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CHANGE IN NATURAL GAS UTILISATION IN THE CONTEXT OF SUSTAINABLE ENERGY MANAGEMENT IN POLAND

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ABSTRACT: The energy transformation requires a change in the structure of the energy used. The article aims to determine the role of natural gas as a transition fuel in the European Union and Poland's energy policy in the context of the promoted sustainable development policy. In the analysed documents presenting visions of energy policy, a differentiated approach to the effects of using natural gas is observed. The possible effects of using natural gas in Poland's energy mix were analysed and evaluated. The study used the method of research document analysis. Six attributes of sustainable energy management and the relations between them were considered. The main results are as follows: 1. natural gas as an energy carrier does not fulfil the requirements of sustainable energy management, 2. from the point of view of utilisation effects, the use of natural gas for power generation purposes is better than using other fossil fuels, 3. in RES and nuclear energy development conditions, using natural gas for power generation will decrease, which should bring positive results for sustainable energy management. The main conclusion is the energy transition is mainly driven by political factors. Therefore, the energy carriers' sustainable management issue shall be approached comprehensively.

KEYWORDS: natural gas, sustainability, transformation, policy

Introduction

Climate change observed since 2015 has been progressing faster than expected. Actions taken globally have become directed towards the set objectives. The war between Russia and Ukraine and decisions to resign from the Russian energy media supplies can accelerate the abandoning of fossil fuels. The European Union countries will take measures to ensure climate neutrality by 2050.

The development plans of the global and European economies assume resigning from fossil fuels. It applies primarily to abandoning the use of coal. Fossil fuels dominate the energy mix in Poland, and their change in the last decade has progressed very slowly. In 2020 in Poland, 45% of the energy consumed was generated based on coal (35% hard coal and 5% of lignite), 26% from oil, 17% from natural gas and only 7% was derived from renewable sources (including 5% from wood biomass) (Ministerstwo Klimatu i Środowiska, 2021). Between 2011 and 2020, coal's share decreased by eight percentage points, the share of oil and natural gas increased (by 3 and 5 percentage points, respectively), while the share of wood remained unchanged. Poland was ranked the sixth country globally for the emissivity of primary energy consumption (2.85 t CO_2/toe) (Dusiło, 2022).

Natural gas causes lower emissions of greenhouse gases in energy generation processes. That is why the Polish government's documents concerning energy transition stipulate that natural gas shall replace coal temporarily until low- or zero-carbon, economically efficient and effective energy supply methods become widespread.

The research problem applies to whether the transition of energy and climate policies relating to natural gas considers compliance with sustainable development. The paper aims to determine the role of natural gas in the EU's and Poland's energy policies as a transition fuel in the context of the promoted sustainable development policy. The issue is presented in the example of Poland because the Polish economy's adaptation to the EU's requirements can be particularly challenging due to the specific and coal-dominated structure of the energy mix.

Literature overview

The term "sustainable energy" has gained popularity owing to MacKay's book (2008). It was used in the Sustainable Energy for All Initiative (UN Global Compact and Accenture, 2011). The Initiative was aimed to accelerate actions for three essential objectives that should be attained by 2030: ensur-

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ing access to energy for all, significant improvement of energy efficiency and increasing the share of renewable energy in the global energy mix (UN Global Compact and Accenture, 2011).

Patterson (2009) defines sustainable power engineering as the consumption and supply of energy that satisfies parents' needs without compromising children's capacity to meet their needs. The International Energy Agency (IEA, 2005), operating under the OECD, defines sustainable power engineering as long-lasting power engineering with a global range, guaranteeing environmental protection, economic effectiveness, competitiveness, and social responsibility. Graczyk (2019) states that Patterson's definition does not reflect the essence of the notion, as it applies selectively to sustainable development aspects, emphasising the inter-generation fairness principle. Even though the IEA's definition emphasises development durability, it does not consider all the determinants of sustainable development dimensions. Graczyk systematises the notion that sustainable power engineering is the sustainable economy's sector where sustainable energy development occurs and sustainable energy policy is executed. Even if the economy cannot be considered generally sustainable, its part where sustainable development orders are balanced and its objectives and rules are fulfilled can be regarded as sustainable and named a sustainable economy.

A balanced power (energy) system is vital to sustainable power engineering (Graczyk, 2019). A sustainable energy system should be based on a combination of renewable energy generation/acquisition, renewable transport of fuels, renewable heat, demand reduction, effective use and energy cogeneration (Mitchel, 2010).

The issue of sustainable development measurement was mentioned in international organisations' documentation and scientific papers. For example, in 2004, the IEA developed the Energy Development Index (EDI), which was used in a publication cycle called the World Energy Outlook 2004 (International Energy Agency, 2004). The Index was supposed to "improve the understanding of the contemporary power engineering's role in the economic and social development". It consisted of three components: commercial energy consumption per capita, the share of commercial energy in the total energy consumption by end-users and the share of the population with access to electricity.

Scientific literature proposes various systems of power engineering sustainable development indices. The proposals represent two streams. One involves creating a set of indices that can comprehensively characterise sustainable development problems in the energy management area. Tsai (2010) analysed a system of Taiwan's sustainable development indices concerning energy. Streimikiene and Sivickas (2008) proposed applying an index framework to analyse the EU's policy on sustainable energy and presented a case

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study of using this policy tool in the Baltic countries. García-Álvarez et al. (2016) identified a comprehensive set of energy sustainability indices for the EU-15 member states. They grouped the indices according to three dimensions, including the security of energy supplies, competitive energy market and environmental protection. Gunnarsdóttir et al. (2020) presented an extensive literature overview analysing fifty-seven sets of indices for which various construction methods of complex indices are used.

