following ways. First, they provide a comprehensive analysis of the results of the main capacity auctions for the delivery years 2021–2029, in particular in the context of the long-term contracts concluded by the new/planned gas-fired power generation units. Secondly, they quantify the demand for natural gas consumption resulting from long-term capacity contracts signed by these units. Thirdly, they broaden the discourse on the future supply of primary energy and Poland's energy and mineral security.

The article is structured as follows. Section 2 outlines the key assumptions and describes the research methodology employed. Section 3 discusses the results of the analysis of the main capacity auctions conducted to date (for delivery years 2021–2029) and the estimated future demand for natural gas for power generation in new/planned gas-fired units that have secured long-term capacity contracts. Section 4 provides a summary and conclusions of the conducted research.

2. Materials and methods

In the conducted research, a multi-stage research procedure was employed, encompassing both qualitative methods related to data collection, followed by their processing, correction, and preparation for subsequent stages, as well as quantitative methods, including the analysis of pre-processed data and the performance of estimative calculations of the natural gas demand volume for new/planned generating units, in accordance with the formulas presented later in the chapter (Figure 1).

The qualitative and quantitative analyses were based on data concerning the final results of the main capacity auctions conducted between 2018 and 2024 for the delivery years 2021–2029 (inclusive), as well as on techno-economic data characterizing the operation of existing generating units, publicly available information (annual reports of energy companies, press releases, industry analyses, etc.) regarding planned investments in new generating units (primarily gas-fired generating units, as well as renewable energy units and battery energy storage systems), and information/data held by the Mineral and Energy Economy Institute

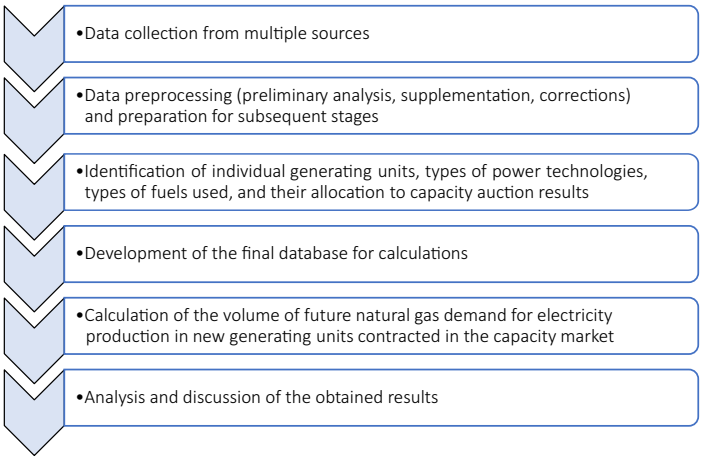

Fig. 1. The general framework of the applied research procedure

Rys. 1. Ogólna struktura stosowanej procedury badawczej

of the Polish Academy of Sciences. The use of multiple data and information sources was necessary due to the limited scope of capacity auction results, which included the volume of capacity obligation (which is not equivalent to installed capacity of a power unit), the duration of the contract, the name of the capacity provider (although the capacity provider may not be the owner of the unit and may act as a provider for more than one capacity market unit), and the type of capacity market unit (existing, refurbishing, new/planned, demand side response, or cross-border). In the results of the last two capacity auctions, information on the name of the generating unit was also included; however, due to the lack of restrictions or rules in this regard, identification of the power generation unit is not always possible.

Following the process of analyzing input data, their appropriate processing, and the allocation of identified generating units to the results of the capacity auctions conducted for the delivery years 2021–2029, the volume of natural gas demand for new/planned generating units that signed the long-term capacity contracts were estimated.

$$Gas\_Demand_{gu} = \frac{\left(\frac{Gross\_Capacity_{gu} \cdot 8,760 \cdot 3.6 \cdot 10^3 \cdot Capacity\_factor_s}{Electrical\_Efficiency_{gt}} \right)}{Gas\_Net\_Calorific\_Value} \quad (1)$$

- Gas_Demand_{gu} – total yearly gas consumption in gas unit gu, m^3,
- $Gross\_Capacity_{gu}$ – gross installed electrical capacity of the gas unit gu, MWe,
- $Electrical\_Efficiency_{gt}$ – gross efficiency of electricity production for gas technology, $gt \in \{CCGT, SCGT, gas\ engine\}$,

$Capacity\_factor_s$ – yearly capacity factor for analysed gas units under assumed scenario s, $s \in \{90\%, 70\%, 50\%, 30\%\}$,

$Gas\_Net\_Calorific\_Value$ – average high-methane natural gas net calorific value, MJ/m^3.

According to Equation (1), the demand for this fuel (Gas_Demand_{gu}) depends on the installed capacity of a given generating unit ($Gross\_Capacity_{gu}$), the efficiency of electricity generation ($Electrical\_Efficiency_{gt}$), the annual capacity factor ($Capacity\_factor_s$), and the net calorific value of natural gas (*Gas_Net_Calorific_Value*).

Due to the lack of actual data on the generation efficiency of individual new/planned gas units that have signed capacity contracts, the assumed values for this parameter have been differentiated between the identified groups of gas technologies, namely combined cycle gas turbines (CCGT) units, simple cycle gas turbines (SCGT) units, and gas engines. Capacity factor assumptions are also subject to considerable uncertainty. Although the annual availability of new gas units is high (~93%), the actual operating time of a given unit relative to its installed capacity depends, among other factors, on the economics of production and the role the unit plays in the system (the competitiveness of electricity generation of the naural-gas units was the subject of the study by Grudziński and Stala-Szlugaj 2024). For this reason, a scenario-based approach has been adopted, and in the calculations carried out, the results of which are presented in Section 3, have assumed four different levels of the capacity factor: 90%, 70%, 50%, and 30%, respectively.

3. Results

In the initial step of analyzing the outcomes of the main capacity auctions, with respect to their long-term impact on the development of new gas-fired generating units within the power system, the results of the capacity auctions conducted thus far (a total of 9 auctions for delivery years 2021–2029) were considered, categorized by the type of contracted unit (Figure 2). Additionally, the figure illustrates the auction clearing price and the announced capacity demand (target capacity) for each auction.

