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Energy Security Management in the Context of Technological Development and Legal Regulations

Zarządzanie bezpieczeństwem energetycznym w kontekście rozwoju technologicznego i regulacji prawnych

Abstract

The article contains an analysis of key aspects of energy security management in Poland, taking into account the impact of technological development and legal regulations. In the context of the dynamically changing energy landscape, the Authors emphasize the role of stable energy supplies as the foundation of modern societies. They describe how technological innovations, such as renewable energy sources (RES) and smart grids, support the reliability of supplies. They also present the importance of key legal regulations, both national and EU, in implementing a sustainable, stable and secure energy system.

Keywords: energy security, renewable energy sources, legal regulations, diversification, smart grids

Streszczenie

Artykuł zawiera analizę kluczowych aspektów zarządzania bezpieczeństwem energetycznym w Polsce, uwzględniając wpływ rozwoju

technologicznego i regulacji prawnych. W kontekście dynamicznie zmieniającego się krajobrazu energetycznego, Autorzy podkreślają rolę stabilnych dostaw energii jako fundamentu nowoczesnych społeczeństw. Opisują, jak innowacje technologiczne, takie jak np. odnawialne źródła energii (OZE) i inteligentne sieci, wspierają niezawodność dostaw. Przedstawiają także znaczenie kluczowych regulacji prawnych, krajowych i unijnych, w implementowaniu zrównoważonego, stabilnego i bezpiecznego systemu energetycznego.

Słowa kluczowe: bezpieczeństwo energetyczne, odnawialne źródła energii, regulacje prawne, dywersyfikacja, inteligentne sieci

Introduction

Energy security is one of the pillars of the functioning of modern states, because almost every area of everyday life and the entire technical infrastructure are directly dependent on stable and reliable energy supplies. The lack of energy not only disrupts basic economic processes, but also directly threatens the health, safety and quality of life of citizens[1].

In the area of public safety, energy plays a key role. One of the important components of this infrastructure are water and sewage systems, which are fully dependent on stable electricity supplies. Their proper operation requires power both for pumping and distributing water, as well as for sewage treatment and waste management. An efficient sanitary network directly affects social health, disease prevention and the quality of life of residents – especially in large, densely populated cities.

The role of energy in the operation of systems responsible for maintaining order is equally important. City monitoring, traffic lights and alarm devices are powered by electricity and play an important role in preventing threats and rapid response of services. Their failure can lead to disruptions in road traffic, increased crime or difficulties in rescue operations.

The healthcare sector is another example where power reliability is key. Hospitals, laboratories and clinics rely on advanced medical equipment – from ventilators to CT scanners – that requires uninterrupted

[1] J. Fouladvand, Y. Sarı, A. Ghorbani, *Infrastructure and governance: Prioritising energy security dimensions for community energy systems*, "Energy Research & Social Science" 2024, 116, 103676.

access to energy. A power outage can pose a serious threat to the lives of patients, especially those in intensive care units or operating rooms[2].

In the age of digitalization, energy security is also fundamental to the telecommunications and IT sector. Servers, data centres and network infrastructure enable the functioning of public services, electronic banking and interpersonal communication. Any power outage can disrupt these processes and lead to serious economic and information losses[3].

Education is also becoming increasingly dependent on modern technologies that require stable power supply. Interactive boards, computers, e-learning platforms – all of this is an everyday occurrence in schools and universities. During remote learning, access to energy and the Internet is a condition for basic equality of educational opportunities, especially for children and young people from smaller towns.

The development of the transport sector also has a significant impact on energy security. The growing popularity of electromobility, including electric buses, trams and private vehicles charged from the network, requires an appropriate energy base. Additionally, road and rail traffic control systems are fully automated and dependent on uninterrupted power supply, and their failures can paralyze communication in cities[4].

In the economy, energy is indispensable for industry, logistics and services. Production plants, storage centres, cold stores and server rooms must operate continuously. Power outages lead to financial losses, damage to machines and the risk of data loss, which negatively affects the stability of the entire economic system.

Finally, the everyday needs of citizens cannot be ignored. Air conditioning, heating, lighting, ventilation, charging phones or using household appliances are activities that absolutely depend on energy. Particularly vulnerable groups are the elderly, children and people with disabilities, for whom a lack of electricity can mean a real threat to health and life[5].