Another stream in scientific literature covers the proposals of sustainable energy development comprehensive indicators for the power engineering sector or its selected elements, including but not limited to renewable energy. A publication authored by Iddrisu and Bhattachaaryya (2011) provided an impulse for this type of study; the authors evaluated the versatility of the existing indices and proposed an index focusing on determining the level of intra- and inter-generation needs' balance. Cucchiella et al. (2017) constructed a sustainable energy and environment index for the EU-28 using a multi-criteria analysis. Kauertz et al. (2020) developed an index describing the environmental aspects of the energy transition in Germany. A study by Ligus and Peternek of 2021 is worthy of special attention; the authors proposed a comprehensive system of indices related to sustainable development in the EU-28 energy policy, grouped into social, economic and environmental dimensions (Ligus & Peternek, 2021).

Only a few papers concern the assessment of natural gas management sustainability. The papers concentrate on environmental hazards along the entire natural gas supply chain. The studies published focus primarily on the first part of the chain and refer to the impact of search and mining on water resources and the emission of greenhouse gases. Crow et al. (2019) estimated the potential impact of greenhouse gas emissions from natural gas production, combining the estimated CO_2 and methane emissions with a dynamic, techno-economic gas supply model. Xu and Lin (2019) focused on the relationship between natural gas consumption and CO_2 emission downstream. Mac Kinnon et al. (2018) investigated natural gas emissions in the context of greenhouse gas emission reduction and air quality improvement. Fu et al. (2021) systematically reviewed the whole lifecycle of the natural gas industry chain. They focused on identifying such environmental aspects as air pollution, land use, water consumption, environmental impact and the greenhouse effect.

Lower emissions were the premise for creating concepts, scenarios and programmes of gradual coal replacement with natural gas until low-carbon technologies become widespread and stable. Such an approach can be noticed in the International Energy Agency's studies (IEA, 2019) or in the European Commission's Communication entitled "Clean Planet for All" of November 2018. Blazquez et al. (2019) pointed out that politics drive the

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energy transition. This feature is missing in the previous energy transitions, where the market played a key role. That is why every country can have its own energy transition path, depending on the decarbonisation policies.

In 2021, it was believed that the role of natural gas in the energy transition greatly depended on the transition course and on how the industry and public policies would handle the issue of methane leaks at the stage of gas mining and transport, as well as on the availability of other clean energy sources. The European energy policy experts treated the increase in gas prices in 2021 as a step in the right direction, i.e. towards limiting the use of fossil fuels. They assumed that higher prices of natural gas would discourage the use of gas for household heating and encourage house owners to invest in electric heat pumps, which would reduce CO_2 emissions in the EU even further and lessen the reliance on fossil fuels. The political narrative matters, highlighting actions for the climate and emphasising the significance of adapting to the future variability of prices and supporting customers during the energy transition. The specificity of such a narrative depends on various country-specific factors, e.g. availability and investments in renewable energy sources and/or the country's plans concerning future dependence on nuclear energy (Wong et al., 2021).

The policy towards natural gas changed in 2022 after significant price increases and actions were taken to reduce the import of natural gas from Russia. The change in the approach to natural gas was included synthetically in the IEA's report: "The traditional arguments in favour of natural gas have focused on its role as a reliable partner for the clean energy transition and its ability to step in to fill the gap left by declining coal and oil. … The depth and intensity of today's crisis have led to concerns about the future cost and availability of natural gas, which have damaged confidence in its reliability and put a major dent in the idea of it serving as a transition fuel. As a result, the era of rapid global growth in natural gas demand is drawing to a close" (IEA, 2019).

The literature review reveals that the issue of sustainable development in energy management was analysed primarily from the point of view of energy in general, without differentiating between the impact of individual energy carriers. The literature items on the sustainable management of natural gas focus on the environmental and climate issues related to the use of natural gas. Indicating the vital role of political factors in the decision about natural gas utilisation volume and method constitutes a significant aspect.

Therefore, there is a research gap concerning a comprehensive evaluation of the sustainable management of gas, exceeding the analyses of the natural gas supply chain or utilisation method. Because the place of gas in the energy mix has not been resolved yet, a question is justified if compliance with sustainable development is considered in the energy and climate policy

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transition in reference to natural gas. The research issue is whether using natural gas complies with the conditions of sustainable energy management.

Research methods

The European Union's intentions concerning economic transition were formulated in The European Green Deal (2019). The research method was developed while writing the monograph on sustainable energy management in the energy transition from the energy policy perspective (Graczyk et al., 2021). It was applied to the analysis of Poland's energy policy. Here the method is presented regarding the use of natural gas.

Following this concept, it can be assumed that sustainable development in energy management contributes to the durable improvement of life quality. An efficient and reliable sustainable energy system helps establish and strengthen social, economic and territorial cohesion. The dimensions typical for sustainable development are the social, economic and environmental ones. They apply to essential attributes of sustainable energy management (Graczyk et al., 2021):

- durable security of satisfying the energy needs,
- long-term economic effects of energy management, considering external costs,
- non-discriminating access to energy,
- energy generation/acquisition, processing and consumption safe for human health and the natural environment's balance,
- neutral impact on the natural environment – emissions limited to the level of pollution reduction and reception capacity,
- the scale of renewable resources uses enabling their renewal.

Relationships exist between these attributes. They are shown in Figure 1. The links and dependencies in the diagram refer to a positive interaction of the components in a long-term perspective.