Analyzing the obtained results, it is noteworthy that the first four capacity auctions allowed for transactions involving high-emission units, including conventional power plants fueled by hard coal and lignite. Consequently, among the units that secured long--term capacity agreements (for 15 years), over 4 GWe of such power plants were contracted (Jaworzno, Kozienice, and Opole – hard coal power units; Turów – lignite power unit). Issues related to coal-fired units were examined in the works of Kaszyński et al. 2021; Komorowska et al. 2023 and Komorowska 2023. The highest auction clearing price in the period before the key change in the rules regarding participation of generating units in the capacity market, described in the following paragraph, was achieved in the fourth main capacity auction (259.9 PLN/kW/year). At that time, two combined cycle gas turbine units

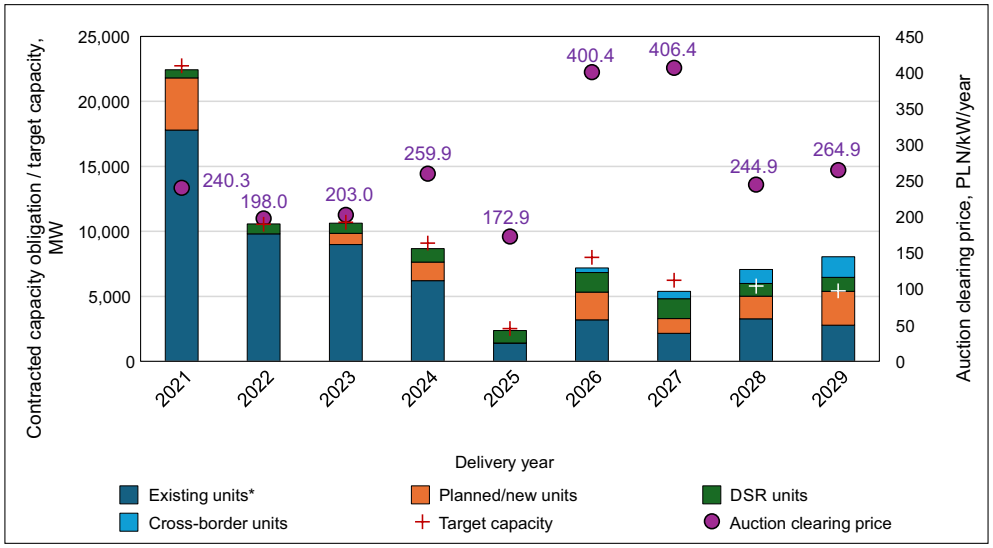

Fig. 2. Analysis of the results of the main capacity auctions conducted for the delivery years 2021–2029, categorized by types of capacity market units and including auction clearing prices
(* – including refurbishing units)
Source: own work based on capacity auction results (ERO 2018a–2025)

Rys. 2. Analiza wyników głównych aukcji mocy przeprowadzonych na lata dostaw 2021–2029, w podziale na rodzaje jednostek rynku mocy i z uwzględnieniem cen zamknięcia aukcji
(* – z uwzględnieniem jednostek modernizowanych)

(CCGT) planned for construction at the Dolna Odra power plant, each with an installed capacity of approximately 700 MWe, were contracted.

From mid-2025, pursuant to the entry into force of Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity, public support, including capacity remuneration mechanisms such as the capacity market, was restricted to low-emission units with a CO_2 emission factor not exceeding 550 kg CO_2 per MWh of electricity produced. As a result, new gas-fired power plants, primarily large-scale combined cycle gas turbine units, were contracted in the auctions for delivery years 2026 and 2027, including units in Grudziądz (~563 MWe), Ostrołęka (~745 MWe, replacing a coal-fired unit whose construction was abandoned), Adamów (~600 MWe), and Rybnik (~882 MWe). Additionally, long-term capacity agreements (up to 17 years for low-emission units) were secured by cogeneration units, such as EC Czechnica (~179 MWe), EC Gdynia (~180 MWe), EC Poznań (~122 MWe), and EC Łódź (~189 MWe). These were the only two capacity auctions that concluded with the maximum price, as the supply of capacity was lower than the targeted demand.

The clearing prices of the two most recent main capacity auctions (for delivery years 2028 and 2029), influenced by significant capacity supply from cross-border units (e.g.,

existing hydroelectric and nuclear units accepting low prices) and, crucially, a substantial share of battery energy storage systems (BESS), which contributed to an oversupply of offered capacity obligations relative to the targeted capacity, settled at relatively low levels of 244.9 PLN/kW/year and 264.9 PLN/kW/year, respectively. These capacity prices did not provide sufficient incentive to contract new gas-fired units, which are essential for ensuring the security and stability of electricity supply to end consumers and for providing flexible dispatchable capacity in a Polish power system that is undergoing a transition towards decarbonization and an increase in weather-dependent renewable units, such as solar PV and wind turbines. Consequently, long-term capacity agreements were mainly secured by battery energy storage systems (with a total capacity obligation volume exceeding 4.2 GWe) and only a limited number of gas-fired units (gas engines with a total volume slightly above 0.1 GWe).

The development of gas-fired projects was hindered by rising investment costs for gas turbines (driven by high global demand exceeding the supply capabilities of major manufacturers) and elevated natural gas prices on the European market (stemming, inter alia, from Russia's aggression against Ukraine, the embargo on Russian gas supplies, and the need for supply diversification). Also, investment costs for BESS technologies have been decreasing.

It is worth emphasizing that, over the period from 2021 to 2029, a total of approx. 55.6 GWe of capacity obligation volumes were contracted for existing power generation units (including refurbishing units) (Figure 3 – left side). This accounted for the vast majority – over 67.5% – of the total volume of capacity agreements concluded during this period. New/planned units, which were intended to be the primary beneficiaries of this support mechanism, ranked second, with a total contracted volume of over 13.9 GWe, representing just under 17% of the total. The share of demand side response (DSR) units (both confirmed and unconfirmed) amounted to slightly over 11% (9.3 GWe in total), while cross-border units accounted for 4.3% (3.6 GWe).