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[2] A.L. Soares, S.C. Buttigieg, B. Bak, S. McFadden, C. Hughes, P. McClure, J.G. Couto, I. Bravo, *A review of the applicability of current green practices in healthcare facilities*, "International Journal of Health Policy and Management" 2023, 12, 6947.

[3] P.F. Borowski, *Digital Transformation and Prosumers Activities in the Energy Sector*, [in:] C. Kahraman, E. Haktanır (eds), *Intelligent Systems in Digital Transformation: Theory and Applications*, Cham 2022, pp. 129-150.

[4] P.F. Borowski, *Innovation management in transport – an economic perspective in the era of climate transformation*, "Transport Problems" 2025, vol. 20, iss. 2.

[5] G. Jiglau, M. Hesselman, A. Dobbins, K. Grossmann, R. Guyet, S. Tirado Herrero, A. Varo, *Energy and the social contract: From energy consumers to people with a right to energy*, "Sustainable Development" 2024, 32(1), pp. 1321-1336.

For these reasons, energy security should not be treated solely as a technological or economic issue, but as a strategic element of state policy, having a direct impact on the functioning of society. Investments in infrastructure, diversification of energy sources, development of renewable technologies and storage systems are necessary, which will ensure resistance to crises and guarantee continuity of supply. This is the only way to maintain a high quality of life and social stability in a dynamically changing world.

1. Methodology

In this study, the desk research method was applied, based on a systematic review of scientific literature, industry reports, regulatory documents, and legal acts, including laws, regulations, and directives, as well as analyses prepared by international and national institutions dealing with energy security issues. The analysis covered both theoretical sources, presenting the foundations of management sciences and concepts related to energy security, and practical sources, including case studies, government agency reports, and studies of international organizations such as the International Energy Agency, the European Commission, or national regulatory bodies. The main objective of the study was to identify the key technological and regulatory determinants shaping energy security management strategies, with particular emphasis on the development of technologies enhancing system and the analysis of legal regulations and public policies concerning security of supply and decarbonization. The advantage of this method lies in its broad access to interdisciplinary knowledge, encompassing the fields of management sciences, energy law, technology, and public policy, which allows for a comprehensive approach to the problem. Desk research is also cost- and time-efficient, as it does not require significant organizational resources while enabling quick access to cross-sectional information. By analyzing industry reports, regulatory and legal documents—including laws, regulations, and directives—it is possible to capture the latest technological and legislative trends, while comparing the experiences of different countries helps identify best practices in energy security management. This method also provides solid theoretical and practical foundations for further empirical research and allows the formulation of actionable conclusions

for policymakers and energy sector managers. Moreover, desk research enables the identification of research and regulatory gaps, for instance concerning the impact of new EU regulations on technological innovation or the role of distributed energy sources in ensuring system stability.

2. Literature Review

The concept of energy security has been systematically analyzed in the academic literature for over two decades. Novikau provides a comprehensive review of this issue within the field of security studies, emphasizing the evolution of definitions, methodological approaches, and the growing interconnections between energy policy and environmental issues[6]. These studies show that energy security is no longer viewed solely through the lens of supply stability but increasingly as a multidimensional construct encompassing geopolitical, technological, and climate aspects.

The link between global energy politics and climate change is further highlighted in the volume edited by Singh and Ao, which situates energy transitions within the broader framework of international relations and global environmental governance[7]. The authors underline the complexity of reconciling decarbonization goals with geopolitical energy dependencies.

From a technological perspective, Duan et al. examine the process of coal gasification in a CO_2 atmosphere, offering theoretical insights into the use of slag waste heat. Their findings indicate both opportunities and technological challenges related to emission reduction in fossil fuel–based processes[8]. Complementing this discussion, Nibedita and Irfan present an econometric analysis of energy mix diversification in emerging economies, identifying economic, political, and institutional determinants that shape countries' ability to shift toward more sustainable energy portfolios[9]. Similarly, Gitelman et al. argue that diversification of energy

[6] A. Novikau, *Energy security in security studies: A systematic review of twenty years of literature*, "Central European Journal of International and Security Studies" 2023, 17(3), pp. 36-64.

