SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 216

ENERGY SECURITY OF POLAND – ENERGY EFFICIENCY AND DEPENDENCE COMPARED TO THE EUROPEAN UNION

Karolina CZERWIŃSKA[1], Ryszard RADWAŃSKI[2], Andrzej PACANA[3*]

[1] Rzeszow University of Technology, Faculty of Mechanical Engineering and Aeronautics; k.czerwinska@prz.edu.pl, ORCID: 000-0003-2150-0963
[2] Association of Veterans and Reservists of the Polish Army in Warsaw; ryszard.radwanski@vip.onet.pl, ORCID: 0000-0002-2100-6845
[3] Rzeszow University of Technology, Faculty of Mechanical Engineering and Aeronautics; app@prz.edu.pl, ORCID: 0000-0003-1121-6352
* Correspondence author

Purpose: The aim of the study was to present the issue of energy efficiency and dependency as key factors in the country's energy security and to diagnose the current state of Poland's energy security against the background of the European Union.
Design/methodology/approach: The paper uses a descriptive and explanatory research method, primarily analysis of Eurostat data, as well as causal analysis based on a literature review.
Findings: The study presents quantitative ways of determining the level of energy security of a country and also presents rankings of EU countries in the context of energy efficiency and energy dependency. The study presents recommended development actions for Poland and the European Union to increase energy security.
Research limitations/implications: Constraints in the implementation of the research included difficult access to complete and adequate data or a complete lack thereof. Future research will concern the diagnosis and analysis of the energy mixes of CEE countries in the context of their energy security.
Practical implications: Development recommendations for the EU and Poland are presented (reducing the level of network losses in energy transmission and distribution, building highly efficient generation units, increasing the level of use of high-efficiency cogeneration and increasing end-use energy efficiency).
Originality/value: The analyses presented fill the research gap concerning the diagnosis of the level of efficiency and energy dependence (of Poland in comparison with EU countries) in the context of ensuring Poland's energy security.
Keywords: energy security, energy efficiency, energy mix, European energy policy, energy diversification.
Category of the paper: Research paper.

1. Introduction

Energy security is an important value in any country and is an end in itself. For many years, the issue relating to the future of energy has been one of the most significant issues considered within national and global politics (Belch et al., 2024). This is related to the energy sector's responsibility for progressive climate change, as well as to the concern to provide adequate amounts of energy for the years to come (Hajduk-Stelmachowicz, 2018). Long-term projections indicate that in 2050, humanity will consume energy at a level two or three times that recorded in 2010. During the 20th century, humanity's energy needs were mainly met by fossil fuels. However, depletion of deposits has contributed to a decline in the importance of fossil fuels (Wolniak et al., 2020; Esfahani et al., 2021).

Energy efficiency is an important pillar for maintaining energy security and increasing the competitiveness of the economy. This type of efficiency is a measure that indicates how efficiently energy is being managed. The most common measure of energy efficiency is the energy intensity of GDP. This figure expresses the ratio of energy consumption expressed in tonnes of oil equivalent (toe) to a country's gross domestic product (Pacana, Czerwińska, 2020). In Poland, the essence of energy efficiency is becoming increasingly important, resulting in the Energy Efficiency Act, which defines: the tasks of public sector entities in the field of energy efficiency, the rules for the implementation of the obligation to achieve energy savings, the rules for carrying out energy audits in enterprises and the rules for keeping a central register of final energy savings (Dyczkowska et al., 2024). In Poland, as of 22 May 2021, the provisions of the Act on amending the Energy Efficiency Act (Act of 20 April 2021 on amending the Energy Efficiency Act and certain other acts) entered into force. The Act implements a provision of the Directive of the European Parliament and of the Council (EU) on energy efficiency (Directive of the European Parliament and of the Council (EU) 2018/2002 of 11 December 2018 amending Directive 2012/27/EU on energy efficiency). The aforementioned law aims to adapt Polish law to the solutions provided for in the Directive, amended in 2018, which imposes increased obligations on Poland regarding the degree of final energy savings at the end of 2030 of 5580,000 toe. The primary target in the area of efficiency in addition to the targets set out in the European Union's efficiency directives is to achieve a 32.5 per cent reduction in energy consumption compared to 2035 projections as a result of energy efficiency improvements. Poland's energy efficiency in 2022. increased by 0.9 per cent in relation to 2021, while the annual cumulative growth rate of energy efficiency between 2012 and 2022 was 0.9 per cent. During this period, primary energy intensity of GDP was reduced by an average of 2.6% per year and final energy intensity of GDP by 2.4%. Industry saw the fastest rate of improvement in energy efficiency (up 1.9%). The level of total primary energy consumption increased between 2012 and 2022 from 92.8 Mtoe to 98.6 Mtoe (cumulative annual growth rate of 0.6%). Final energy consumption also increased in the period under

review from 64.4 to 72.4 Mtoe (cumulative annual growth rate of 1.2%). Total consumption reached its highest value in 2018 (104.1 Mtoe), and final energy consumption in 2021 (75.2 Mtoe) (www.ec.europa.eu/eurostat). However, despite systematic growth, the level of energy efficiency of the Polish economy is still not at a satisfactory level - it is approximately three times lower than the efficiency of economies in the most developed European countries and at the same time approximately twice as low as the average in European Union countries.