However, the impact of power generation units on the national power sector also depends on the duration of the capacity contract. As previously noted, for new low-emission generating units, the maximum contract duration is 17 years. Existing units may enter into one-year contracts while refurbishing units can secure contracts for up to 7 years. DSR units predominantly secure one-year contracts, though five-year contracts are occasionally observed. For cross-border units, the capacity contract duration is limited to one year, similar to existing power plants. When the duration of capacity contracts is included in the analysis (Figure 3 – right side), new/planned units are shown to have a critical and dominant influence on the electricity generation sector in the long term, accounting for over 61% of the total capacity obligation volume contracted in the auctions to date, when weighted by contract duration. Existing units, while still significant, particularly in the short term due to the refurbishment of some units, have a considerably smaller impact, representing 35% of the total volume. The influence of DSR and cross-border units is marginal, with shares of 2.6% and less than 1%, respectively.

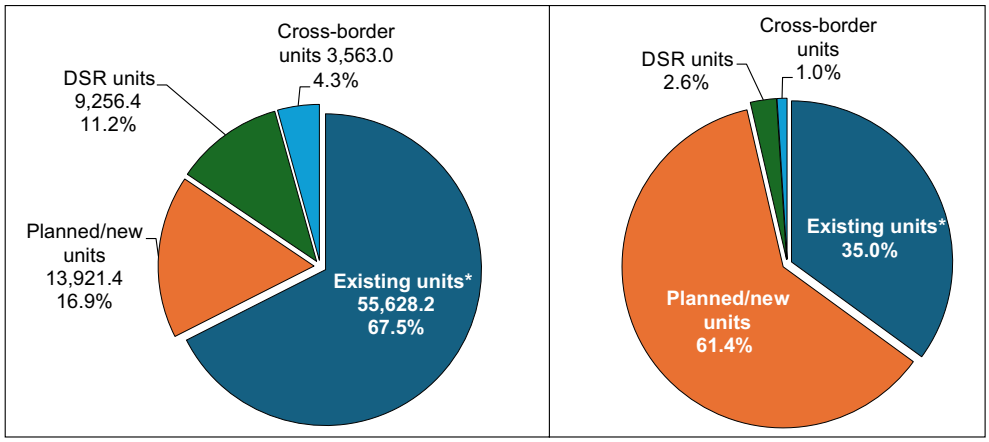

Fig. 3. Aggregated results of analyzed main capacity auctions for delivery years 2021–2029 in terms of the share of different types of capacity market units relative to the total contracted capacity obligations (left side – without taking into account capacity contracts duration; right side – including capacity contracts duration)
Source: own work based on capacity auction results (ERO 2018a–2025)

Rys. 3. Zagregowane wyniki analizowanych głównych aukcji mocy na lata dostaw 2021–2029 pod kątem udziału poszczególnych typów jednostek rynku mocy w stosunku do całości zakontraktowanych obowiązków mocowych (lewa strona – bez uwzględnienia czasu trwania umów mocowych; prawa strona – z uwzględnieniem czasu trwania umów mocowych)

In the second step of the analysis, considering the perspective related to new/planned units that secured capacity contracts in the conducted auctions and the objectives of the research described in this article, the fuel type or technology of each new/planned generating unit was identified and categorized. According to the aggregated results presented in Figure 4, gas-fired units constitute the largest share among new units, accounting for over 41%, with a total contracted volume of approximately 5.8 GWe. Interestingly, battery energy storage systems ranked second, with 4.4 GWe, representing about 31% of all new units, despite their active participation in only the two most recent capacity auctions. It should be noted that while BESS is a necessary component of a power system characterized by a high share of photovoltaic and wind sources, from the perspective of the capacity market's objectives – related to generating/delivering power during periods when system security and electricity supply to end consumers are at risk (stress events) – relying on energy storage may not be efficient or effective. Assuming a fully charged battery, the discharge process for delivering contracted capacity obligation typically lasts approximately 4–8 hours.

The issue of insufficient low-emission and flexible dispatchable power units in the system, which the capacity market mechanism was intended to address, has been recognized by the transmission system operator (PSE SA) and the Ministry of Climate and Environment. As a result, remedial actions have been initiated, which will be discussed in the subsequent sections of the article.

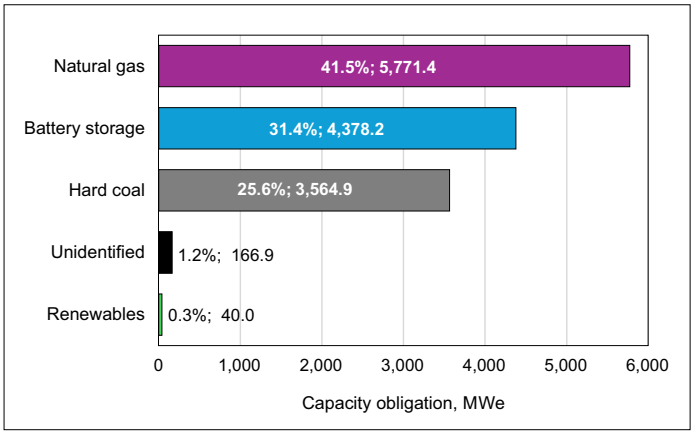

Fig. 4. Total volume of contracted capacity obligations of new/planned generating units in the main capacity auctions for the delivery years 2021–2029 – breakdown by fuel and technology type
Source: own work

Rys. 4. Łączna wielkość zakontraktowanych obowiązków mocowych nowych/planowanych jednostek wytwórczych w głównych aukcjach mocy na lata dostaw 2021–2029 – podział według rodzaju paliwa i technologii

The results of the first four main capacity auctions, held prior to the entry into force of Regulation (EU) 2019/943 contributed to a relatively significant share of coal-fired units (3.6 GWe in total, approx. 26% of all new units). Attention should also be drawn to the minimal participation (0.3%) of renewable energy source (RES) units in the capacity market due to an unfavorable de-rating factor and the availability of other support mechanisms dedicated to RES. Additionally, a small volume of capacity obligations (around 0.17 GWe; 1.2%) relates to units that could not be clearly assigned to any of the fuel types or technology groups specified in the analysis carried out.