[7] P. Singh, B. Ao (eds.), *The Intersection of Global Energy Politics and Climate Change. Advances in Geographical and Environmental Sciences*, Singapore 2025.

[8] W. Duan, R. Li, S. Yang, J. Han, X. Lv, Z. Wang, Q. Yu, *Theoretical study on coal gasification behavior in CO2 atmosphere driven by slag waste heat*, "Energy" 2024, 305, 132269.

[9] B. Nibedita, M. Irfan, *Energy mix diversification in emerging economies: An econometric analysis of determinants*, "Renewable and Sustainable Energy Reviews" 189, 114043.

supply represents a key method for strengthening system resilience and ensuring long-term stability in the context of the energy transition[10].

At the political level, Borowski analyzes the paradoxical phenomenon of simultaneous green energy development and a return to fossil fuels in response to the 2022 energy crisis. This dynamic illustrates the fragile balance between long-term decarbonization strategies and the short-term necessity of ensuring energy security, a balance that continues to influence the policies of the European Union and other states[11]. Building on this theme, Borowski points to the pivotal role of hydrogen both as an energy carrier and as a form of storage, emphasizing its potential in stabilizing energy systems and decarbonizing industry[12].

In the broader context of management and digital transformation, the volume edited by Kahraman and Haktanır demonstrates how intelligent systems and digital tools support energy transition processes[13]. The development of digital technologies—such as artificial intelligence, predictive systems, and advanced data analytics—finds increasing application in monitoring, optimizing, and managing energy security, highlighting the growing importance of innovation in this field.

The regulatory and legal framework of the European Union plays a key role in shaping energy security and market design. Directive (EU) 2019/944 established the foundations of common rules for the functioning of the internal electricity market, strengthening consumer rights and promoting market integration[14]. The more recent Directive (EU) 2024/1711 introduced reforms aimed at improving the design of the EU electricity market, with a focus on greater flexibility, resilience, and integration of renewable energy sources[15]. In parallel, Directive (EU) 2024/1788 established new rules for the internal markets of renewable gases, natural gas, and hydrogen, underscoring the EU's commitment

[10] L. Gitelman, M. Kozhevnikov, Y. Visotskaya, *Diversification as a method of ensuring the sustainability of energy supply within the energy transition*, "Resources" 2023, 12(2).
[11] P.F. Borowski, *Mitigating climate change and the development of green energy versus a return to fossil fuels due to the energy crisis in 2022*, "Energies" 2022, 15(24), 9289.
[12] P.F. Borowski, *Innovation management in transport…*, iss. 2.
[13] C. Kahraman, E. Haktanır (eds), *Intelligent Systems in Digital Transformation: Theory and Applications*, Cham 2022.
[14] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (i.e. OJ L 158 14.6.2019).
[15] Directive (EU) 2024/1711 of the European Parliament and of the Council of 13 June 2024 amending Directives (EU) 2018/2001 and (EU) 2019/944 as regards improving the Union's electricity market design, (i.e. OJ L, 2024/1711).

to low-emission alternatives and long-term security of energy supply[16]. Additionally, Regulation (EU) 2024/1747 amended existing market regulations, focusing on improving the functioning of the electricity market by enhancing its stability and transparency, thereby further supporting the objectives of the energy transition[17].

The reviewed works illustrate the multifaceted nature of research on energy security. The literature encompasses both theoretical and empirical perspectives, addressing issues of technological innovation, economic diversification, and the impact of energy crises, while EU regulations and directives provide binding legal frameworks that translate scholarly insights and political commitments into concrete action. The integration of these perspectives underscores that energy security in the 21st century should be understood as a dynamic process shaped by technological progress, regulatory evolution, and the tensions between sustainable development goals and short-term geopolitical conditions.