The diagram above is the base for analysing energy and climate policy documents referring to natural gas formulated in Poland. The analysis applies to including these elements and considering the links between them. Poland was selected for the analysis because the energy transition starts with a stage that most European Union countries have already completed, i.e. the dominance of coal to satisfy energy needs. If such member states are ready to abandon fuel gases, it is an important signal for such countries as Poland that developing energy management with a higher share of natural gas might not be sustainable.

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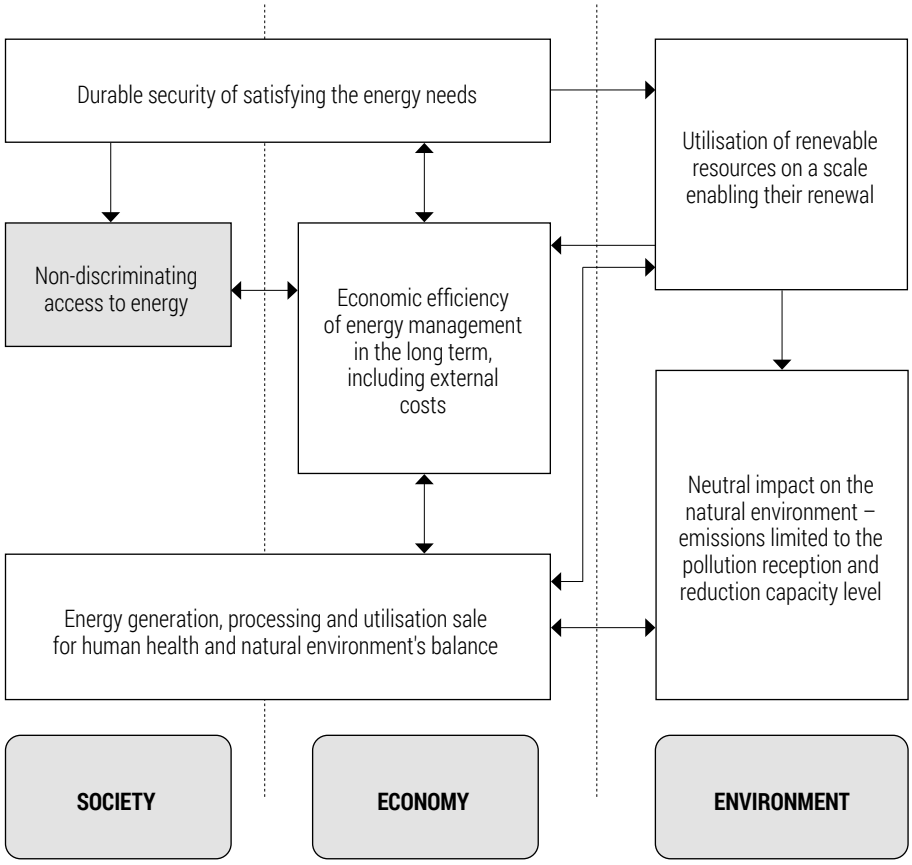

Figure 1. Attributes of sustainable energy management

Source: Graczyk et al., 2021.

This shall help assess if the transition of energy and climate policies in reference to natural gas takes into consideration compliance with sustainable energy management.

Observation of energy policy components relating to natural gas

The 2030 Energy Policy for Poland, effective in 2020 (Ministerstwo Gospodarki, 2009), prioritised "An increase in the security of fuel and energy supplies". *Reasonable and effective management of coal deposits in Poland* was highlighted as the energy policy's primary objective. It was pointed out that the *implementation of the coal supplies security policy posed a significant challenge in the analysed period due to fluctuations of the resource prices in the*

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global markets, the need for restructuring the sector and reducing the energy sector's environmental impact. Still, it was considered that *previous actions should be continued, especially those related to ensuring the sector's profitability and preventing the building-up of strategic resources of coal.* (Obwieszczenie, 2021). Strengthening Poland's position in the European market of natural gas was considered vital. To that end, necessary infrastructure shall be provided in order for the market to respond to the needs of new segments using this fuel and creating conditions to combine the gas and power sectors (Obwieszczenie, 2021).

The directions of the gas sector transition were indicated in another document called the National Plan for Energy and Climate in 2021-2030 (NPEC) (Ministerstwo Klimatu i Środowiska, 2019). Each member state had to present such a plan to the European Union, according to the regulation of the European Parliament and the Council (EU) No. 2018/1999 of 11 December 2018 on energy union management and climate actions. The document presents national objectives and actions to create a framework for Poland's fair transition towards a low-carbon economy. The role of natural gas in the process of reaching the zero-carbon economy status was described in the document in the context of implementing Poland's key climate and energy objectives by 2030; the objectives are divided into actions under five dimensions of energy union: emission reduction, energy efficiency and security, internal energy market, scientific research, innovation and competitiveness.

The significant objective of the Plan assumes reducing the share of hard coal and lignite in energy generation to 56-60% in 2030 and a further declining trend by 2040. The objective shall be attained through changes in the electricity generation sector, e.g. closing down the conventional, old generating units that do not fulfil environmental requirements on pollution emissions, implementing traditional high-performance technologies, gradual implementation of low- and zero-carbon technologies, including but not limited to renewable energy sources and nuclear energy. The important role of natural gas in this process was indicated; in Polish conditions, it has a vital role as it can temporarily become the fuel enabling energy transition. An increase in this fuel's significance was expected in power engineering as a support for renewable energy sources and in the district and individual heating and transport (as an alternative fuel, e.g. LNG or CNG). Investments in gas generation infrastructure were vital for balancing the national power grid because of the high technological flexibility of their operation.