The final stage of the conducted research involved estimating the natural gas demand for the identified new/planned gas-fired generating units that secured long-term contracts in the capacity market. The estimates were performed using the methodology outlined in Section 2, assuming an electrical efficiency of 60% for combined cycle gas turbine units, 40% for simple-cycle gas turbines, and 45% for gas engines. The calorific value of natural gas was set at 36.5 MJ/m^3. Additionally, to simulate the potential market participation of these units and their role in the power system (ranging from baseload to peak-load operation), calculations were conducted for four values of the capacity factor (CF), namely 90%, 70%, 50%, and 30%. It is also worth noting that three new gas-fired units, which secured capacity contracts in the first capacity auctions (Żerań, Stalowa Wola, and Płock CCGT units), were excluded from the analysis, as they were already under development and commissioned between 2018 and 2022. On the other hand, the analysis included two CCGT units at the Dolna Odra power plant, despite their commissioning at the end of 2024 (2025 will be their first fully operational year).

In total, approximately 4.5 GWe of contracted capacity obligation from new gas-fired units were considered in the analysis. Taking into account the information regarding the planned installed capacity of individual units (where the maximum volume of capacity obligation that can be certified for auction participation cannot exceed the product of the net achievable capacity and the de-rating factor, which for gas turbines and CCGT units ranges from 93.1% to 93.7%), this may correspond to a gross electrical capacity of approximately 5.0 GWe.

It should be emphasized that the construction of gas-fired power plants and combined heat and power plants will increase the dependence of the national power sector on a fuel that is predominantly imported. Consequently, the results regarding the additional natural gas demand arising from the contracting of new gas-fired units in the capacity market are of significant importance for the entire fuel and energy sector, particularly in the context of the stability and security of this fuel's supply in the long-term horizon (natural gas supplies to Poland were analyzed in the study by Biały et al. 2024).

According to the results presented in Figure 5, the additional natural gas demand from the electricity sector (beyond the existing demand of approximately 1.5 billion m^3) by 2030 could range, depending on the assumed capacity factor, from approximately 2.8 billion m^3 (CF = 30%) to approximately 8.5 billion m^3 (CF = 90%), with intermediate values of 4.7 billion m^3 (CF = 50%) and 6.6 billion m^3 (CF = 70%).

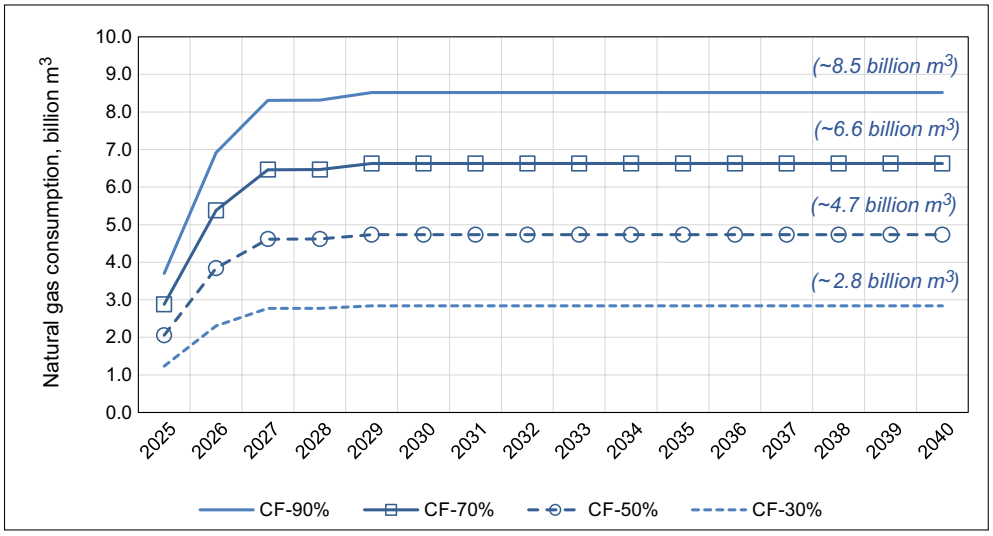

Fig. 5. Estimated natural gas demand by 2040 for new/planned generating units contracted in the main capacity market auctions for the delivery years 2021–2029
Source: own work

Rys. 5. Szacunkowe zapotrzebowanie na gaz ziemny do 2040 r. dla nowych/planowanych jednostek wytwórczych zakontraktowanych w głównych aukcjach rynku mocy na lata dostaw 2021–2029

As previously noted, the contracting of battery energy storage systems in place of dispatchable gas-fired units prompted an amendment to the capacity market law and the addition of catch-up auctions to the approved auction schedule/framework for the delivery years 2029 and 2030. For these auctions, new maximal capacity obligation limits were established, setting the de-rating factor for battery energy storage systems at 12.33% (Dz.U. 2025 poz. 571) to reflect their actual availability during system stress events. As a result, the participation of these units in catch-up auctions may be economically unviable, thereby increasing the likelihood that long-term capacity contracts will be secured by gas-fired units that participated in previous auctions but exited due to insufficient capacity prices. Available information (Enea 2024) indicates that new gas-fired units planning to secure capacity contracts include two CCGT units at Kozienice Power Plant with a total capacity of approximately 1.3 GWe, a CCGT unit in Gdańsk with a capacity of approximately 450 MWe, and a CCGT cogeneration unit at the Siekierki CHP in Warsaw with a capacity of approximately 550 MWe (Orlen 2024; PAP 2025). Incorporating these units into the calculations of estimated natural gas demand, as shown in Figure 6, resulted in