3. Energy Security

Energy security can be defined in various ways, depending on the perspective adopted – political, economic, technological or environmental. In geopolitical terms, it focuses on the independence of states from external suppliers of energy resources and on the ability to protect critical infrastructure. The economic perspective emphasizes the importance of energy price stability and its availability to both consumers and industry. In the technical approach, the reliability of transmission networks, the flexibility of energy systems and the ability to respond to sudden disruptions are key. The environmental approach is also becoming increasingly important, emphasizing the need for energy transformation towards renewable energy sources and improving energy efficiency as the basis for long-term security. In public policy practice, responses to threats to energy security continue to focus on foreign policy actions, diversification

[16] Directive (EU) 2024/1788 of the European Parliament and of the Council of 13 June 2024 on common rules for the internal markets for renewable gas, natural gas and hydrogen, amending Directive (EU) 2023/1791 and repealing Directive 2009/73/EC, (i.e. OJ L, 2024/1788).

[17] Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 amending Regulations (EU) 2019/942 and (EU) 2019/943 as regards improving the Union's electricity market design, (i.e. OJ L, 2024/1747).

of energy suppliers and sources, increasing domestic energy efficiency and creating strategic reserves[18].

One of the most recognized definitions of energy security is presented by the International Energy Agency (IEA), according to which it is the ability to ensure uninterrupted energy supplies at affordable prices and in a sustainable manner. According to the IEA, energy security is based on three pillars: availability, i.e. the continuity of supply and the resilience of energy systems to crises and disruptions; affordability, which means the ability of all social groups to use energy without excessive financial burden; and sustainable development, including actions to protect the environment, promote renewable energy sources and rational management of natural resources[19].

This comprehensive approach allows us to build modern and resilient energy systems that respond to both the current needs of societies and the long-term challenges related to energy transformation and climate change.

1. Availability means not only the physical presence of energy, but also the ability of the system to respond to crises. A key aspect here is redundancy – the development of alternative sources and technologies that can replace basic supplies in the event of infrastructure failure or disruptions in the raw material chain. Flexibility and resilience of the system are essential to meet changing demand and threats, such as extreme weather events or droughts that limit hydropower production. Only such a system can ensure stable energy supplies in various conditions. Availability also means continuity of supply, which translates into minimizing the risk of blackouts, i.e. long-term and extensive power outages that can paralyze the functioning of entire regions or even countries. Energy continuity is therefore becoming a basic condition for the security of critical infrastructure and the everyday lives of citizens.
2. Affordability concerns maintaining energy costs at a socially acceptable level, with special protection for people with lower incomes, who are most sensitive to price fluctuations. At the same time, low prices cannot exclude investment – the development of infrastructure and

[18] A. Novikau, *Energy security in security studies*…, pp. 36-64.

[19] A. Sonowal, B. Ao, *Energy Security and Sustainability: Lessons and Future Challenges*, [in:] P. Singh, B. Ao (eds.), *The Intersection of Global Energy Politics and Climate Change. Advances in Geographical and Environmental Sciences*, Singapore 2025, pp. 373-387.

the implementation of modern technological solutions, including renewable energy sources, are necessary actions leading to increased efficiency and stability in the long term. Affordability is also a key element in the fight against energy poverty, a situation in which households are unable to provide themselves with an adequate level of heating, cooling, lighting or power supply for devices necessary for life. Reducing this phenomenon is important not only from the point of view of social justice, but also for ensuring social cohesion and public health.

3. Sustainable development focuses on environmental protection and the rational use of natural resources. A key role here is played by the transformation towards renewable energy sources – wind, sun, water and biomass – which are an alternative to fossil fuels. In parallel, energy efficiency should be promoted: buildings should be modernised, low-emission industrial technologies should be implemented and the management of transmission networks should be optimised. The aim is not only to reduce emissions, but also to ensure long-term access to energy by investing in resources that are less prone to depletion.

Energy security in the IEA's understanding is therefore not only a matter of current energy availability, but also its social justice and ecological responsibility. Only a balance between these three pillars will allow the construction of a system that is resistant to crises, friendly to the environment and accessible to all citizens.

