

**Filip Czepto**

Polish Photovoltaic Installation  
ORCID: 0009-0005-9181-2323

**Piotr F. Borowski**

Vistula University,  
ORCID: 0000-0002-4900-514X

[doi.org/10.34765/sp.0323.a09](https://doi.org/10.34765/sp.0323.a09)

# **ANALYSIS OF LEGAL, POLITICAL, SOCIAL AND TECHNICAL ASPECTS CONCERNING ENTERPRISES IN THE ENERGY SECTOR IN THE ERA OF LOW-EMISSION ECONOMY**

## **Summary**

The conducted research using the desk research method aimed to provide a detailed analysis of legal and political aspects influencing the operations of businesses in the energy sector. The scope of the study also included an evaluation of the state's policies, the formation of public-private partnerships, and mobilization of both individual consumers and entrepreneurs towards actions for energy security and the pursuit of a low-emission economy.

The research results revealed that issues related to energy security, climate protection, and greenhouse gas emission reduction are influenced by various factors. A key conclusion is that effective actions in these areas depend not only on diverse structural elements but also on the collaboration between the government, businesses, and individual consumers. Both individual consumers and entrepreneurs play a crucial role in the transformation process towards a secure and low-emission economy.

Legal aspects, such as emission regulations and energy security standards, prove to be significant in shaping the behavior of businesses. The impact of government policies, especially through the establishment of public-private partnerships, can

significantly influence the effective achievement of goals related to energy and environmental protection.

**Keywords:** energy companies, energy policy, emission reduction, energy security, low-emission economy, photovoltaic farms.

**JEL Codes:** Q2, Q4

## **ANALIZA ASPEKTÓW PRAWNYCH, POLITYCZNYCH, SPOŁECZNYCH I TECHNICZNYCH DOTYCZĄCYCH PRZEDSIĘBIORSTW SEKTORA ENERGETYCZNEGO W DOBIE GOSPODARKI NISKOEMISYJNEJ**

### **Streszczenie**

W przeprowadzonych badaniach, zastosowano metodę *desk research*, która miała na celu dostarczenie szczegółowej analizy aspektów prawnych i politycznych wpływających na działalność przedsiębiorstw w sektorze energetycznym. Zakres studium obejmował również ocenę polityki państwa, tworzenie partnerstw publiczno-prywatnych oraz mobilizację zarówno indywidualnych konsumentów, jak i przedsiębiorców do działań na rzecz bezpieczeństwa energetycznego i dążenia do gospodarki o zerowych emisjach.

Wyniki badań ujawniły, że kwestie związane z bezpieczeństwem energetycznym, ochroną klimatu i redukcją emisji gazów cieplarnianych są kształtowane przez różne czynniki. Kluczowym wnioskiem jest, że skuteczne działania w tych obszarach zależą nie tylko od różnorodnych elementów strukturalnych, ale także od współpracy między rządem, przedsiębiorstwami a indywidualnymi konsumentami. Zarówno indywidualni konsumenci, jak i przedsiębiorcy odgrywają kluczową rolę w procesie transformacji ku bezpiecznej i gospodarce o zerowych emisjach.

Aspekty prawne, jak regulacje dotyczące emisji i standardy bezpieczeństwa energetycznego, są istotne dla kształtowania zachowań przedsiębiorstw. Wpływ polityk rządowych, zwłaszcza poprzez tworzenie partnerstw publiczno-prywatnych, może znacząco wpływać na skuteczne osiągnięcie celów związanych z energią i ochroną środowiska.

**Słowa kluczowe:** przedsiębiorstwa energetyczne, redukcja emisji, polityka energetyczna, bezpieczeństwo energetyczne, gospodarka zeroemisyjna, farmy fotowoltaiczne.

**Kody JEL:** Q2, Q4

## Introduction

Energy companies operate in a dynamically changing environment where state policies play a crucial role. Numerous studies have focused on the consequences of government energy policies, with earlier research concentrating on the government's impact on reducing energy consumption in energy-intensive sectors (e.g. food economy, heavy industry) and energy efficiency (Wojdalski, Niznikowski 2019; Safarzadeh et al. 2020) or energy security policies (Jakstas 2020; Sachs et al. 2019). The impact of policies on energy companies can be significant and encompasses various aspects shaping their strategies, operations, and management decisions (Borowski 2022a).