The current state of energy security within the Polish energy sectors varies significantly (Czerwińska, Pacana, 2019). In terms of heating and electricity based on its own hard coal and lignite resources, Poland is self-sufficient (Grebski, Ulewicz, 2022; Kwiatkowska et al., 2021). The gas and liquid fuels sector, is heavily dependent on imports, mainly from Russia. Poland has considerable renewable energy resources, but their use is at a relatively low level (Orłowska et al., 2024; Wolniak, Skotnicka-Zasadzień, 2022). Based on the country's fuel and energy balances, it becomes necessary to develop a long-term energy strategy that takes into account the growing needs of consumers (individual, industrial) and at the same time ensures energy security (Orman et al., 2020; Jursova et al., 2014). Therefore, attempts are being made to develop a new, adequate energy mix model that takes into account the needs of consumers and responds to the environmental challenges posed by the European Union. With regard to Poland, the new energy mix model should be largely based on high self-sufficiency. The current state of energy security within the Polish energy sectors varies significantly (Czerwińska, Pacana, 2019). In terms of heating and electricity based on its own hard coal and lignite resources, Poland is self-sufficient (Grebski, Ulewicz, 2022; Kwiatkowska et al., 2021). The gas and liquid fuels sector, is heavily dependent on imports, mainly from Russia. Poland has considerable renewable energy resources, but their use is at a relatively low level (Orłowska et al., 2024; Wolniak, Skotnicka-Zasadzień, 2022). Based on the country's fuel and energy balances, it becomes necessary to develop a long-term energy strategy that takes into account the growing needs of consumers (individual, industrial) and at the same time ensures energy security (Orman et al., 2020; Jursova et al., 2014). Therefore, attempts are being made to develop a new, adequate energy mix model that takes into account the needs of consumers and responds to the environmental challenges posed by the European Union. With regard to Poland, the new energy mix model should be largely based on high self-sufficiency.

Rational and responsible energy management improves energy security, translates into reduced pollutant emissions (especially carbon dioxide) and reduced expenditure on the purchase of renewable and non-renewable energy carriers (Czerwińska, Pacana, 2021; Orman et al., 2020). Measures that enhance energy security are now an essential determinant of a country's security and an objective of its security policy. The aim of this article was to present the issue of energy efficiency and dependence as key factors in the state's energy security and to diagnose the current state of Poland's energy security against the background of the European Union.

2. Concept of Polish energy security

Energy security is a concept that is complex and difficult to define unambiguously, however, in general terms it can be said to be about access to a variety of energy carriers and ensuring the continuity of their supply. The key to achieving energy security is to diversify sources of supply, use domestic resources, rationalise energy consumption, protect the environment, increase energy efficiency through the use of the latest technologies (Streimikiene, 2023; Kilinc-Pala, 2021).

The concept of energy security is defined in the Energy Law, which indicates that energy security is a state of the economy that makes it possible to cover the current and prospective demand of consumers for fuels and energy in a technically and economically justified manner, while maintaining the requirements of environmental protection (Law of 10 April 1997 Energy Law. Dz.U. 1997, No. 54, item 348, as amended, art. 3, p. 16). The most important entity to which the term energy security should apply to the greatest extent is the energy consumer. To a certain extent, consumers should be guaranteed energy at the required time, in the required quantity and form, and at an available price. The priority activity in terms of conducting energy policy is to take care of stable and uninterrupted supplies of energy carriers based on long-term contracts thanks to an independent industrial infrastructure that directly connects supply sources (including deposits) with the territory of Poland (Rosicki, 2023).

The main tasks of the state within the energy sector are considered to be ensuring a significant degree of energy security, which is understood as (Czerwińska, Pacana, 2024):

- security of supply by ensuring a certain quality and continuity of energy supply at a level that is determined by social and economic needs,
- economic security meaning that the cost of purchasing energy will not lead to energy poverty and will not create obstacles to economic development,
- environmental security, which ensures that energy generation will not contribute to excessive pollution and environmental degradation.