3.1. Actions to Ensure Energy Security

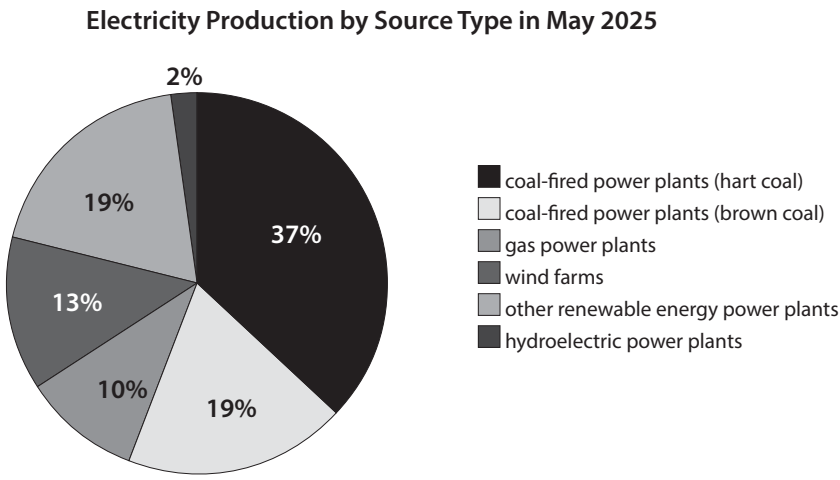
Energy security depends largely on the diversification of both energy sources and the directions of their supply. A diversified energy mix reduces the risk of excessive dependence on one type of fuel, while the development of alternative import routes – such as interconnections or LNG terminals – allows independence from a single supplier. Both of these elements strengthen the system's resistance to disruptions and increase its stability.

3.2. Diversification of Energy Sources

Diversification of energy sources is one of the foundations of energy security, as it reduces the risk associated with excessive dependence on

one type of fuel or one supplier. A diversified energy mix increases the resilience of the system to disruptions, both technological and geopolitical. In this context, the development of renewable energy sources – such as wind, solar or water – is of particular importance, as they not only contribute to reducing greenhouse gas emissions, but also make the national energy system independent of fossil fuel imports. Figure 1 shows the share of individual sources in electricity production in Poland in May 2025.

Figure 1: Share of individual types of sources in the energy mix



Source: own study based on https://www.pse.pl/dane-systemowe

At the same time, it is worth investing in innovative infrastructure that enables the production of energy from coal with minimal or zero carbon dioxide emissions. Technologies such as CO_2 capture and storage (CCS) or more advanced coal gasification methods can help reduce the carbon footprint, while using existing domestic resources. Implementing such solutions can be an element that increases energy security and reduces the economic pressure associated with the import of energy or raw materials[20].

[20] W. Duan, R. Li, S. Yang, J. Han, X. Lv, Z. Wang, Q. Yu, *Theoretical study on coal gasification behavior in CO2 atmosphere*…, 132269.

Investments in onshore and offshore wind farms and the expansion of photovoltaic installations allow for a dynamic increase in domestic generation capacity, while adapting it to climatic and geographical conditions. However, effective integration of RES (renewable energy sources) with the power system requires significant expenditure on the modernization of transmission networks and the development of energy storage technologies. This is the only way to ensure the stability of supplies in the case of variable energy production from wind or sun. It is also crucial here to create an appropriate regulatory framework that will support the development of green energy and encourage investors to engage in the long term.

In addition to renewable energy, nuclear energy also plays an important role in diversification, offering a stable, zero-emission energy source that can be planned and scaled. Modern nuclear power plants can act as a stabiliser for a system largely based on variable renewable energy sources. In parallel, modern gas power plants are being developed, which – thanks to the possibility of adapting to hydrogen combustion – can be a transitional element on the way to climate neutrality. However, due to fluctuations in gas prices and its import nature, the long-term strategy should assume a gradual reduction of its share in the energy mix[21].

Diversification of energy sources is not only a response to the challenges related to security of supply, but also an element of a long-term energy transformation towards a more sustainable, flexible and resilient energy system.

3.3. Diversification of Energy Supply Routes

The energy supply diversification strategy focuses on expanding import routes, developing alternative sources of energy generation, and modernizing the transmission infrastructure – all of which contribute to increasing the country's energy stability and security. Diversification of energy sources brings full benefits only when accompanied by an equally well-thought-out diversification of supply routes. This means expanding the import, transmission, and storage infrastructure so that the energy system is resilient to both technological disruptions and geopolitical tensions. Relying on a single source of supply carries significant risks – both

[21] B. Nibedita, M. Irfan, *Energy mix diversification in emerging economies*…, 114043.

in terms of technical failures and political and economic pressure from the dominant supplier. Expanding import routes, such as new gas pipelines, oil pipelines, LNG (liquefied natural gas) terminals, or offshore FSRUs (Floating Storage Regasification Units), gives the country greater flexibility in responding to changing market and political conditions, and strengthens its negotiating position in the international arena[22].