The NPEC assumed the use of natural gas as fuel in cogeneration units. They shall replace old heat plants and cogeneration plants operating based on hard coal. After 2030 they shall also replace some currently operating gas-fired heat and power generating plants. The new gas-fired cogeneration units and gas and steam power plants were supposed to improve the reliability

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and flexibility of the national power grid. The necessary development of generation capacity based on gas sources was indicated, and in a long-term perspective, also the development of sources alternative to natural gas, e.g. biomethane, hydrogen and synthesis gas.

Polish Energy Policy by 2040 (PEP2040) is another vital document determining the direction of the Polish gas industry and identifying natural gas as the bridging fuel (Ministerstwo Klimatu i Środowiska, 2020). PEP2040 was the Polish government's response to the most significant challenges for the Polish energy sector in the upcoming decades in relation to the Paris Agreement provisions and the resulting European Union's climate and energy policy. It was supposed to determine the energy transition framework for Poland, considering the most significant assumption expressed in the European Green Deal – reaching climate neutrality by the member states by 2050. Natural gas was first mentioned as a bridging fuel in the energy transition in Poland. The extended gas capacity, in addition to the development of energy storage, was considered indispensable for balancing the operation of unstable renewable sources. They were supposed to support the reliable operation of the national power grid and hence the country's energy security.

The potential to increase the use of natural gas results from the development of district heating included in the PEP. The heating needs of all households shall be covered by district heating and zero- or low-carbon individual sources. Partial replacement of coal with natural gas in cogeneration plants shall help achieve the objective of greenhouse gas emissions reduction and air quality improvement due to the emissivity of natural gas lower than that of coal (Ministerstwo Klimatu i Środowiska, 2020). In order to ensure the status of bridging fuel for natural gas, PEP2040 highlights the need to extend gas infrastructure and diversify the directions and sources of supplies because the demand for natural gas will be covered mainly with imported resources.

State Resource Policy (PSP2050), adopted in March 2022 (Uchwała, 2022), identifies natural resources critical for the national economy, considering their individual specificity. When resources critical for the European Union are additionally accounted for, the Policy highlights the resources indispensable for implementing the set national and European economic objectives. According to PSP2050, in relation to the valid climate policy and quality parameters of natural gas, it was expected to gain significance in the Polish energy mix, especially in power engineering (because of its significant role in the power grid balancing) and district heating (cogeneration). Natural gas was considered a transition fuel, which is why it shall be gradually replaced by more environmentally friendly technologies, depending on their availability.

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The Russian invasion of Ukraine and the EU's adoption of successive action packages to reduce the import of energy carriers from Russia accelerated the actions to reduce the use of gas in the European Union. In March 2022, the European Commission published the REPowerEU communication containing a plan to stop importing fossil fuel energy from Russia long before 2030 (European Commission, 2022a). In the new reality, gas consumption in the EU will decrease sooner, limiting the role of gas as a transition fuel (European Commission, 2022a). It is expected that owing to the full implementation of the REPowerEU Plan, high prices, solutions alternative to gas (sustainable biomethane production, renewable hydrogen), further use of renewable energy sources and demand-related structural measures such as energy efficiency, the EU's demand for gas will decrease faster than expected under the "Fit for 55" package.

The arrangements above, made on the European Union's level, forced the Polish government to update the PEP2040's pillars and objectives at the end of March 2022 (Ministerstwo Klimatu i Środowiska, 2022). Polish government shall strive for a gradual reduction of the economy's dependence on natural gas. However, in the perspective of the upcoming decades, the security of supplies to customers must be guaranteed. Furthermore, measures shall be taken to replace the demand for natural gas with decarbonised gases and other proven fuels. It was announced that due to a change in the geopolitical situation and gas market unpredictability, gas-fired units would maintain their significant role in regulating the power grid's operation, but the utilisation level of the existing coal-fired units might increase in a mid-term perspective. As a result of these changes, the investment plans concerning new gas capacities shall be verified for production economics. In the heating sector, the conversion rate of coal-fired units into gas-fired ones shall depend on the availability of resources. Simultaneously, the possibilities of using other energy sources shall be investigated, making a real alternative to using natural gas for heating purposes. It can be observed that Poland intends to follow the direction of complying with the REPowerEU plan provisions related to reducing natural gas utilisation. Still, the announced maintenance of coal-fired units in the power and heating sector contradicts the "Fit for 55" intentions.

A similar inconsequence can be noticed in the determination of gas prices. The document presenting the assumptions for the PEP 2040 updates emphasises that the natural gas market in Poland requires continued liberalisation to release the last group of regulated users, i.e. households, from the tariff obligation for fuel gas sales. In the second half of the year, the government took contradictory measures – the stock exchange obligation was cancelled and setting the maximum gas price for households was announced.

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It was justified with customer protection against an excessive increase in fuel gas supply costs.

An analysis of the policy changes presented above in relation to natural gas accentuates some attributes of sustainable energy management. One of them is the strive to reduce greenhouse gas emissions. This policy direction results from the obligation adopted all over the European Union to reduce greenhouse gas emissions. Such an effect is achieved by replacing coal with natural gas. Still, it does not ensure fulfilling the essential premise of neutral impact on the natural environment. On the contrary, it would require reducing natural gas combustion emissions to the level of pollution reception and reduction capacity.

Reduced emissions apply directly to using natural gas instead of hard coal. Methane and carbon dioxide emissions also occur at the stage of mining and transport to the destination sites. They enhance the greenhouse effect, which has a global dimension. Additionally, the local natural environment's balance is disturbed, especially in the mining areas. Therefore it can be confirmed that utilising natural gas meets the requirements of energy generation/acquisition, processing and utilisation safe for human health and the natural environment's balance.