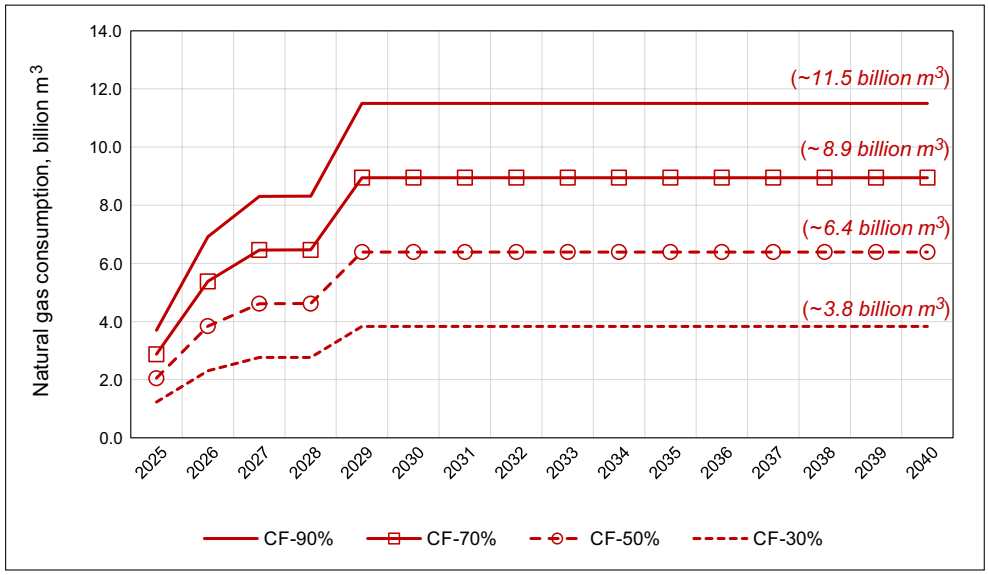

Fig. 6. Estimated natural gas demand by 2040 for new/planned generating units contracted in the main capacity market auctions for the delivery years 2021–2029, including additional gas-fired units that may be contracted in the catch-up auction for the 2029 delivery year
Source: own work

Rys. 6. Szacunkowe zapotrzebowanie na gaz ziemny do 2040 r. dla nowych/planowanych jednostek wytwórczych zakontraktowanych w głównych aukcjach rynku mocy na lata dostaw 2021–2029, z uwzględnieniem dodatkowych jednostek gazowych, które mogą zostać zakontraktowane w aukcji dogrywkowej na rok dostaw 2029

an increase in the projected demand by 2030 by approximately 1.0–3.3 billion m^3, reaching levels ranging from 3.8 billion m^3 (CF = 30%) to 11.5 billion m^3 (CF = 90%).

Conclusions

The article analyzes and discusses the demand for natural gas required for electricity production in new/planned generating units that have secured long-term support through Poland's capacity market mechanism, which has been operational since 2018. The analysis includes the results of all main capacity auctions conducted to date, including the auction held in December 2024 for the 2029 delivery year.

The obtained results, based on the methodology proposed in Section 2 and the collected and processed data indicate that the additional demand volume for high-methane natural gas (primarily from CCGT power plants and, to a lesser extent from cogeneration CCGT units, simple cycle gas turbines, and gas engines, with a total gross installed capacity of approximately 5.0 GWe) could range between 2.8 and 8.5 billion m^3 by 2030, depending on the assumed capacity factor, with an estimated value of approximately 6.6 billion m^3 for a capacity factor of 70%. As previously emphasized, the last two capacity auctions did not provide sufficient financial incentives to contract new large-scale gas units, due to an oversupply of capacity obligations relative to the announced target capacity demand, primarily from cross-border units and, above all, battery energy storage systems, which accepted lower capacity prices than new gas units. However, in a situation where the security of electricity supply to consumers is threatened, especially during unfavorable weather conditions over large areas (e.g., the autumn dunkelflaute phenomenon, meaning low generation from both photovoltaic and wind installations), cross-border units, and energy storage systems will not prevent a system blackout. In response, the Ministry of Climate and Environment, considering the arguments of domestic energy companies, amended the capacity market law to allow a catch-up auction for the 2029 delivery year to be organized in July 2025. As a result, additional gas units with a total gross installed capacity of approx. 2.3 GWe could be contracted. In this case, the estimated natural gas demand volume could increase by an additional 1.0–3.3 billion m^3 by 2030, reaching a range of 3.8–11.5 billion m^3 (depending on the assumed capacity factor), with an estimated value of approximately 8.9 billion m^3 for a capacity factor of 70%.

The results clearly indicate that capacity market support, which includes the construction of new gas units essential for the system due to the ongoing transformation and decarbonization of Poland's power sector and the need to replace decommissioned coal units in order to guarantee safe and stable operation of the system, in which the share of RES units is growing year by year, significantly impacts the fuel sector in the long term perspective. Such a substantial increase in gas-fired generating unit capacity will affect the necessity of importing significantly larger volumes of natural gas to Poland than currently (due to insufficient domestic resources and production capacities), affecting the security of

natural gas supply to Poland. In a broader context, related to disruptions in gas supply on the European and global markets due to the ongoing war in Ukraine and the embargo on Russian natural gas supplies, this will also impact the security and competitiveness of the national economy in the long term.

In this context, the transmission capacity of Poland's natural gas transmission system and forecasts of the energy sector's natural gas demand are also significant. Current estimates in this regard, provided by the gas transmission system operator, Gaz-System SA, in the strategic document *Development Plan to Meet Current and Future Demand for Gas Fuels for 2026–2035 (*KDPRSP 2025*)*, project a dynamic increase in natural gas demand from the energy sector in the coming years, from approximately 5.0 billion m^3 in 2025 to around 10.5 billion m^3 in 2032 in the baseline scenario, and up to approximately 11.9 billion m^3 in 2031 in the Energy+ scenario. Subsequently, demand decreases to 9.4 billion m^3 (baseline scenario) and 9.8 billion m^3 (Energy+ scenario) by 2040. The projected increase in natural gas demand compared to the 2025 baseline ranges from 5.5 to 6.9 billion m^3, depending on the scenario. Only a slightly larger increase (by 1 billion m^3 between 2025 and 2031; from 6.5 to 7.9 billion m^3) was assumed by the operator for the forecast of gas transmission demand for consumers (not only in the energy sector) connected to the transmission system (also via distribution systems). In this case, demand for transmission services rises from 20.7 billion m^3 in the baseline scenario in 2025 to approximately 27.2 billion m^3 in 2031. After this period, demand in the baseline scenario slightly decreases to 26.1 billion m^3 by 2040. In the Energy+ scenario, the initial demand growth is more dynamic, with forecasted demand for transmission services reaching 28.6 billion m^3 in 2031, before gradually declining to 26.5 billion m^3 by 2040.