Diversification also applies to electricity – therefore, it is important to develop cross-border electricity connections, enabling the import or export of energy depending on the current needs of the system. In this way, the country can buy surplus energy from its neighbours or transmit its own production, especially from renewable sources. At the same time, it is necessary to modernise the national transmission infrastructure – so that it is bidirectional, automated and capable of integrating variable sources, such as renewable energy sources. The development of smart energy networks (smart grids) and the construction of large-scale energy storage facilities and strategic reserves (gas, oil, heat) increase the system's resilience to sudden fluctuations in supply and demand, reduce the risk of blackouts and allow for maintaining continuity of supply at critical moments.

In a long-term energy security strategy, the diversification of supply routes and import directions should be treated equally with the diversification of the generation sources themselves. Only the combination of these two elements – with appropriate legislative and investment support – ensures real resilience of the system and the country's energy security.

Diversification of energy supply directions is one of the key pillars of energy security, alongside the development of generation sources. Its main goal is to make the energy system independent from the risk associated with the dominance of one supplier or one transmission route. In practice, this means the need for intensive investments in transmission and storage infrastructure, as well as deeper integration with the European energy market.

The expansion of national infrastructure, including the modernization of existing and the construction of new cross-border connections – such as gas and electricity interconnectors with Germany, the Czech Republic and Ukraine – allows for increased import capacity and mutual support

[22] L. Gitelman, M. Kozhevnikov, Y. Visotskaya, *Diversification as a method of ensuring the sustainability of energy supply*…, p. 19.

between countries in crisis situations. It also facilitates the balancing of energy demand and supply in real time. At the same time, the development of the internal energy market of the European Union, based on the principles of the free flow of energy and the integration of national systems, increases the flexibility of supplies and enables the purchase of energy at more favourable prices from different directions, which reduces susceptibility to local disruptions. In this context, the diversification of natural gas and oil supply routes is of particular importance. Investments such as the Baltic Pipe gas pipeline, connecting Poland with Norway *via* Denmark, or the LNG terminal in Świnoujście, enable the import of raw materials from various geographical directions, which significantly reduces dependence on a single partner – in particular Russia. The expansion of the LNG infrastructure and the planned FSRU units allow for flexible gas import from the global market, increasing competitiveness and security of supply[23].

All these activities – developing international connections, integrating with the EU energy market and building a diversified and independent supply network – together create a resilient energy system capable of withstanding crises, stabilising prices and ensuring uninterrupted energy supplies to the economy and citizens.

4. Legal Regulations and Energy Security

For obvious reasons, energy security is very closely linked to legal regulations that set the framework for the functioning of the entire energy sector – from production, through distribution, consumer protection, to investments in new technologies.

4.1. Key National Laws

In the subject of the analysis conducted here, the most important legal act in Poland is the Energy Law[24], which regulates the principles of shaping the state's energy policy, the principles of the functioning of the energy market, the conditions for granting concessions, the obligations

[23] P.F. Borowski, *Mitigating climate change and the development of green energy*…, 9289.
[24] Act of 10 April 1997 – Energy Law (i.e. Journal of Law No. 54, item 348 as amended).

of energy companies and the rights of recipients. Already in Article 3, section 16, it defines that energy security is "a state of the economy that allows for covering the current and future demand of recipients for fuels and energy in a technically and economically justified manner, while maintaining the requirements of environmental protection." The act, amended many times, provides a good basis for developing a long-term energy policy and state strategy, which aim to maintain the stability of energy supplies, develop renewable energy sources and improve energy efficiency. It also specifies the principles of operation of the energy sector: concession requirements, the obligations of transmission and distribution system operators, as well as standards for providing services to recipients. It also promotes the sustainable development of the country, economical use of energy and the implementation of modern and ecological technologies. Additionally, it obliges the creation of appropriate reserves, emergency planning and development of infrastructure so that the Polish energy system is resistant to crises or sudden changes in demand[25].