Natural gas is a non-renewable energy carrier. Even its limited use exhausts the resources, though at a slower rate. If the use of natural gas enables supplying the energy that renewable sources cannot supply, it prevents excessive use of renewable energy on a scale that makes their renewal impossible. It applies particularly to the renewable energy carriers which use biological material. The Polish potential of biomethane production amounts to 7,8 bln m^3 a year (Dach, 2022), and its use could reach 50% in 2030. Then, at least 7 per cent of the fuel mix will belong to advanced biofuels and biocomponents. A further increase in the use of biological materials will encounter agricultural production barriers and consequently reduce the plants' potential to absorb carbon dioxide. Using natural gas protects against such a situation and meets the requirement of sustainable energy management, not in reference to gas resources but in maintaining proper plant production.

The two previously mentioned aspects (excessive use of natural gas and excessive use of renewable energy sources) affect the level of energy generation/acquisition external costs. From a long-term perspective, generating renewable energy volumes adequate to the renewal capacity does not mean eliminating external costs completely. Their occurrence can result from a competitive use of resources. The optimisation of external costs level is determined during their internalisation. A state is responsible for the process, which is driven by the premise of maximising social well-being in a long-term perspective when making appropriate decisions about the energy mix structure.

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The problem applies to natural gas utilisation as well. External costs are among the components of gas management economic efficiency balance in a long-term perspective. Economically efficient energy management should ensure energy availability at acceptable costs and prices for all users. Subsidising energy generation or supporting the use of its specific forms makes no sense in the long term. A relevant market mechanism should ensure energy availability for all users. Appropriately designed infrastructure and organisational forms of providing access to energy play a crucial role, especially for supplies conditioned by the network development.

Investment costs matter a lot for efficiency assessment. Eliminating natural gas from the Polish economy by 2030 would require investment expenditures on the infrastructure of electrical energy transmission and distribution – amounting to 200-300 bn PLN, and on generation capacity – amounting to 150-200 bn PLN. The expenditures will not have to be incurred if natural gas is temporarily left and then a smooth transition to its green and low-carbon substitutes takes place; such a situation would require "standard" modernisation activities and investing in gas infrastructure (Izba Gospodarcza Gazownictwa & Instytut Studiów Energetycznych, 2022).

The possibility of energy storage plays a vital role in developing sustainable energy management. Due to its land topography, Poland has limited possibilities of building pumped-storage power plants. Current technologies of electrical energy storage in batteries are extremely costly. Underground natural gas storages located in salt caverns are a much cheaper solution.

Using gas in households is the area of adapting to the EU climate and energy policy objectives that is most challenging for economic efficiency. In Poland, households use ca. 7.1 M devices fired with solid fuels and ca. 4.1 M devices fired with fuel gas. Sticking to natural gas and replacing all coal-fired stoves with gas-fired ones means ca. 160 bn PLN investment in the whole country. An alternative solution involving shifting to electric heating is much more expensive. The cheapest option of selecting electric heaters means a cost of ca. 300 bn PLN for households; still, it significantly increases the current heating costs. The other option, assuming that half of the households shift to electric heaters and the other half chooses heat pumps, means that the investment outlays for households will reach 530 M PLN, while selecting the most energy-efficient solution (heat pumps) entails the cost of ca. 860 bn PLN (Izba Gospodarcza Gazownictwa & Instytut Studiów Energetycznych, 2022). Such a change in the heating method with no public support will be financially inaccessible for most households.

Replacing coal combustion in households would help reduce external costs caused by a high concentration level of particulate matter and benzo(a) pyrene in the atmospheric layer closest to the earth. The problem occurs primarily in winter and in most cities. Individual coal furnaces and wood com-

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bustion in households are the primary sources of such pollution emissions. According to the World Health Organisation's study, PM 2.5 is often used as the leading indicator of air pollution. Pollution exerts the most significant impact on long-term health effects. The estimated costs, presented in the Report, of premature deaths caused by air pollution in 2010 for Poland amounted to 101.8 bn USD (WHO, 2015). It is estimated that PM 2.5 emissions generate the external cost in Poland, amounting to 18.2 bn EUR/year, i.e. 76.4 bn PLN a year (Lachman & Mirowski, 2017).

In May 2008, the European Commission adopted Directive 2008/50/EC on „ambient air quality and cleaner air for Europe", setting new air quality objectives concerning PM 2.5. The effects of achieving the objectives set out in the Directive were estimated for all member states in 2020. If all countries achieved their objectives, whereby the emission reduction costs amounted to ca. 0.01% of GDP, on the EU scale, the GDP would rise by 1.28% between 2010 and 2020. Poland would achieve the highest GDP increase – by 2.9% – as a country with the highest particulate matter pollution level (Dechezleprêtre et al., 2020). The estimate indicates the high economic efficiency of reducing coal combustion emissions.

Investments in gas infrastructure development, which could potentially limit discrimination, suffer the risk of premature decarbonisation of the sector. In the gas sector, the currently designed infrastructure will be built within the next ten years and then used for 20-30 years, which means that gas investments planned nowadays can significantly deteriorate their profitability if the market starts to shrink considerably around 2035 and the executed projects will still be in the operating stage (Moskwik et al., 2020).