As a result, energy companies must adapt to continuous changes and adjust to state policies while attempting to influence the regulatory process to safeguard their interests (Borowski 2019). The mutual relationship between the energy sector and politics is a vital element in both the economy and the formation of a sustainable and efficient energy system (Gitelman, Kozhevnikov 2015).

Contemporary energy companies, faced with increasing environmental protection requirements, are obligated to take an active approach and implement measures to meet ecological standards. In this context, innovation in energy production becomes a crucial element of the energy sector's strategy (Bashir et al. 2023). One of the main directions in which companies take action is the development and implementation of renewable energy-based technologies. Photovoltaic technologies, converting solar energy into electricity, constitute a significant part of activities in the energy sector (Maka, Alabid 2022).

In the context of biomass, companies explore opportunities to use organic materials for energy production, contributing not only to the reduction of organic waste but also serving as an alternative to traditional energy sources. The implementation of these innovative solutions not only contributes to achieving environmental goals but also creates new business opportunities for energy companies. With the growing societal awareness of sustainable energy issues, investments in such technologies become a strategic step towards creating an efficient and ecological energy system.

The scientific objective of the conducted study was to gain an in-depth understanding of the mechanisms shaping the energy market, focusing on analysing the relationships between various elements of this market (legal, political, social, technological aspects). The scientific aim was not only to deepen knowledge about the functioning of the energy market but also to identify

key factors influencing its structure and dynamics. By analysing the relationships between individual elements of the market, the study aimed to capture significant patterns, trends, and interactions. This approach allows for a better understanding of how economic, technological, social, and political factors impact the operation of the energy market.

In the context of utilitarian goals, specific directions for the development of the energy sector were indicated, aiming to achieve a low-emission economy. This meant identifying areas where actions and investments should be taken to transform the energy sector in a more sustainable and ecological manner.

As a result, the study not only provided scientists with a thorough analysis of the energy market but also had practical applications in defining development paths for the energy sector, contributing to the achievement of goals related to a low-emission economy. The integration of scientific and utilitarian goals in such a study enables the use of scientific knowledge for practical actions towards a sustainable energy future.

The scientific research problem of this study is to explore the existing interdependencies in the legal, political, social and technological dimensions of the energy sector in the context of a low-emission economy. The main focus of the study is on identifying and understanding the mechanisms that exist between these dimensions, with the ultimate goal of identifying optimal strategies and solutions. The research problem consists in particular in analysing the impact of legal regulations and political decisions on the development of new technologies, social acceptance and overall sustainable development in the energy sector. By answering the research questions, this study aims to provide valuable insights that can help develop effective policies, legislation and practices to enable a successful transition to a zero emissions economy. The study focused on three key areas: political issues, energy security, and the development of energy companies in the context of the transition towards a low-emission economy and emission reduction. Below are the research questions that motivated the analysis in the three main areas.

1. Energy security and questions related to this area:
  - What are the main strategies and mechanisms aimed at ensuring energy security?
  - How are energy systems prepared for potential threats and disruptions to energy supplies?
  - What are the key factors influencing the energy security of a country?

2. Energy policy and research questions in this area:
  - What are the main goals and priorities of energy policy in the context of a low-emission economy?
  - How does energy policy impact the development and innovations in the energy sector?
  - What are the relationships between energy policy and the country's energy security?
3. Development of energy sector enterprises and questions related to this Area:
  - How do energy companies adapt to the shift towards a low-emission economy?
  - What investments and innovations are undertaken by companies to reduce emissions?
  - What are the barriers and challenges that energy companies must face in the process of transformation?

Moreover, in the conducted research, relationships between energy security, energy policy, and investments in renewable energy sources were also analyzed, and the following questions were posed:

- How does energy policy influence the investment decisions of companies in the field of renewable energy sources?
- How do investments in renewable energy contribute to the energy security of the country?
- What are the mutual relationships between energy policy and the increased share of renewable energy sources in the country's energy structure?

By answering these research questions, the study aimed to gain a deeper understanding of the relationships between policy, energy security, and the development of energy enterprises in the context of efforts towards a low-emission economy.