The level of energy security of a country depends on a considerable number of factors among which the key ones are (Fouladvand et al., 2024):

- balancing supply and demand for fuels and energy,
- diversification of supply sources (degree of dependence on imports),
- diversification of the structure of energy carriers making up the national fuel balance,
- economic conditions of energy companies, including their financial results,
- technical condition (efficiency) of power equipment and installations,
- size of fuel reserves,
- the state of regional energy security, i.e. the ability to satisfy energy needs at the level of local communities.

Energy security has an impact on almost every segment of the proper functioning of the state, as energy resources affect the ability of state bodies to carry out functional activities in the political, economic and environmental areas (Gitelman et al., 2023).

The political aspect involves the need for the state to carry out actions leading to the elimination or reduction of the possibility of political influence by entities that have the status of energy suppliers. The aim of the measures outlined is to achieve permanent access to energy resources by ensuring correct political relations with the states that have the resources of energy carriers and those states through whose territory they are transported (Aykin, 2024).

The economic context of energy security is largely concerned with features that indicate the proper functioning of the energy sector, which is linked to the health of the national economy and development. In this aspect, there is a correlation: the higher the level of energy security, the stronger and more stable the economy. Energy security is of strategic importance for each state in the aspect of broadly understood internal and national security and continuous economic development (and including changes in production capacity, economic relations, production, structure and mechanism of functioning of the economy, consumption and the environment) (Czerwińska, Pacana, 2022).

The environmental aspect concerns the minimisation of the negative consequences of the energy sector's impact on the natural and natural environment (Iyke, 2024). It refers to the energy management stage, which includes: acquisition of energy carriers, processing, transport and their use. Within each stage, there are specific risks that require the implication of adequate countermeasures. In this area, energy security is combined with environmental security (Grebski et al., 2022; Pacana, Czerwińska, 2023).

The European Union's climate and energy policy has a significant impact on the development and shape of the Polish energy sector in the run-up to 2050. This applies to conventional energy, renewable energy and prospective nuclear energy (Deirmentzoglou et al., 2024). The implementation of the 3×20 energy package and the EU ETS (European Emissions Trading Scheme) is closely linked to large capital expenditures in the area of modernising conventional energy sources (especially investments in low-carbon technologies), promoting the use of renewable energy sources, and considering the creation of nuclear energy (Pereira et al., 2024). Taking these actions is important with regard to meeting the stringent emission requirements of the IED (Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) and improving the level of energy efficiency.

3. Energy security of the Polish economy in relation to the EU-27 economy

3.1. Energy efficiency of the Polish economy compared to the EU economy

Energy efficiency is an integral part of energy security, sustainable development and belongs to modern energy policy. Improving energy efficiency means improving the energy intensity of the economy at the same time, as more final products can be obtained from a given amount of resources (Pacana et al., 2023). Therefore, the levels of primary energy consumption, final energy consumption, energy efficiency and energy self-sufficiency were analysed.

The primary energy consumption indicator measures a country's total energy demand, excluding any non-energy use of energy carriers (e.g. natural gas used not for combustion but for the production of chemicals). In 2023, the level of primary energy consumption in the EU was 1211 million tonnes of oil equivalent (Mtoe). The figures presented show a decrease of 3.9% compared to 2022. In 2023, the EU was still approaching the 2030 target of 992.5 Mtoe, currently the gap has narrowed to 22.0%. Figure 1 shows the level of primary energy consumption in EU countries in 2023.

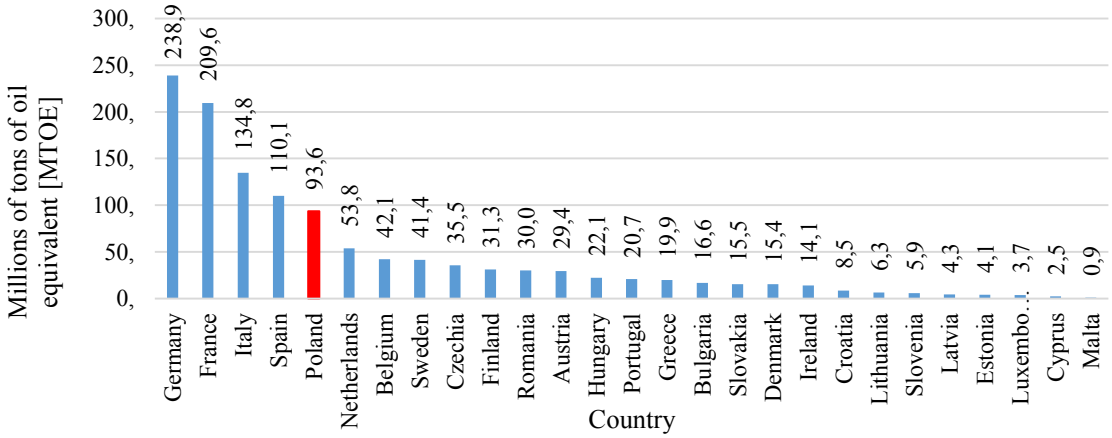

Figure 1. Primary energy consumption of European Union countries – 2023.