In the context of the results presented in this article, the gas transmission system operator's forecast values may prove insufficient/underestimated, especially since, under current regulations, two additional capacity auctions are scheduled, during which new gas-fired generating units can conclude capacity contracts: the main capacity auction for the 2030 delivery year and a catch-up auction for the same period (with the possibility of extending the capacity market as a support mechanism beyond 2030). The contracting, construction, and commissioning of additional gas units are also desirable from the perspective of the power transmission system operator (PSE SA). Ensuring the security and stability of electricity supply to individual and industrial consumers, particularly during ongoing decarbonization, the planned decommissioning of coal-fired power generation units, and the increasing share of weather-dependent renewables requires the construction of new, flexible dispatchable capacities (including gas units). As part of the resource adequacy assessment conducted by PSE SA, presented in the *Development Plan to Meet Current and Future Electricity Demand for 2025–2034* (PRSP 2024) was estimated that the required level of additional dispatchable capacity to meet the network security standard, where the loss of load expectation parameter (LOLE) does not exceed 3 hours per year, necessitates the construction of approximately 11.6 GWe of capacity by 2035.

It should also be emphasized that the role of gas-fired units will change in the medium and long-term horizon, driven by the changing fuel mix of the Polish power sector as a result of the commissioning of a nuclear power plant and the increasing share of renewable energy sources (including offshore wind farms) and battery energy storage systems.

This work was carried out as part of the statutory research activity of the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences.

The Author have no conflict of interest to declare.

REFERENCES

ARE 2024 – *Information on energy of tools (monthly bulletin) No. 12(372). Ministry of Climate and Environment, Energy Market Agency SA* (*Informacja statystyczna o energii elektrycznej (biuletyn miesięczny) Nr 12(372). Ministerstwo Klimatu i Środowiska, Agencja Rynku Energii SA*) (*in Polish*).

Biały et al. 2024 – Biały, R., Żywczak, A. and Szurlej, A. 2024. The Influence of the Changes in Natural Gas Supplies to Poland on the Amount of Hydrogen Produced in the SMR Reactor. *Energies* 17, DOI: 10.3390/en17051221.

Dz.U. 2018 poz. 9 – *Act of Capacity Market* (*Ustawa z dnia 8 grudnia 2017 r. o rynku mocy*) [Online:] https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id = WDU20180000009 (*in Polish*).

Dz.U. 2019 poz. 42 – *Act of the promotion of electricity from high-efficiency cogeneration* (*Ustawa z dnia 14 grudnia 2018 r. o promowaniu energii elektrycznej z wysokosprawnej kogeneracji*) [Online:] https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id = WDU20190000042 (*in Polish*).

Dz.U. 2025 poz. 571 – *Regulation of the Minister of Climate and Environment of 29 April 2025 on the parameters of the additional auction for the delivery year 2029* (*Rozporządzenie Ministra Klimatu i Środowiska z dnia 29 kwietnia 2025 r. w sprawie parametrów aukcji dogrywkowej dla roku dostaw 2029*) [Online:] https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id = WDU20250000571 (*in Polish*).

Enea 2024 – *Current report no. 37/2024* (*Raport bieżący nr 37/2024*) [Online:] https://ir.enea.pl/pr/845234/informacja-w-sprawie-wyniku-aukcji-rynku-mocy-na-2029-rok (*in Polish*).

ERO 2018a – *Energy Regulatory Office. ERO President's Announcement No. 99/2018 of the Final Results of the Capacity Auctions for the Delivery Year 2021* (*Informacja Prezesa Urzędu Regulacji Energetyki nr 99/2018 w sprawie ogłoszenia ostatecznych wyników aukcji głównej na rok dostaw 2021*) [Online:] https://www.ure.gov.pl/download/9/9604/InformacjaPrezesaUREnr992018wsprawieogloszeniaostatecznychwynikowaukcjiglownejna.pdf (*in Polish*).

ERO 2018b – *Energy Regulatory Office. ERO President's Announcement No. 103/2018 of the Final Results of the Capacity Auctions for the Delivery Year 2022* (*Informacja Prezesa Urzędu Regulacji Energetyki Nr 103/2018 w sprawie ogłoszenia ostatecznych wyników aukcji głównej na rok dostaw 2022*) [Online:] https://www.ure.gov.pl/download/9/9687/14122018-Ostateczneogloszeniewynikowaukcjimocy-2022.pdf (*in Polish*).

ERO 2019a – *Energy Regulatory Office. ERO President's Announcement No. 14/2019 of the Final Results of the Capacity Auctions for the Delivery Year 2023* (*Informacja Prezesa Urzędu Regulacji Energetyki Nr 10/2019 w sprawie ogłoszenia ostatecznych wyników aukcji głównej na rok dostaw 2023*) [Online:] https://www.ure.gov.pl/download/9/9800/InformacjaPrezesaUrzeduRegulacjiEnergetykinr102019.pdf (*in Polish*).

ERO 2019b – *Energy Regulatory Office. ERO President's Announcement No. 106/2019 of the Final Results of the Capacity Auctions for the Delivery Year 2024* (*Informacja Prezesa Urzędu Regulacji Energetyki Nr 106/2019 w sprawie ogłoszenia ostatecznych wyników aukcji głównej na rok dostaw 2024*) [Online:] https://www.ure.gov.pl/download/9/10683/Ostateczneogloszeniewynikowaukcjimocy-2024.pdf (*in Polish*).

ERO 2021 – *Energy Regulatory Office. ERO President's Announcement No. 2/2021 of the Final Results of the Capacity Auctions for the Delivery Year 2025* (*Informacja Prezesa Urzędu Regulacji Energetyki Nr 2/2021*

w sprawie ogłoszenia ostatecznych wyników aukcji głównej na rok dostaw 2025) [Online:] https://www.ure.gov.pl/download/9/11635/Ostateczneogloszeniewynikowaukcjimocy-2025.pdf (*in Polish*).