## Research Methodology and Research Model

The applied method in the conducted research was based on primary research, referred to as desk research. Desk research is a hypothetical-deductive method in which research questions are formulated, followed by an analysis of available

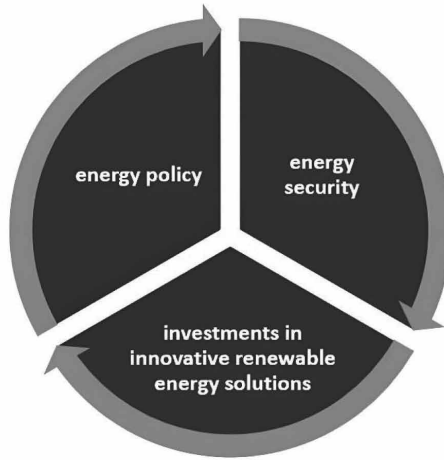
sources to gather data and provide answers to the questions (Borowski, Czepło 2023). This means that existing theories, models, or concepts were used in the study to formulate questions, and then information was collected to answer the initially posed research questions. The desk research method allows for a comprehensive and detailed analysis, utilizing available sources of information. By harnessing the potential of this research methodology, a dual benefit was realized: a reduction in research costs while maintaining undisturbed access to an extensive repository of databases. In the process of conducting desk research, a key aspect is the use of credible sources. The analysis of desk research is a significant research tool that enables the collection of information from various sources, such as industry reports, scientific articles, statistical data, or market analyses. This allowed for a more complete picture of the researched area in the conducted study and a precise understanding and description of reality (Taylor et al. 2006).

An important step during desk research is the selection of credible sources. The reliability and objectivity of information are crucial for obtaining accurate and valuable results. Therefore, in the conducted study, the credibility of each source was carefully assessed, paying attention to the author, publication date, and potential conflicts of interest. The credibility of the source is assessed through the prism of the publisher or publishing house and its reputation, and the importance of the journal and the value of the article through the impact factor, Hirsh index and the number of citations (Borowski, Czepło 2023).

Desk research is valued for its effectiveness in quickly obtaining information and analysing a given area. However, its effectiveness and value depend largely on the care in selecting and evaluating sources, emphasizing the importance of relying on credible sources to maintain accuracy and high-quality analysis.

The developed research model is a key tool enabling a comprehensive analysis of the relationships between energy policy, energy security, and investments in environmentally friendly innovative solutions. This interdisciplinary model presented in Figure 1 is oriented towards a holistic understanding of the dynamics of the energy sector, simultaneously considering economic, environmental, political, and technological aspects.

**Figure 1.** Holistic approach to the interdisciplinary model



Source: own elaboration.

Energy Policy Integration – a component of the model that examines how the country’s energy policy influences the shaping of the energy sector structure. It analyses political decisions regarding regulations, subsidies, greenhouse gas emission goals, and support for various types of energy sources. This allows determining how these decisions impact the development of renewable energy sources, energy efficiency, and the competitiveness of the sector.

Energy Security as a Pillar of Stability – a component of the model that focuses on identifying key elements related to energy security. It analyses the diversity of energy supply sources, energy infrastructure, the ability to quickly respond to energy crises, and strategies for diversifying the supply of energy resources. It introduces elements of risk forecasting, enabling effective planning of preventive actions.

The Role of Investments in Environmental Innovations – a component of the model that concentrates on identifying investment areas that support the development of innovative and environmentally friendly energy solutions. It analyses research and development funding, fiscal incentives, support mechanisms for start-ups, and the state’s investment policy. Understanding these issues allows assessing the innovative potential of the energy sector and its ability to adapt to changing market conditions. Investments in innovative solutions using renewable energy sources also impact efficiency and sustainable development indicators. This model element enables monitoring progress

in achieving goals related to a low-emission economy. It also analyzes the impact of taken actions on various environmental aspects, such as emission reduction, natural resource consumption, and biodiversity impact (Borowski, Karlikowska 2023).

The developed research model provides a solid foundation for making informed policy and strategic decisions, allowing for the simultaneous consideration of diverse factors influencing the energy sector. As a result, researchers, policymakers, and entrepreneurs can approach energy issues comprehensively, fostering effective transformation towards sustainable and energy-efficient development.