Source: Own elaboration based on: www.ec.europa.eu/Eurostat, 24.01.2025.

Among EU-27 countries, Poland ranked fifth in terms of primary energy consumption in 2023. This was a decrease in the level of consumption by 5.07% compared to 2022. The highest level of energy consumption (2.55 times higher than in Poland) was recorded in the German economy.

The final energy consumption indicator, only includes energy consumed by end users (industry, transport, households, services and agriculture) and does not include energy consumption in the energy sector or losses that occur during energy processing and distribution. The Council of the European Union has legislated to reduce final energy consumption at EU level by 11.7% in 2030. This means that a cap on EU final energy consumption of 763 million tonnes of oil equivalent will apply. Between 2024 and 2030, Member States will provide new annual savings averaging 1.49% of final energy consumption, until reaching 1.9% on

31 December 2030. Figure 1 indicates the level of final energy consumption of EU countries in 2023.

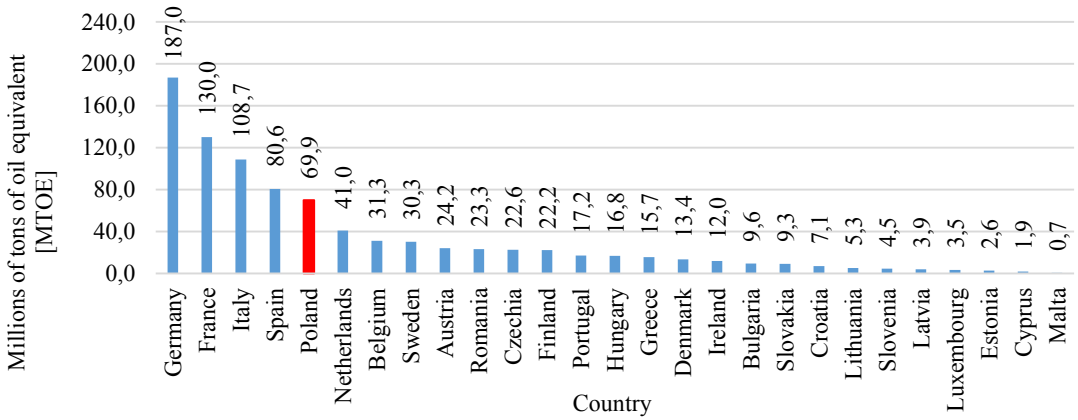

Figure 2. Final energy consumption of European Union countries – 2023.

Source: Own elaboration based on: www.ec.europa.eu/Eurostat, 24.01.2025.

The EU's final energy consumption was 894.4 Mtoe, a reduction of 3% compared to 2022. The EU has therefore moved closer to achieving the target listed in the Energy Efficiency Directive (EED) [Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC]. - 763 Mtoe in this case. The result of 894.4 Mtoe in final energy consumption was the second lowest since 1990, when data on this subject began to be collected. The level of Poland's final energy consumption was 69.9 Mtoe which contributed to the 5th place among EU countries. In relation to 2022, this level decreased by 2.23%.

In the context of energy efficiency, the values achieved by the EU countries do not show significant differences from the primary energy consumption data (Figure 3). EU energy efficiency in 2023 was 1210.77 Mtoe, a decrease of 3.89% on 2022 and 7.79% on 2021, respectively.

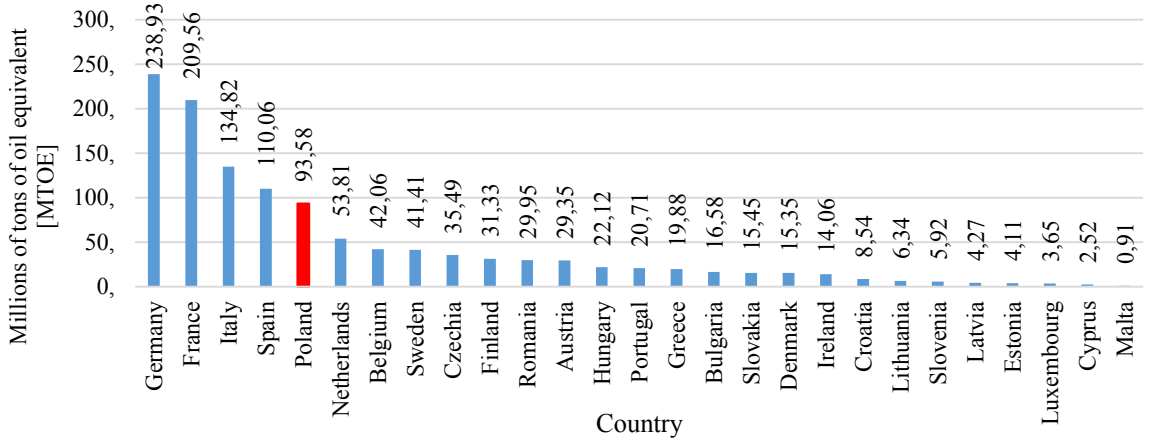

Figure 3. Energy efficiency of EU countries – 2023.