ERO 2022 – *Energy Regulatory Office. ERO President's Announcement No. 2/2022 of the Final Results of the Capacity Auctions for the Delivery Year 2026* (*Informacja Prezesa Urzędu Regulacji Energetyki Nr 2/2022 w sprawie ogłoszenia ostatecznych wyników aukcji głównej na rok dostaw 2026*) [Online:] https://www.ure.gov.pl/download/9/12529/OstatecznewynikiaukcjiglownejnarokdostawZ026.pdf (*in Polish*).

ERO 2023 – *Energy Regulatory Office. ERO President's Announcement No. 2/2023 of the Final Results of the Capacity Auctions for the Delivery Year 2027* (*Informacja Prezesa Urzędu Regulacji Energetyki Nr 2/2023 w sprawie ogłoszenia ostatecznych wyników aukcji głównej na rok dostaw 2027*) [Online:] https://www.ure.gov.pl/download/9/13461/20230109INFOPUREwynikiaukcjiglownejnarokdostaw2027.pdf (*in Polish*).

ERO 2024 – *Energy Regulatory Office. ERO President's Announcement No. 2/2024 of the Final Results of the Capacity Auctions for the Delivery Year 2028* (*Informacja Prezesa Urzędu Regulacji Energetyki Nr 2/2024 w sprawie ogłoszenia ostatecznych wyników aukcji głównej na rok dostaw 2028*) [Online:] https://www.ure.gov.pl/download/9/14266/Ostateczneogloszeniewynikowaukcjiglownejna2028.pdf (*in Polish*).

ERO 2025 – *Energy Regulatory Office. ERO President's Announcement No. 2/2025 of the Final Results of the Capacity Auctions for the Delivery Year 2029* (*Informacja Prezesa Urzędu Regulacji Energetyki Nr 02/2025 w sprawie ogłoszenia ostatecznych wyników aukcji głównej na rok dostaw 2029*) [Online:] https://www.ure.gov.pl/download/9/15112/Ostateczneogloszeniewynikowaukcjiglownejna2029.pdf (*in Polish*).

Fuksa, D. 2021. Opportunities and Threats for Polish Power Industry and for Polish Coal: A Case Study in Poland. Energies 14(20), DOI: 10.3390/en14206638.

Grudziński, Z. and Stala-Szlugaj, K. 2024. The competitiveness of fuels in electricity generation. *Polityka Energetyczna – Energy Policy Journal* 27(3), pp. 193–206, DOI: 10.33223/epj/192860.

Kaszyński et al. 2021 – Kaszyński, P., Komorowska, A., Zamasz, K., Kinelski, G. and Kamiński, J. 2021. Capacity Market and (the Lack of) New Investments: Evidence from Poland. *Energies* 14(23), DOI: 10.3390/en14237843.

KDPRSP 2025 – *National Ten-Year Transmission System Development Plan – Development plan for meeting current and future demand for gas fuels for 2026–2035, Gaz-System SA, March 2025* (*Krajowy Dziesięcioletni Plan Rozwoju Systemu Przesyłowego – Plan rozwoju w zakresie zaspokojenia obecnego i przyszłego zapotrzebowania na paliwa gazowe na lata 2026–-2035, Gaz-System SA, marzec 2025*) (*in Polish*).

Komorowska, A. 2021. Can Decarbonisation and Capacity Market Go Together? The Case Study of Poland. *Energies* 14(16), DOI: 10.3390/en14165151.

Komorowska, A. 2023. The impact of long-term contracts of the capacity market on the consumption of steam coal in the power system. *Gospodarka Surowcami Mineralnymi – Mineral Resources Management* 39(2), pp. 165–176, DOI: 10.24425/gsm.2023.144637.

Komorowska et al. 2022 – Komorowska, A., Benalcazar, P., Kaszyński, P. and Kamiński, J. 2022. Economic consequences of a capacity market implementation: The case of Poland. *Energy Policy* 144, DOI: /10.1016/j.enpol.2020.111683.

Komorowska et al. 2023 – Komorowska, A., Kaszyński, P. and Kamiński, J. 2023. Where does the capacity market money go? Lessons learned from Poland. *Energy Policy* 173, DOI: 10.1016/j.enpol.2023.113419.

Orlen 2024 – *Warsaw heating on the way to emission neutrality* (*Warszawskie ciepłownictwo na drodze do neutralności emisyjnej*) [Online:] https://www.orlen.pl/pl/o-firmie/media/komunikaty-prasowe/2024/Sierpien-2024/Warszawskie-cieplownictwo-na-drodze-do-neutralnosci-emisyjnej- (*in Polish*).

PAP 2025 – *Orlen announces construction of gas power plants in Gdańsk and Grudziądz for PLN 6 billion* (*Orlen zapowiada budowę elektrowni gazowych w Gdańsku i Grudziądzu za 6 mld zł*) [Online:] https://biznes.pap.pl/wiadomosci/firmy/orlen-zapowiada-budowe-elektrowni-gazowych-w-gdansku-i-grudziadzu-za-6-mld-zl (*in Polish*).

Popescu et al. 2020 – Popescu, C., Panait, M., Palazzo, M. and Siano, A. 2020. *Energy Transition in European Union – Challenges and Opportunities* [In:] Khan, S.A.R., Panait, M., Puime Guillen, F. and Raimi, L. (eds) *Energy Transition. Industrial Ecology*. Springer, Singapore, DOI: 10.1007/978-981-19-3540-4_11.

PRSP 2024 – *Development plan for meeting current and future electricity demand for 2025–2034. Polskie Sieci Elektroenergetyczne (PSE SA)* (*Plan rozwoju w zakresie zaspokojenia obecnego i przyszłego zapotrzebowania na energię elektryczną na lata 2025–2034. Polskie Sieci Elektrooenergetyczne (PSE SA)*), December 2024 (*in Polish*).