Another important regulation in the context of dynamic technological development and changing legal regulations is the Act on Renewable Energy Sources[26]. This legal act allows for an increase in the share of clean, domestic energy in the energy mix, which has a direct impact on reducing dependence on imports of raw materials, increasing the resilience of the energy system to potential crises and more efficient transformation towards modern technological solutions.

The Act on Energy Efficiency[27] is undoubtedly one of the key pillars of managing Poland's energy security, especially in a period of very dynamic technological development and growing regulatory requirements. Its main goal is to create a transparent and fair legal framework for reducing energy consumption, promoting innovation and achieving national and EU climate and energy goals. Thanks to the systematic, although burdened with high financial costs, improvement of energy efficiency, Poland can significantly reduce the demand for imports of raw materials, thus strengthening its own energy sovereignty.

[25] See K. Stachowiak, *Selected aspects of ensuring energy security in the municipality*, "Scientific Journal of the Military University of Land Forces" 2021, Vol. 53, No. 4(202), pp. 690-701; Z. Dobrowolski, *Energy and Local Safety: How the Administration Limits Energy Security*, "Energies" 2021, 14, 4841.

[26] Act of 20 February 2015 on Renewable Energy Sources (i.e. Journal of Law item 478 as amended).

[27] Act of 20 May 2016 on Energy Efficiency (i.e. Journal of Law item 831 as amended).

One of the key legal acts supporting Poland's energy security is the Act on Crisis Management[28], which provides a basis for the state to effectively respond to situations that may threaten the stability of energy supplies and the functioning of critical infrastructure[29]. The Act specifies the bodies responsible for crisis management, their tasks, principles of operation and regulates the financing of tasks in this area. Its main objective is to ensure the efficient functioning of the state and society in crisis situations that may lead to disruptions or interruptions in energy supplies.

Finally, the main objective of the Act on the Capacity Market[30] is to ensure stable and reliable supplies of electricity by implementing a system of financial incentives for energy producers to maintain the availability of generation capacity – not only during periods of regular demand for electricity, but above all in times of crisis. The Act introduced the so-called dual-commodity market in the energy sector, in which, in addition to electricity trade, the capacity market also operates. Within this market, the capacities required to cover peak electricity demand are, by definition, contracted, very often as a rule, several years in advance, which in the long term has an impact on the stable operation of generating sources and decisions on the construction of new energy capacities[31].

4.2. EU Regulations and Their Impact on Poland

The Polish energy sector is also subject to a number of European Union regulations that aim to integrate markets, ensure cross-border security and transform towards renewable energy sources.

[28] Act of 26 April 2007 on Crisis Management (i.e. Journal of Law No. 89, item 590 as amended).

[29] See S. Jaśkiewicz-Kamińska, *Infrastruktura krytyczna*, [in]: E. Wittbrodt, Z. Brodecki, M. Dargas-Draganik (eds.), *Przedwiośnie ery sztucznej inteligencji. Technologia – zarządzanie – prawo*. Vol. 2: *Czy algorytmy połączą Biblię z komputerem?*, Gdańsk 2024, pp. 100-107; A. Tyburska, *Infrastruktura krytyczna i jej ochrona w polskich unormowaniach prawnych*, "Przegląd Policyjny" 2018, 4 (132), pp. 43-52.

[30] Act of 8 December 2017 on the Capacity Market (i.e. Journal of Law item 9 as amended).

[31] G. Kinelski, *Rynek dwutowarowy i istota jego konkurencyjności w sektorze elektroenergetycznym*, "Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauki" 2018, no. 102, p. 278. See D. Kotlewski, *Rynek mocy a rynek energii*, "Kwartalnik Nauk o Przedsiębiorstwie" 2018, XII, no. 4 (49), pp. 49-61; T. Dąbrowski, *Capacity market in Poland – purpose of implementation of the Act, EU and Polish conditions, key assumptions of the concept and the Act*, "Quarterly on Antitrust and Regulation" 2018, 7(5), pp. 9-16.