## **Results and discussion**

In this chapter, the results of the conducted research have been presented, and an in-depth scientific discussion on the discussed topic has been carried out. The analysis of research results is a crucial component, showcasing discoveries and conclusions drawn from the collected data. Each research aspect has been analysed in terms of significance and implications for the discussed issue. The scientific discussion involves a critical approach to the results, comparing them with existing scientific literature, and applying theoretical frameworks to the practical economic context. The juxtaposition of results with existing scientific knowledge and practical reality enriches the discussion and provides it with social and applicative context.

## **State Energy Policy**

Energy policy is a decision-making area that has a significant impact on society at multiple levels. State decisions regarding the production, distribution, and consumption of energy have a substantial influence on citizens' lives, the economy, and the natural environment. Among Poland's key energy policy goals are ensuring the reliability of fuel and energy supplies, increasing energy efficiency, and minimizing the negative impact of the energy sector on the natural environment. Achieving these objectives involves increasing the share of renewable energy in energy production. Energy efficiency refers to the ratio



of useful energy output to the total energy input in a given system or process. Higher energy efficiency implies that a system can achieve the same level of output or service with less energy input, resulting in reduced energy consumption and associated costs. Improving energy efficiency is a fundamental aspect of sustainable and responsible energy management, contributing to environmental conservation, cost savings, and the overall optimization of energy resources (Wojdalski et al. 2023).

It is crucial for the energy sector not to adopt a monopolistic structure managed by the state, as such a situation negatively affects the efficiency of businesses and leads to price increases, generating harmful social effects. Monopolistic control over the energy sector can result in limited choices for consumers, lack of competition, a decrease in innovation, and operational inefficiency for companies. Consequently, businesses in such an environment are often not motivated to improve their services, negatively impacting the quality and availability of energy for society. Additionally, a monopolistic structure in the energy sector often leads to increased energy prices for consumers, as the lack of competition limits pressure to maintain attractive prices. Moreover, a monopolistic energy sector is usually less inclined to adopt modern technologies or sustainable practices, as the absence of competition diminishes incentives for investing in innovations. Therefore, to increase efficiency, reduce costs, and promote sustainable solutions, there is a need to support competition in the energy sector, contributing to better market functioning for both businesses and society.

Government policy can include greater incentives and programs, such as subsidies, tax incentives, and various types of funding aimed at attracting domestic and foreign investors to invest in renewable energy projects and various energy initiatives. Below are aspects that illustrate how energy policy affects society (Nicolli, Vona 2019).

Energy security, in the context of energy policy, is a fundamental element that determines the stability and availability of electrical energy in the country. Effective energy strategies developed and implemented by the state, as well as appropriate government agencies, play a crucial role in ensuring security of access to electrical energy sources (Daintith, Hancher 2019). The country's energy security is defined as a comprehensive state in which access to energy is not only stable and sufficient but also economically accessible, in line with sustainable development principles and independence (Lu et al. 2020; Hdom, Fuinhas 2020). Decisions regarding energy sources, the development of energy infrastructure, and diversification of supplies directly impact the stability of energy access for

various sectors of the economy and society, including households, businesses, and public institutions. Energy security is not limited to quantitative aspects of delivered energy; it also considers economic, sustainable development, and independence from external factors (Can, Ahmed 2023). Moreover, the complexity of energy security arises from the interaction of various factors such as geopolitical situations, dynamic technological developments, the diversity of energy policies, and types of energy sources used (Borowski 2022b). Energy security considerations become particularly important in the face of climate change and global challenges related to resource availability. Taking care of these diverse aspects and factors is a crucial issue for minimizing the risk of disruptions in energy supplies. Securing access to energy is fundamentally important for maintaining the country's economic and social stability; therefore, an effective approach to energy security requires a holistic approach, considering technical, economic, and ecological aspects (Borowski 2019).

## **Public-Private Partnership in the Energy Market**

Ensuring energy security is a comprehensive challenge that requires collaboration and synergy between the public and private sectors. The key factor necessitating this collaboration is related to the investment of financial resources. The joint efforts of both sectors create an opportunity for the efficient use of resources, translating into the effective safeguarding of energy supplies within the country (Soliński 2011; Sobocińska-Maciejewska 2014).