PSE 2011 – Polskie Sieci Elektroenergetyczne S.A. Summary of quantitative data on the functioning of the National Power System in 2010 (*Polskie Sieci Elektroenergetyczne SA Zestawienie danych ilościowych o funkcjonowaniu Krajowego Systemu Elektroenergetycznego w 2010 roku*) [Online:] https://www.pse.pl/dane-systemowe/funkcjonowanie-kse/raporty-roczne-z-funkcjonowania-kse-za-rok/raporty-za-rok-2010.

PSE 2024 – *Polskie Sieci Elektroenergetyczne SA Summary of quantitative data on the functioning of the National Power System in 2023* (*Polskie Sieci Elektroenergetyczne SA Zestawienie danych ilościowych o funkcjonowaniu Krajowego Systemu Elektroenergetycznego w 2023 roku*) [Online:] https://www.pse.pl/dane-systemowe/funkcjonowanie-kse/raporty-roczne-z-funkcjonowania-kse-za-rok/raporty-za-rok-2023 (*in Polish*).

Regulation 2019/943 – Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity.

Tucki et al. 2019 – Tucki, K., Orynycz, O., Wasiak, A., Świć, A. and Dybaś, W. 2019. Capacity Market Implementation in Poland: Analysis of a Survey on Consequences for the Electricity Market and for Energy Management. *Energies* 12(5), DOI: 10.3390/en12050839.

Zamasz et al. 2020 – Zamasz, K., Kapłan, R., Kaszyński, P. and Saługa, P.W. 2020. An Analysis of Support Mechanisms for New CHPs: The Case of Poland. *Energies* 13(21), DOI: 10.3390/en13215635.

THE IMPACT OF THE CAPACITY REMUNERATION MECHANISM ON THE DECARBONISATION OF THE ENERGY SECTOR IN POLAND IN THE CONTEXT OF THE FUTURE DEMAND FOR NATURAL GAS FOR ELECTRICITY PRODUCTION

Keywords

capacity market, natural gas consumption, power system,
gas-fired generating units, energy security

Abstract

The energy transition of the power system in Poland has accelerated recently. The plans for coal phasing out are developed, and role of the natural gas is emphasized in mid- and long-term strategies. This trend is also observed in the recent capacity market results in which natural-gas-fired power plants and combined heat and power plants are among the main beneficiaries, provided the duration of the capacity contract is taken into account. The study is devoted to examining the impact of the main capacity auctions results (for the delivery years 2021–2029) on the future natural gas consumption in the Polish power system. For this purpose, the results of this support mechanism are analysed, and the capacity market units are identified with regard to the fuel used for electricity production. The auctions held by December 2024 are analysed to provide the most up-to-date remarks. The obtained results indicate that the additional demand for high-methane natural gas (mainly from CCGT power plants, but also from cogeneration CCGT units, simple cycle gas turbines, and gas engines, with a total gross installed capacity of approximately 5.0 GWe) could range between 2.8 and 8.5 billion m^3 by 2030, depending on the assumed capacity factor (30–90%), with an estimated value of approx. 6.6 billion m^3 for a capacity factor of 70%. The construction of large-scale gas-fired generating units with the support of capacity market mechanism, significantly impacts (i.e. changes in the fuel mix, the need for expansion of natural gas transmission infrastructure, dependence on imported fuel prices, risks of supply shortages, etc.) – in the long term perspective – not only on the power sector but also on the fuel sector, affecting the security of natural gas supply to Poland.

WPŁYW MECHANIZMU WYNAGRADZANIA ZDOLNOŚCI WYTWÓRCZYCH NA DEKARBONIZACJĘ SEKTORA ENERGETYCZNEGO W POLSCE W KONTEKŚCIE PRZYSZŁEGO ZAPOTRZEBOWANIA NA GAZ ZIEMNY DO PRODUKCJI ENERGII ELEKTRYCZNEJ

Słowa kluczowe

bezpieczeństwo energetyczne, system elektroenergetyczny, rynek mocy, zapotrzebowania na gaz ziemny, gazowe jednostki wytwórcze

Streszczenie

W ostatnich latach transformacja energetyczna systemu elektroenergetycznego w Polsce uległa przyspieszeniu. Opracowywane są plany dekarbonizacyjne związane z odchodzeniem od węgla, a w strategiach średnio- i długoterminowych podkreślana jest rola gazu ziemnego. Tendencja ta jest również obserwowana na rynku mocy – elektrownie i elektrociepłownie opalane gazem ziemnym są jednymi z głównych beneficjentów tego mechanizmu wsparcia, zwłaszcza pod warunkiem uwzględnienia czasu trwania umowy mocowej. Przedstawione w artykule badania poświęcone są zbadaniu wpływu wyników głównych aukcji mocy (na lata dostaw 2021–2029) na przyszłe zużycie gazu ziemnego w polskim systemie elektroenergetycznym. W tym celu przeanalizowano wyniki tego mechanizmu wsparcia oraz zidentyfikowano jednostki rynku mocy pod kątem paliwa wykorzystywanego do produkcji energii elektrycznej. Uzyskane wyniki wskazują, że dodatkowe zapotrzebowanie na gaz ziemny (pochodzące głównie z elektrowni gazowo-parowych, ale także z jednostek kogeneracyjnych, w tym turbin gazowych pracujących w cyklu prostym i silników gazowych, o łącznej mocy brutto około 5,0 GWe), może wynieść od 2,8 do 8,5 mld m^3 w perspektywie 2030 r., w zależności od przyjętego współczynnika wykorzystania mocy zainstalowanej (30–90%), przy czym zapotrzebowanie na poziomie około 6,6 mld m^3 uzyskano dla współczynnika wykorzystania mocy równego 70%. Budowa wielkoskalowych gazowych jednostek wytwórczych przy wsparciu z rynku mocy, istotnie wpływa (m.in. zmiana miksu paliwowego, potrzeba rozbudowy infrastruktury przesyłowej, uzależnienie od cen surowca z importu, ryzyko zakłóceń podażowych etc.) – w perspektywie długoterminowej – nie tylko na sektor energetyczny, ale również paliwowy, oddziałując na bezpieczeństwo dostaw gazu ziemnego do Polski.