The problem occurred in relation to households as well. The current share of gas in the whole structure of household heat sources amounts to 24%. In 2018, the "Clean Air" Priority Programme was activated in Poland in collaboration with the World Bank under the European Commission's initiative called the "Catching-Up Regions". The Programme is aimed to reduce air pollution by improving the energy efficiency of heating systems in single-family buildings and the thermal efficiency improvement of buildings. Over 3 M residential premises/buildings with improved energy efficiency and 3 M of inefficient heat sources replaced were the indicators of reaching the programme's objectives. The programme's implementation period was set for 2018-2029, but the commitments (meant as signing the agreements) were supposed to be made by 31 December 2027, and funds were spent by 30 September 2029. A thermal efficiency improvement tax relief was an additional funding source for the tasks under the programme. The programme's budget was drawn up as 103.3 bn PLN. As of 1 October 2021, three years into the Programme implementation, the total amount of the agreements concluded with the beneficiaries constituted only 4.1% of the PPCP budget. The

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substantive effects of the plan after a quarter of its execution period passed include 66,343 ineffective heat sources (old generation boilers) replaced with low-carbon ones in existing buildings (2.2% of the plan), reducing the emission of particulate matter with diameters lower than 10 micrometres (0.8% of the plan); reducing benzo(a)pyrene emission (ca. 1.4% of the plan); and reducing carbon dioxide emissions – 4.1% of the plan (NIK, 2022).

The data above suggest that despite public financial support, a limited number of users are ready to replace coal-fired furnaces with gas-fired ones as heating sources. The estimated annual heating cost for a 150 m^2 area property for a family of four and WT 2088 energy standard building (i.e. with low thermal insulation efficiency), considering the tariffs effective in Q3 2022 (Zieniewicz, 2022), will amount to ca. 5,710 PLN a year for natural gas heating. This heating season, the cost of heating with 84% and 64% efficiency boilers will amount to 11,570 PLN and 15,130 PLN, respectively, because of an increase in coal prices. In 2023, owing to a protection programme for gas users, the cost of gas heating will increase by ca. 40%, while the following year when the protection programme expires, the cost of heating will likely increase four-fold compared to 2022 and exceed 22,000 PLN. The cost of coal and wood heating should not rise by more than 40% compared to 2022. The heating cost ratios will be unfavourable for households using fuel gas, and the scale of disadvantage is expected to increase further in the future. Moreover, it will contribute to the discrimination scale in the access to fuel gas utilisation. It results from the fact that the disposable monthly income of a household, which amounted to ca. 2,100 PLN in 2021, would have to be spent almost entirely on fuel gas purchases in 2024. It means no funds left for paying the loans taken (even with preferential terms) for replacing a coal-fired heating system with a gas-fired one.

The prices of CO_2 emissions are another component influencing the cost-effectiveness of using natural gas. If coal was utterly replaced with gas in the Polish economy, it would reduce monthly CO_2 emissions by ca. 106 M tons, i.e. by ca. one-third (Izba Gospodarcza Gazownictwa & Instytut Studiów Energetycznych, 2022). Taking the EUA and EUAA licence trading prices on the spot ICE and EEX and forward market ("ICE EUA Futures Dec" for 2022-2028) of 70-100 EUR per tonne between 30 September and 31 October 2022, the value of the annual expenditure reduction for emission licences can be estimated as 33-47 bn PLN. Future prices should not be lower despite the proposals to extend the pool of licences submitted by some countries (including Poland) in the second half of 2022. The high prices of licences are supposed to stimulate the European countries' shift from a coal-based economy. Still, they will place a burden on natural gas users.

The estimations above indicate the potentially high economic efficiency of eradicating environmental pollution owing to eliminating coal from energy

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generation processes. Replacing coal with natural gas greatly depends on other attributes of sustainable energy management, including but not limited to durable security of satisfying energy needs (gas supply security) and related gas prices.

Due to the need to ensure continuous supplies after resigning from Russian gas in March 2022, the European Commission and member states established an EU energy platform for the voluntary joint purchase of gas, LNG and hydrogen (The EU's energy platform will fulfil three functions supporting the common purchase of gas (European Commission, 2022a):

- joining and structuring the demand,
- optimised and transparent use of infrastructure to transport, store and transmit gas, maximising the security of supplies and complementary storage,
- international actions: combined international actions focus on establishing a long-term collaboration framework with trusted partners through binding or non-binding agreements supporting the purchase of gas and hydrogen and the development of clean energy projects, fully leveraging on the EU's joint power.

The activities seem to be able to ensure continuous resource supplies in the short term. Still, they must go along with developing gas transmission and storage infrastructure. The infrastructure will be useful in the distant future for transporting and storing green and low-carbon gases (most likely also hydrogen, after modernising the equipment).

The gas price is the factor influencing the assessment of natural gas utilisation efficiency. The attempt made in 2022 to determine a dynamic price ceiling for imported gas in the EU did not lead to a consensus among the member states. There were proposals to establish the maximum dynamic price ceiling for transactions in the Title Transfer Facility (TTF) gas hub in the Netherlands, which sets the reference price for gas trade in Europe. It is a temporary solution until developing a new price index supplementing the TTF that will better reflect the increasing significance of liquid natural gas in the EU market. A request was made to fill at least 15% of gas storages in the EU through common purchases before spring 2023. Another request concerned a mandatory solidarity mechanism of sharing gas between the EU countries during the crisis.

The activities mentioned above improve the security of natural gas supplies to the EU countries at the expected prices. They do not essentially mean secure supplies to the users in the member states. Technical conditions causing discriminating access to energy can affect sustainable gas management development. In Europe, and so in Poland, the gas network development level and access to connection points (LPG terminals, gas pipelines) vary locally. It can jeopardise the transition of district heating systems where coal

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constitutes 73 per cent of the combusted fuel mix, while the share of gas amounts only to 9 per cent.

Research results

Summarising the analyses above, fulfilling the attributes of sustainable energy management can be evaluated through natural gas utilisation in Poland.