The public sector, representing societal interests, plays a crucial role in shaping energy policy, creating appropriate legal frameworks, and ensuring the stability and security of investments. Furthermore, the government can act as a catalyst for innovation by stimulating research into new technologies and regulating the energy market. Its involvement is indispensable in creating a favorable environment for investments (Pamula 2013).

On the other hand, the private sector contributes to this collaboration with an entrepreneurial approach, innovation, and investment capabilities. Private companies, armed with financial and technological resources, can effectively implement modern solutions, especially those related to renewable energy sources. Their involvement in energy investments not only accelerates infrastructure development but also contributes to the creation of a competitive energy market.

Harmonious collaboration between the public and private sectors also provides an opportunity for sharing investment risk (Kazemi et al. 2023; Martiniello et al. 2020). Public-private partnerships enable the sharing of costs and benefits, making energy investments more attractive for both parties. This opens the door to the realization of larger-scale projects that can better meet the growing needs of society.

As a result of collaboration between the public and private sectors, it is possible to create an integrated energy system that not only ensures stable energy supplies but is also oriented towards sustainable development, innovation, and minimal environmental impact. This joint approach to energy security contributes to the construction of a durable and efficient energy infrastructure that can meet future challenges.

One of the key elements of this collaboration is making strategic decisions that consider both public and private interests to create a sustainable and efficient energy system. Public-private partnership is an effective tool for achieving this goal. Introducing modern energy solutions, especially those related to renewable energy sources, is a crucial element of energy security strategy. Numerous examples of such projects exist, and according to Akomea-Frimpong et al. (2023), public-private partnership opens the door to the effective implementation of innovative initiatives.

The collaboration between the public and private sectors enables a better utilization of financial, technological, and human resources. Private companies often possess innovative technologies and investment capabilities that can accelerate the development of energy infrastructure. Simultaneously, the public sector can provide stable regulatory frameworks, ensuring the security of investments and a balance between social and private interests (Fleta-Asín, Muñoz 2021).

Strategic decisions made within the framework of public-private partnerships should consider long-term goals of sustainable development and greenhouse gas emission reduction. Investments in renewable energy sources can contribute not only to the country's energy security but also to achieving environmental protection goals (Martiniello et al. 2020).

As a result, effective public-private partnerships have the potential to build innovative energy projects that not only secure energy supplies but also promote sustainable social and economic development. It is through the synergistic interaction of both sectors that a comprehensive balance between efficiency, ecology, and energy security can be achieved (Fleta-Asín, Muñoz 2021).

## Individual Consumers and Businesses in the Energy Market

The key factor concerning energy is its cost. Energy prices have a tremendous impact on both individual consumers and businesses, serving as a crucial economic factor that can shape both household budgets and corporate strategies.

Decisions regarding the type and source of energy affect energy prices for individual consumers, businesses, and large manufacturing or corporate enterprises. Subsidies, taxes, or regulations can shape the costs of energy production and distribution, subsequently affecting electricity or fuel bills, with consequences for the household budgets of citizens and the competitiveness of businesses. Table 1 illustrates the impact of energy costs on potential issues and actions taken by individual consumers and businesses.

**Table 1.** Challenges Facing Electricity Consumers

Individual consumers
<p>The increase in energy prices directly impacts the household expenses of individual consumers, serving as a significant factor determining the cost of living. The rise in electricity and heating fuel prices translates into bills for electricity and heating, creating an additional financial burden for households. These costs are associated with basic needs such as lighting, heating, cooling, using induction cookers, and operating electronic devices [Osman et al., 2023].</p> <p>For households, especially those with lower incomes, higher energy prices pose real financial challenges. This situation is particularly severe for individuals with limited financial resources, leading to a phenomenon known as energy poverty. In such cases, households may be forced to forgo maintaining adequate thermal or electrical conditions in their living spaces, exposing them to discomfort and the risk of deteriorating health.</p> <p>The increase in energy prices also influences consumer decisions. Individual consumers may be compelled to make investments aimed at reducing energy costs, such as purchasing more energy-efficient household appliances, electric cars, or installing renewable energy systems, such as photovoltaic panels or heat pumps. This approach is particularly noticeable in the context of growing environmental awareness, where consumers are inclined to seek sustainable and energy-efficient solutions.</p> <p>As a result, the rise in energy prices affects daily life and consumer choices, prompting the search for alternative, more economical, and environmentally friendly energy solutions. It also underscores the need for the development of social and environmental policies aimed at supporting individuals affected by the increase in energy costs and promoting sustainable energy practices in society.</p>