The Winter Package (referred to as *Clean Energy for All Europeans*) and EU directives on the electricity and gas market[32] constitute a comprehensive response of the European Union to the challenges of energy security, technological development and climate transformation. Their aim is to build an innovative and resilient energy system for the entire European Union, taking into account consumer protection and supporting renewable energy sources and the development of new technologies.

The European Union regulations on the security of energy supply[33] constitute the basis for effective energy security management in Europe, especially in a dynamically changing technological and regulatory environment. Their primary goal is to ensure that electricity and gas reach recipients without obstacles even in crisis situations, while supporting the energy transformation and decarbonisation of the economy. It should be emphasised that the regulations in this area are updated on an ongoing basis, which allows for a substantive response to threats such as cyberattacks, instability of energy commodity prices or climate change. They also support the implementation of smart grids and digital solutions that improve the monitoring and management of energy system security.

It should also be noted that common rules for the internal energy market are a key element of the European Union's strategy to integrate the energy markets of the Member States. This integrated approach aims to ensure security of supply, promote competition and support sustainable development in the context of rapidly advancing technological development and changing legal regulations.

Conclusions

Based on the analysis, the following conclusions can be drawn *de lege lata* and *de lege ferenda*:

[32] Among others Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (i.e. OJ L 158 14.6.2019); Directive (EU) 2024/1711 of the European Parliament and of the Council of 13 June 2024 amending Directives (EU) 2018/2001 and (EU) 2019/944 as regards improving the Union's electricity market design, (i.e. OJ L, 2024/1711); Directive (EU) 2024/1788 of the European Parliament and of the Council of 13 June 2024 on common rules for the internal markets for renewable gas, natural gas and hydrogen, amending Directive (EU) 2023/1791 and repealing Directive 2009/73/EC, (i.e. OJ L, 2024/1788).

[33] Among others Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 amending Regulations (EU) 2019/942 and (EU) 2019/943 as regards improving the Union's electricity market design, (i.e. OJ L, 2024/1747).

1. Energy is a key element for the functioning of critical infrastructure, such as water and sewage systems, healthcare or transport systems. The reliability of energy supply has a direct impact on the health, safety and comfort of life of citizens.
2. The development of technologies, including RES, as well as the implementation of smart grids translate into increased resilience of the energy system. Investing in innovative solutions that support sustainable development and reduce dependence on imports of energy resources is key here.
3. National and EU law, such as the Energy Law, RES Acts, the EU Winter Package and common energy market rules, create a legal framework supporting the stability and security of energy supplies. These regulations promote competition, protect consumers and support energy transformation.
4. Diversification of energy supply sources and routes is essential to minimize the risk associated with dependence on individual suppliers. This allows for flexible response to both market and geopolitical changes.
5. Common EU rules for the energy market support the integration of Member States' markets, which increases security of supply and promotes sustainable development. This makes countries better prepared to respond jointly to crises.

Limitations of the Study

Despite the broad scope of the conducted review, several important limitations should be acknowledged. First, the study is primarily based on desk research and secondary sources, such as academic publications, industry reports, and EU legal documents. While this approach allows for a broad and multidimensional understanding of energy security, it does not include primary data, such as interviews with energy sector experts, case studies of specific energy companies, or real-time monitoring of energy systems. As a result, some context-specific or operational information may not be fully captured.

Second, the literature and regulatory framework reviewed focuses primarily on the European context, particularly the EU energy market and legislative instruments. Although these findings are highly relevant for EU member states, their generalizability to other regions, such as

emerging economies, countries with different regulatory systems, or regions heavily dependent on fossil fuels, may be limited.

Third, the study covers a wide array of technological, economic, and policy dimensions, which can lead to a certain breadth at the expense of depth. For example, while hydrogen technologies, smart grids, and digital systems are discussed, the analysis does not provide detailed technical modeling or quantitative assessments of their implementation.

Finally, the dynamic nature of energy markets and technological progress means that some findings may quickly become outdated. Recent legislative changes, market developments, or breakthrough technologies could affect energy security before their full impacts are captured in the literature.

Considering the above limitations, this study provides a solid foundation for further empirical research, including comparative analyses, quantitative modeling, and real-time monitoring of energy systems, which could complement the theoretical and regulatory insights presented here.

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