Source: Own elaboration based on: www.ec.europa.eu/Eurostat, 24.01.2025.

Poland has made significant progress in improving energy efficiency over the past 20 years, but further steps are necessary to achieve the efficiency levels recorded in the leading Western European countries. Poland's energy efficiency in 2023 osiagnene 93.58 Mtoe, the fifth highest among EU countries.

Considering energy efficiency, there is still a lot to be done in this area, especially in the case of Poland. Improving the level of energy efficiency will contribute to reducing the energy intensity of the economy and increasing energy stability and security.

3.2. Energy dependence of the Polish economy towards the EU economy

In order to diagnose the level of energy security, the energy dependency index was also used. This indicator is interpreted as follows: the higher the level of the energy dependency index, the lower the level of energy security in a given country. With the increase in the share of net energy imports in gross domestic energy consumption increased by stored energy, the level of energy security therefore decreases. Dependence on energy imports indicates the share of the country's total energy demand that is met thanks to imports from other countries (Elustu, 2021). This means that the indicator shows the proportion of energy that the economy must import.

The European Union's dependence on single suppliers is of concern and an important component of energy security. The EU seeks to improve the level of energy security by constructing a resilient, consolidated and open internal market, while exercising a multilateral and rules-based development perspective (Novikau, 2022; Elustu, 2021). Current geopolitical efforts and activities highlight the key role of controlling and minimising import dependency. Energy dependence on imports of energy carriers is associated with an increased exposure of the EU economy to the risk of supply shortages AND volatile world market prices. The risk increases with dependence on individual countries, for example determined by supply infrastructure. The level of energy dependency of EU countries in 2023 is shown in Figure 4.

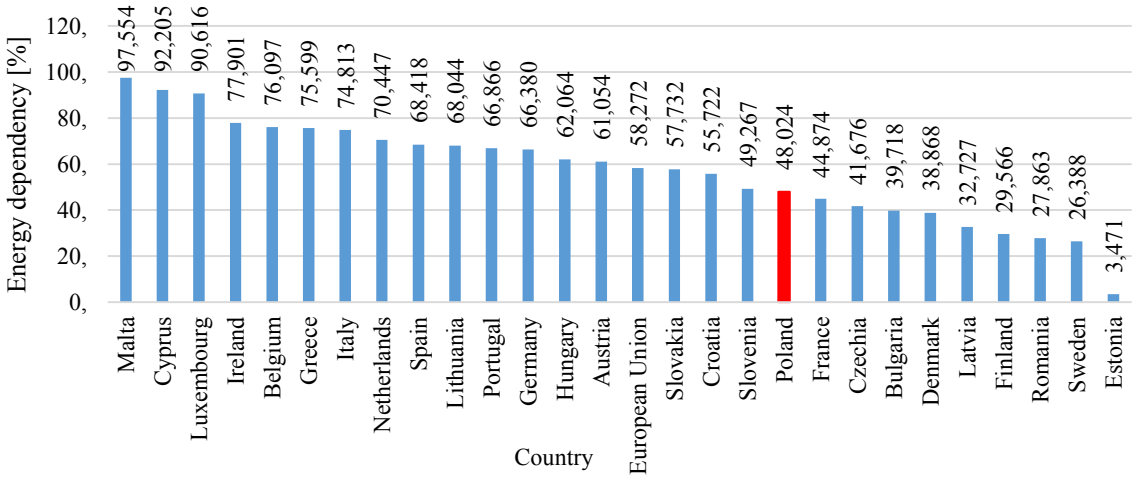

Figure 4. Energy dependency of EU countries – 2023.

Source: Own elaboration based on: www.ec.europa.eu/Eurostat, 24.01.2025.

Based on Figure 4, it can be concluded that Poland is one of the less dependent countries in terms of energy imports in Europe. A lower level of the energy dependency indicator in 2023 was only recorded in France, the Czech Republic, Bulgaria, Denmark, Lithuania, Finland, Romania, Sweden and Estonia. This shows that Poland is characterised by a relatively high level of energy security in relation to EU countries. This is due to the possession of a rich resource base and coal and lignite deposits that are important in this context.

The development of Poland's and the European Union's energy dependence in 2014-2023 is presented in Figure 5.