### Enterprises

Unlike individual consumers, businesses are often much more dependent on energy, which is a key factor in production. The increase in energy prices directly impacts production costs, which, in turn, can lead to higher prices for offered products and services [Wojdalski et al., 2007; Ali et al. 2023]. Companies operating in sectors where energy plays a crucial role in the production process may find themselves in a challenging competitive situation, especially when local energy prices rise, and competitors benefit from cheaper energy sources in other regions.

In such conditions, investments in energy efficiency become a key element of corporate strategies. The rise in energy prices prompts companies to take actions aimed at optimizing energy consumption, which, in turn, translates into long-term benefits through significant reduction in operating costs.

The increase in energy prices also motivates businesses to make decisions in line with the principles of sustainable development. With a focus on growing environmental awareness, companies increasingly choose more sustainable energy sources, which, although may involve certain costs, contribute to improving their social and environmental image. An example of such a transformation is General Electric, which has shifted from an „environmental polluter” image to a company engaged in a technological restructuring plan called ecomagination [Steiber, Alänge 2023].

As some of the largest energy consumers, particularly in energy-intensive sectors such as industry or manufacturing, businesses may experience a significant increase in operating costs due to changes in energy prices. This, in turn, can negatively impact the profitability of firms, especially those operating in low-profit-margin industries, putting them in a challenging competitive position in the market.

Changes in energy prices have a broad impact on society, the economy, and the environment. Individual consumers and businesses must effectively adapt to these changes by making decisions related to energy efficiency, innovation, and conscious and sustainable energy use [Wojdalski et al. 2007]. For businesses, flexibility and innovation in energy management become crucial for maintaining competitiveness in a dynamic market.

Source: own elaboration.

The presented table indicates that energy prices have a versatile impact on society and the economy, shaping consumer behaviours and strategic decisions of businesses. Government regulations, technological innovations, and changing social awareness play a significant role in balancing energy accessibility and prices.

Energy-related issues directly affect the natural environment. Similarly, energy policy also has a tremendous impact on the state of the environment. The choice between traditional, polluting energy sources and renewable ones can influence air pollution levels, greenhouse gas emissions, and climate change. These decisions have long-term consequences for ecosystems, human

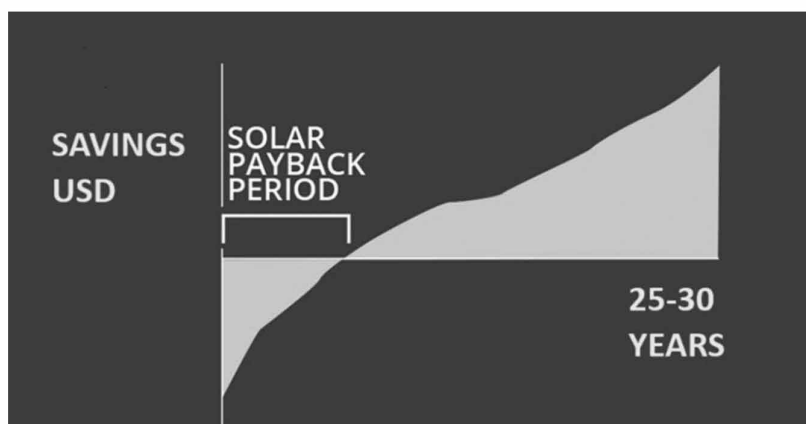
health, and biodiversity. Supplementing the energy mix with units generating electricity from renewable sources allows for reducing the overall emissions of the energy system. The EU's target for 2030 is 32%, with Poland declaring the achievement of a 23% share of renewable energy in gross final energy consumption by 2030. In the perspective of 2040, the share of renewable energy sources is estimated to be at least 28.5% (Sobolewski 2017; Czepło 2022).