Natural gas does not ensure durable security of satisfying the energy needs because:

- at the current consumption level, natural gas resources from conventional and non-conventional sources will expire within a dozen or so years,
- there is a permanent risk of political instability in most mining regions of the world, aggravating the risk of supply discontinuation,
- gas storage possibilities are limited,
- increasing LNG supplies can be a costly alternative to transport in gas pipelines.

Energy generation, processing and utilisation safe for human health and the natural environment's balance are not fulfilled because:

- numerous environmental hazards occur at the gas mining stage,
- gas mining, transmission, and storage processes are uncontrolled emission sources,
- unstable political conditions and terrorist attack hazards pose the risk of damage to gas networks and storage.

It shall be highlighted that emissivity and other environmental impact forms of using gas for energy generation are lower than for other fossil fuels. Moreover, at the stage of gas utilisation, known and proven technologies are employed, meaning a high-security level.

The requirement of neutral impact on the natural environment would be fulfilled if emissions were limited to the pollution reception and reduction capacity level. Still, in reality, the impact of gas mining, transmission and storage highly exceeds their neutralisation capacity.

The prerequisite of using renewable resources on a scale enabling their renewal is not fulfilled because natural gas is not a renewable resource. Nonetheless:

- gas infrastructure can be used to support the development of renewable energy sources – biomethane and hydrogen,
- gas can be used for hydrogen generation in the conditions of limited availability of supplies from wind and photovoltaic units.

The evaluation of meeting the requirement of energy management economic efficiency in the long term, considering external costs, involves the following aspects:

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- natural gas utilisation enables shifting from coal and reducing emissions on condition that energy generation costs are comparable (including external costs internalised in the charges for carbon dioxide and methane emissions),
- due to international agreements on reducing climate effects, new gas projects cannot rely on external funding,
- the economic risk for the development of gas infrastructure and systems of gas utilisation for energy generation increases at the rising gas prices,
- for many entities, including but not limited to households, natural gas is a component of choice when adapting to the increasing prices of heating, which also applies to saving measures or changing the heating technology; at adequately designed economic control instruments, the economic balance can stimulate the entities to reduce their environmental impact,
- with the growing use of renewable energy sources with unstable energy generation efficiency, depending on weather conditions, reserving the energy in the generating units fired with natural gas ensures higher power grid flexibility.

Fulfilling the requirement of non-discriminating access to energy is limited for natural gas due to the following:

- limitations in the transmission and distribution network extension,
- limited flow capacity of interconnectors and limited gas storage volumes,
- relatively high costs of shifting to gas and the risk of relatively high operating costs after such adaptation.

On the other hand, LNG can become an alternative for entities in regions with no access to the power grid.

The general evaluation, based on the analysis and assessment of fulfilling partial attributes by natural gas management, leads to three conclusions:

- natural gas as an energy carrier does not meet the requirements of sustainable energy management,
- from the application point of view, natural gas utilisation is better than the use of other fossil fuels,
- in the RES and nuclear energy technology development, gas utilisation will decrease, which should bring positive effects for sustainable energy management.

Discussion/Limitation and future research

The documents developed by the European Union bodies – the European Commission, Council and Parliament, determine the approach and perspective for all member states' activities. They should significantly affect the solutions adopted in each country. Still, it does not mean that the directions and

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implementation rate of the solutions will be identical. The solutions proposed on the EU level can provide grounds for a discussion, based on Poland's example, the analysis and assessment of natural gas significance for sustainable energy management.

The approach to accepting natural gas as a component of sustainable energy management was discussed and amended under the so-called taxonomy. It is a common name for the Regulation of the European Parliament and the Council (EU) No. 2020/852 of 18 June 2022 on establishing the framework facilitating sustainable investments and amending Regulation (EU) No. 2019/2088. It is a collection of pan-European rules and technical indicators reflecting the EU's climate objectives and ambitions for each economic area. It is also the EU's response to climate change and an opportunity to increase the scale of sustainable investments.

Covering the gas energy sector with the EU taxonomy raised some controversies mainly because of its role in the EU's economic decarbonisation. From the beginning of the works on the EU taxonomy, the issue of atoms and gas was discussed. The essence of the issue was presented by Jones et al. (2020), who claimed that the whole existing energy generation based on natural gas could not be considered compliant with the taxonomy because the related activities have to contribute significantly to achieving the objectives of the Paris Agreement and not only to maintaining the status quo. The authors also pointed out that under many circumstances and in the transition period by 2050, natural gas would help reduce greenhouse gas emissions when compared, e.g. with coal, and will still play an essential role as a support for growing RES. They pointed out that too strict taxonomy criteria (e.g. mandatory use of zero-carbon options by 2050) or following an approach "universal for all" in reference to gas can render results contrary to the expected ones because such zero-carbon options are currently technologically immature or so expensive that even if they were described as a standard in the EU Taxonomy, they would not be used anyway, and the standard approach will not reflect the reality of the EU's electrical energy market. Therefore, the EU taxonomy shall orient investments towards the most sustainable option available, and the actual circumstances occurring during the investment implementation must be considered.

Commission Delegated Regulation (2021) is the first delegated act issued based on the EU taxonomy. It embraces types of operations, including detailed technical criteria which can be considered sustainable from the perspective of climate change and adaptation to climate change. The Regulation specifies superior conditions that the given business activity shall fulfil to be qualified as environmentally sustainable. Gas energy-related operations were initially not included in Regulation No. 2021/2139.