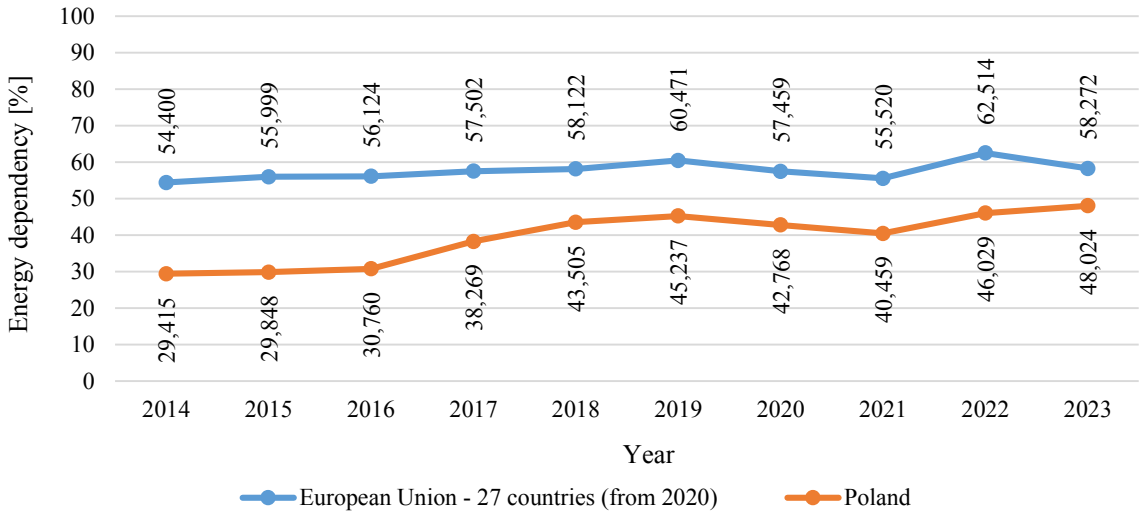

Figure 5. Energy dependency of Poland of the EU countries.

Source: Own elaboration based on: www.ec.europa.eu/Eurostat, 24.01.2025.

For the years 2014 to 2023 under consideration, the EU's energy dependency level oscillates between 54,400% and 62,514% (Figure 5). The lowest value of the EU indicator was reached in 2014, while the highest value was reached in 2022. In 2023, the EU recorded an indicator value of 58.727% (a decrease of 6.78% compared to the previous year). Poland shows a lower level of energy dependence on the EU over the analysed period, but a worrying increasing trend is noticeable. The range of values of the indicator for Poland was 29.415% (2014) - 48.024% (2023). Since 2021, Poland has seen an increase in the level of energy dependency every year. In 2022 an increase of 13.76% (compared to 2021) and 2023 an increase of 4.33% (compared to 2021).

In order to accelerate Poland's transition to a relatively inexpensive, reliable and sustainable energy system, and thereby increase energy independence and energy security, the country should conduct intensive research on clean energy, promote investment in energy infrastructure, and promote clean energy technology.

4. Conclusions and recommendations

In a globalized world, the proper functioning of countries is highly dependent on energy security. It is one of the conditions for the economic and technological development of a particular country. Therefore, the purpose of the article was to present the issue of energy efficiency and dependence as key factors in the energy security of the country, as well as a diagnosis of the current state of energy security of Poland against the background of the European Union.

Increasing energy efficiency in energy generation, transmission and use is key to the implementation of a sustainable energy policy, which is also expressed by national and EU legal regulations and through actions taken by national and EU institutions.

Improving the level of Poland's energy efficiency is crucial to achieving all national and EU energy policy goals and a significant number of environmental and climate policy goals. Therefore, improving energy efficiency should be a priority in modernizing the national economy. This is achievable by, among other things: reducing the level of network losses in energy transmission and distribution, building highly efficient generating units, increasing the level of application of high-efficiency cogeneration and increasing the efficiency of energy end-use.

In recent years, Poland has achieved a relatively low rate of energy dependence in relation to other European Union countries, which indicates a relatively high level of energy security. The key factors that affect the achieved level of energy dependence are the degree of diversification of sources of supply (domestic and foreign) of energy resources, the size and diversity of the domestic fuel base, the possibility of fuel storage, the technical condition and forms of ownership of infrastructure, and the development of national and international energy policy.

EU countries, in order to achieve the expected level of energy security, are forced to develop and undertake a number of specific measures. To a large extent, they should be oriented towards increasing the competitiveness of the EU energy sector. A requirement of which is to ensure identical operating conditions for all countries of the EU energy market. At present, the key seems to be to increase the security of energy supply, which is related to ensuring stable conditions allowing to cover the current and future demand of EU economies.

Future research will deal with the diagnosis and analysis of the energy mixes of Central and Eastern European countries in the context of their energy security.