Innovations and technological development play a crucial role in shaping the future of the energy sector. They act as a driving force for progress, enabling transformations that have a significant impact on efficiency, sustainable development, and energy availability. Innovations are extremely important for the development of the energy sector. Through regulations and investments, the government can stimulate the development of new, innovative energy technologies. Innovation-supporting policies can influence the creation of new jobs, economic growth, and increase the country's competitiveness in the global market, as well as contribute to reducing energy poverty (Mukhtarov, Mikayilov 2023).

Choosing a photovoltaic installation, in addition to criteria such as viability, specifications, and brand, one must also consider its size (i.e., production capabilities and physical dimensions), determining the investment costs. These factors are important for estimating costs and determining the efficiency of the installation. The economic profitability of a photovoltaic farm with a capacity not exceeding 1 MW, under Polish conditions, is considered moderate and requires additional financing of investment outlays by 30%. The simple payback period for the investment is 11 years (Rackiewicz 2020).

The main factor affecting the economic efficiency of a project is the relatively low level of electricity generation throughout the year, resulting from meteorological conditions. Due to low production, the investor has a small annual profit from the sale of electricity relative to investment outlays. However, this trend is continuously changing positively due to increased demand and electricity prices, translating into higher investment profitability and a significant reduction in the payback period. The systematically growing profitability of photovoltaic farms is evident over many years, where year after year, the payback period shortens. Figure 2 illustrates the concept of the Solar Payback Period.

**Figure 2.** Solar payback period



Source: own elaboration based on: <https://gosolarquotes.com.au/commercial-solar/50kw-solar-solar-system/> [access: 15.04.2023].

The widespread use of photovoltaic panels allows for the production of electricity without greenhouse gas emissions, aligning with sustainable development goals (Bukowski et al. 2022) Another way to reduce emissions is through wind turbines, representing another area of innovation in energy production. By harnessing the power of the wind to generate electricity, energy companies contribute to the reduction of carbon dioxide emissions and minimize the negative impact on the environment. Moreover, the development of wind technologies enables the efficient utilization of natural resources.

The transition to sustainable energy sources, especially investments in photovoltaic technologies, is becoming increasingly common in response to growing concerns about the environment and the need to limit greenhouse gas emissions (Młynarski 2017; Mikulčić et al. 2021).

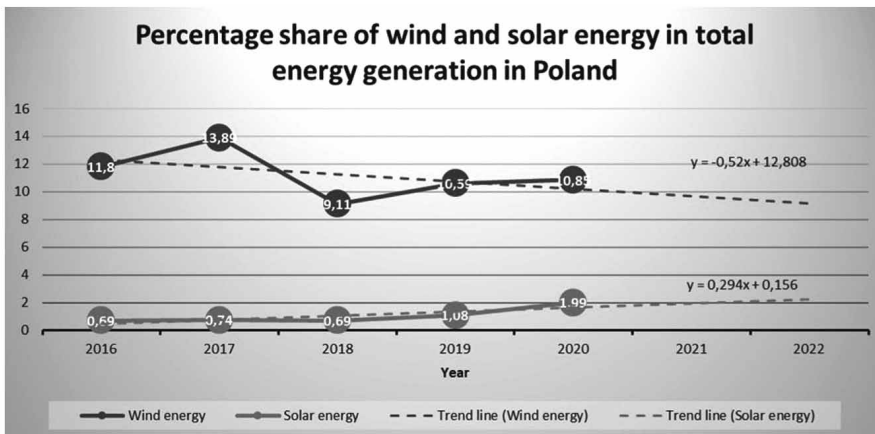
The use of renewable energy sources, especially photovoltaics, is a key step in achieving the intended goal of a low-emission economy. Renewable energy sources, such as solar energy, allow the production of electricity without emitting harmful greenhouse gases, which helps to reduce the negative impact on the environment. Legal aspects also play a key role in the energy transition towards a low-emission economy. Creating and enforcing regulations promoting renewable energy sources and limiting emissions of harmful substances is becoming necessary. Creating a favourable legal framework can encourage businesses and consumers to invest in green energy solutions. Innovative

technologies, such as energy monitoring and optimization systems, also play an important role in achieving low-emission goals. By introducing digital energy management solutions, it is possible to more precisely adjust energy production and consumption, which leads to greater efficiency and minimization of the negative impact on the environment (Borowski 2022a).