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In February 2022, a decision was made to include natural gas in the EU taxonomy but under some conditions. The draft was formally adopted on 9 March 2022 (Commission Delegated Regulation, 2022). It was justified by the fact that the EU taxonomy covers not only climate-neutral and renewable investments but also business operations that can enable shifting to a sustainable energy system under strict conditions and in a limited time. They are activities for which there are no alternative low-carbon solutions feasible technologically and economically, but they support the transition to a climate-neutral economy, alleviate climate change, comply with the EU's objectives and do not jeopardise the implementation of low-carbon solutions. The inclusion of gas into the taxonomy will help accelerate the transition from solid or liquid fossil fuels, including coal, towards a climate-neutral future.

The following investment types were considered sustainable:

- electrical energy generation from gas fossil fuels,
- high-performance heat/cool and energy generation from gas fossil fuels,
- heat/cool generation from gas fossil fuels in an efficient heating and cooling system.

All types of operations mentioned above are transient by nature. It is worth noting that according to the proposed delegated act, the objects under which the aforementioned actions are carried out should be designed and constructed to use renewable and/or low-carbon fuel gas. The transition to full use of renewable and/or low-carbon fuel gas should occur by 31 December 2035.

The reasons for the change in the EU's natural gas policy were diagnosed in the middle of 2022. Russia's attack on Ukraine provided an additional impulse to discuss the role of gas in reaching climate neutrality by 2050. In order to adhere to the Paris Agreement objective of 1.5°C, unlimited use of fossil gas would have to end much earlier – by 2035. The EU's current policy entails a risk of prolonged dependence on fossil gas rather than striving for alternative solutions, particularly in the heating sector. In response to Russia's war against Ukraine, the EU forces a wave of new fossil gas import projects, many of which will probably turn out unnecessary considering the decreasing gas demand in the EU. Decision-makers should be more active in developing an approach to an immediate withdrawal from the use of fossil gases, simultaneously building a sustainable, zero-carbon power grid (Schwarzkopf, 2022).

In the next three decades, the gas industry will be under intense pressure from public opinion and the EU's carbon dioxide emissions reduction and elimination regulations. According to critics, natural gas is not the right solution to reach the EU's climate neutrality despite lower emissivity than coal. Those who criticise the validity of fossil fuel utilisation as a source of negative climate changes in power engineering, transport and other sectors of the

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economy do not perceive the technological necessity to use natural gas in controlling power systems ensuring stable operation of other power systems, including the national grid.

Concluding, it can be stated that ambiguous policy defining the role of natural gas in energy and climate policy results from considering selected aspects of this energy carrier management. Such an approach typically focuses on one aspect. Initially, it was about limiting the emissivity from gas combustion for energy generation, followed by energy security issues. The ambiguity of the "sustainable energy" term in the EU's policy seems critical. It can be noticed in the European Commission's communication stating that transition to green energy is the only way to simultaneously ensure sustainable, secure and affordable energy worldwide (European Commission, 2022b). Energy sustainability was treated separately against security and affordability attributes, which essentially belong to sustainable energy management.

Therefore, an attempt should be made to thoroughly analyse gas's role in sustainable energy management. It seems purposeful to refer the evaluations not only to other fossil fuels whose consumption can be reduced owing to gas utilisation. The evaluations shall also include the issue of making energy management sustainable through the use of hydrogen or biomethane. It should answer whether maintaining natural gas in the energy mix created through the energy policy of the European Union and each member state will be favourable for sustainable energy management in a long-term perspective. Such an answer seems pivotal for Poland and other countries that can "leap" in their energy management development from the management stage dominated by fossil fuels to the power generation stage based on renewable energy sources. Then, it might turn out that entering the stage of a "transition" increases in the gas share in the energy mix, which can last a dozen or so years, is unnecessary.

Conclusions

The research issue is whether the energy and climate policy transition in reference to natural gas takes into account compliance with sustainable energy management. The issue is of particular significance for Poland, where the broad use of natural gas is perceived as a solution for improving energy management efficiency and reducing air pollution emissions.

Based on the analysis and evaluation of natural gas management fulfilling the criteria of sustainable energy management's partial attributes, the following conclusions were formulated:

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- natural gas as an energy carrier does not fulfil the requirements of sustainable energy management,
- from the point of view of utilisation effects, the use of natural gas for power generation purposes is better than using other fossil fuels,
- in RES and nuclear energy development conditions, using natural gas for power generation will decrease, which should bring positive results for sustainable energy management.

Energy transition in recent years has been triggered by factors other than the previous transition stages – shifting from renewable energy to coal and then to oil, gas and atom. They were mainly caused by economic and market factors. Using new energy generation forms caused more negative effects, including environmental pollution, greenhouse effect aggravation and more compromised security of energy supplies. The risk of resource exhaustion and adverse effects of the growing prices of resources were identified from a long-term perspective.

Although the article is theoretical, substantive evidence supporting the result and conclusions is reflected in the announced changes in energy policy. They indicate the need to abandon natural gas in a faster perspective than previously assumed.

The current energy transition is mainly driven by political factors. The EU's gas policy underwent a kind of evolution. Since 2015, it has emphasised the need to reduce the greenhouse effect. Natural gas was supposed to be used temporarily to enable shifting away from coal. Still, the progress in the development of renewable energy sources and the need to reduce supplies of energy carriers from Russia first resulted in perceiving natural gas as inadequate for the energy mix, but then some methods of its utilisation were considered compliant with the taxonomy criteria. It means treating natural gas as sustainable from the perspective of climate change and adaptation to climate change.

The deliberations presented in the article indicate the need for a comprehensive approach to the sustainable management of energy carriers. On the one hand, it means simultaneously considering many attributes of such management. On the other hand, the effects of the solutions proposed in the energy policy shall be analysed in a broader sustainability context, covering the use of other energy carriers in the long term.

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