References

1. Aykin, I. (2024). Sustainable Power: Transformations In Global Energy Security. *Turkish Policy Quarterly, Vol. 23, Iss. 2,* pp: 120-128. DOI: 10.58867/KXRD2370.
2. Bełch, P., Szczygieł, E., Hajduk-Stelmachowicz, M. (2024). Electromobility in Poland Against the European Union–Results of Preliminary Analysis. *Research Papers of Wroclaw University of Economics and Business, Vol. 68, Iss. 1*.
3. Czerwińska, K., Pacana, A. (2019). Quality analysis in the supply chain of transported LNG. *Energy Policy Studies*, *Vol. 2, Iss. 4*, pp. 3-18.
4. Czerwińska, K., Pacana, A. (2021). Analysis of the Possibility Of Using KPIs in Measuring the Achievements of Business Entities from the Energy Sector-Case Study. *Energy Policy Studies, Vol. 1, Iss. 7*, pp. 41-53.
5. Czerwińska, K., Pacana, A. (2022). Analysis of the maturity of process monitoring in manufacturing companies. *Production Engineering Archives*, *Vol. 28, Iss. 3*, pp. 246-251.
6. Czerwińska, K., Pacana, A. (2024). Analysis of Energy Security Based on Level of Alignment with the Goals of Agenda 2030. *Energies, Vol. 17, Iss. 2*, p. 2831. DOI: 10.3390/en17122813.
7. Deirmentzoglou, G.A., Anastasopoulou, E.E., Skilias, P. (2024). International economic relations and energy security in the European Union: a systematic literature review. *International Journal Of Sustainable Energy*, *Vol. 43, Iss. 1*. DOI: 10.1080/14786451.2024.2385682.
8. Dyczkowska, J.A., Chamier-Gliszczynski, N., Wozniak, W., Stryjski, R. (2024). Management of the Fuel Supply Chain and Energy Security in Poland. *Energies, Vol. 17, Iss. 2*. DOI: 10.3390/en17225555.
9. Dyrektywa Parlamentu Europejskiego i Rady (UE) 2018/2002 z dnia 11 grudnia 2018 r. zmieniająca dyrektywę 2012/27/UE w sprawie efektywności energetycznej.
10. Dyrektywa Parlamentu Europejskiego i Rady 2010/75/UE z dnia 24 listopada 2010 roku, w sprawie emisji przemysłowych.
11. Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE z dnia 25 października 2012 r. w sprawie efektywności energetycznej, zmiany dyrektyw 2009/125/WE i 2010/30/UE oraz uchylenia dyrektyw 2004/8/WE i 2006/32/WE.
12. Elustu, S. (2021). Energy Import Dependency and Economic Growth. *Istanbul Iktisat Dergisi-Istanbul Journal of Economics*, *Vol. 71, Iss. 1*, pp. 133-162. DOI: 10.26650/ISTJECON2021-942116.
13. Esfahani, A.N., Moghaddam, N.B., Maleki, A., Nazemi, A. (2021). The knowledge map of energy security. *Energy Reports*, *Vol. 7,* pp. 3570-3589. DOI: 10.1016/j.egyr.2021.06.001.

14. Fouladvand, J., Sari, Y., Ghorbani, A. (2024). Infrastructure and governance: Prioritising energy security dimensions for community energy systems. *Energy Research & Social Science, Vol. 116*. DOI: 10.1016/j.erss.2024.103676.
15. Gierszewski, J., Mlynarkiewicz, L., Nowacki, T.R., Dworzecki, J. (2021). Nuclear Power in Poland's Energy Transition. *Energies, Vol. 14, Iss. 12*. DOI: 10.3390/en14123626.
16. Gitelman, L., Magaril, E., Kozhevnikov, M. (2023). Energy Security: New Threats and Solutions. *Energies, Vol. 16, Iss. 6*. DOI: 10.3390/en16062869.
17. Grebski, M.E., Czerwińska, K., Pacana, A. (2022). Swot analysis of individual components within the innovativeness ecosystem. *Modern Management Review*, *Vol. 27, Iss. 2*, pp. 57-66.
18. Grebski, W., Ulewicz, R. (2022). Heat and power system as an independent source of electric power. Case study. *Management Systems in Production Engineering*, *Vol. 30, Iss. 3*, pp. 626-686.
19. Hajduk-Stelmachowicz, M. (2018). Atrybuty systemu zarządzania energią. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, 538.* Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu, pp. 155-163.
20. Ingaldi, M., Klimecka-Tatar, D. (2020). People's attitude to energy from hydrogen—from the point of view of modern energy technologies and social responsibility. *Energies, Vol. 13, Iss. 24*, p. 6495. DOI: 10.3390/en13246495.
21. Iyke, B.N. (2024). Climate change, energy security risk, and clean energy investment. *Energy Economics*, *Vol. 129*. DOI: 10.1016/j.eneco.2023.107225.
22. Jursova, S., Ingaldi, M., Kardas, E. (2014). Legislacyjne wsparcie wykorzystania alternatywnych źródeł energii w Republice Czeskiej iw Polsce. *Rynek energii*, *5*, p. 144.
23. Kilinc-Paca, P.B. (2021). Approaches in Energy Exclusive Security: Theories of Energy Security and the Dominance of Realism. *Politics & Policy*, *Vol. 49, Iss. 3,* pp. 771-794. DOI: 0.1111/polp.12411.
24. Kwiatkowska, A., Gajdzik, B., Wolniak, R., Vveinhardt, J., Gębczyńska, M. (2021). Leadership competencies in making Industry 4.0 effective: the case of Polish heat and power industry. *Energies*, *Vol. 14, Iss. 14*, p. 4338. DOI: 10.3390/en14144338.
25. Novikau, A. (2022). Rethinking demand security: Between national interests and energy exports. *Energy Research & Social Science*, *Vol. 87*. DOI: 10.1016/j.erss.2022.102494.
26. Orłowska, J., Suchacka, M., Trembaczowski, Ł., Ulewicz, R. (2024). Social Aspects of Establishing Energy Cooperatives. *Energies, Vol. 17, Iss. 22*, p. 5709. DOI: 10.3390/en17225709.
27. Orman, Ł.J., Radek, N., Pietraszek, J., Szczapaniak, M. (2020). Analysis of Enhanced Pool Boiling Heat Transfer on Laser—Textured Surfaces. *Energies, Vol. 13, Iss. 11*, p. 2700. DOI: 10.3390/en13112700.
28. Pacana, A., Czerwińska, K. (2020). Analysis of energy efficiency in Poland in 2008-2018 in the context of sustainable development. *Energy Policy Studies*, *Vol. 2, Iss. 6*, pp. 29-42.

29. Pacana, A., Czerwińska, K. (2023). A Quality Control Improvement Model That Takes into Account the Sustainability Concept and KPIs. *Sustainability*, *Vol. 15, Iss. 12*, p. 9627. DOI: 10.3390/su15129627.
30. Pacana, A., Czerwińska, K., Ostasz, G. (2023). Analysis of the level of efficiency of control methods in the context of energy intensity. *Energies, Vol. 16, Iss. 8*, p. 3507. DOI: 10.3390/en16083507.
31. Pereira, M.B., Robaina, M., Silva, S. (2024). *Energy security in the European Union - main determinants.* 2024 20th International Conference on the European Energy Market, EEM 2024. DOI: 10.1109/EEM60825.2024.10608952.
32. Piwowar, A., Dzikuc, M. (2022). Water Energy in Poland in the Context of Sustainable Development. *Energies, Vol. 15, Iss. 21*. DOI: 10.3390/en15217840.
33. Rosicki, R. (2023). *Energy Security of Central and Eastern European Countries*. Politics and Security of Central and Eastern Europe, pp. 215-235. DOI: 10.1007/978-3-031-16419-4_11.
34. Streimikiene, D. (2023). Energy Supply Security in Baltic States. *Montenegrin Journal of Economics, Vol. 19, Iss. 3*, pp. 125-135. DOI: 10.14254/1800-5845/2023.19-3.14.
35. Ustawa z dnia 10 kwietnia 1997 r. Prawo energetyczne. Dz.U. 1997, nr 54, poz. 348, z póź. zmianami, art. 3, p. 16.
36. Ustawa z dnia 20 kwietnia 2021 r. o zmianie ustawy o efektywności energetycznej oraz niektórych innych ustaw.
37. Wiśniewski, R., Daniluk, P., Nowakowska-Krystman, A., Kownacki, T. (2022). Critical Success Factors of the Energy Sector Security Strategy: The Case of Poland. *Energies, Vol. 15, Iss. 17*. DOI: 10.3390/en15176270.
38. Wolniak, R., Saniuk, S., Grabowska, S., Gajdzik, B. (2024). Identification of energy efficiency trends in the context of the development of industry 4.0 using the Polish steel sector as an example. *Energies, Vol. 13, Iss. 11*, p. 2867. DOI: 10.3390/en13112867.
39. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies, Vol. 15, Iss. 2*, p. 662. DOI: 10.3390/en15020662.
40. Wolniak, R., Skotnicka-Zasadzień, B. (2023). Development of wind energy in EU countries as an alternative resource to fossil fuels in the years 2016-2022. *Recources, Vol. 12, Iss. 8*, p. 96. DOI: 10.3390/resources12080096.
41. www.ec.europa.eu/eurostat