Both energy producers and individual consumers now prioritize more ecological and renewable solutions. Businesses realize that investing in photovoltaics not only contributes to environmental protection but also becomes a financial benefit. Advancing technologies allow for a more efficient use of solar energy, resulting in reduced costs of electricity production.

On the other hand, individual customers are increasingly opting for the installation of photovoltaic panels on the roofs of their homes or standalone installations. This is not only a step towards energy independence but also an active commitment to environmental care. With technological advancements and increasingly favourable financial solutions, the upward trend in photovoltaics appears to be enduring, with the potential for further increasing the share of this form of energy in the global energy mix. Consequently, investments in photovoltaics become an integral part of the strategies of both energy companies and homeowners. The figure illustrates the share of photovoltaics and wind turbines in the production of energy from renewable sources.

**Figure 3.** The share of wind and solar energy in energy production in Poland



Source: own elaboration based on: GUS (2021).



The Figure 3 shows a growing trend in the share of photovoltaics in total energy production. Electricity generated from solar sources is gaining increasing recognition both among businesses and individual customers.

Comparing the generating capacity of wind turbines to energy from photovoltaics, it can be observed that currently, wind power plants exhibit a higher capacity utilization factor of 23.36%, compared to photovoltaic farms (12.97%) (Czepło 2022).

Table 2 below presents a simplified structure of investment costs for wind farms and photovoltaic farms.

**Table 2.** Average investment outlays for 1 MW of installed capacity in 2020–2021

Wind farm			Photovoltaic farm		
Components	MIn PLN	share [%]	Components	MIn PLN	share [%]
Turbins	4	60	Photovoltaic panels, inverters	3,2	72
Preparation	1	14	Purchase of 1.1 hectares of land	0,1	2
Grid Connection Point and cabling, construction works	1,5	20	Installation of supporting structures and modules, earthworks	0,9	20
Connection fee	0,2	3	Implementation of the connection	0,1	2
Others	0,2	3	Monitoring system, fencing	0,2	4
<b>Total</b>	<b>6,7</b>	<b>100</b>	<b>Total</b>	<b>4,5</b>	<b>100</b>

Source: own elaboration based on: Czepło (2022).

An extremely important issue related to the energy sector is employment and the social aspects of energy transformation. The transition from traditional to renewable energy sources can impact the job market. Creating new jobs in the renewable sector while simultaneously losing jobs in the traditional sector requires appropriate social policies, vocational training, and plans for a fair transition.

National security is a matter that should be a key element of energy policy. Dependency on energy imports and the associated political risks constitute a significant aspect of energy policy (Lorek 2017). Taking care of one's own independent energy sources can contribute to strengthening national security.

In light of the above aspects, energy policy is a crucial area of state action that requires consideration of diverse social, economic, and environmental interests. Decisions made in this area have far-reaching consequences for both contemporary and future generations, emphasizing the need for wise and sustainable decision-making. The growing demand and the escalation of the energy crisis in Europe are factors directly influencing continuous increases in energy prices. Based on these factors and the conducted analysis, it can be concluded that investing in renewable energy sources can be a pillar of sustainable development and cost reduction for households and businesses (Borowski 2022a; Czepło 2022).

## Conclusion

The study focused on several key aspects: the legal aspect, the state's energy policy, energy security, and investments in innovative solutions in the field of renewable energy sources. Investments in the energy sector primarily involve new technological solutions, new infrastructure, and digitalization. Within these several aspects, research questions were posed, and answers were provided in the results section, representing a significant step in understanding and shaping the future of the energy sector. The study results reveal that these three areas are not only interconnected but also fundamentally important for achieving goals related to a low-emission economy.

State energy policy emerges as a crucial factor shaping the energy landscape. Research indicates that states focused on energy efficiency, source diversification, and the promotion of renewable energy are more resilient to market fluctuations and geopolitical changes. Well-thought-out energy policies also support innovation and technological development, contributing to the long-term growth of the energy sector.

Energy security is a key foundation for the stability of a state and its economy. Studies suggest that states capable of securing energy supplies and maintaining a balance between different sources are more resilient to fluctuations in energy commodity prices and gain a strategic advantage. Protecting energy

supplies becomes not only a matter of national security but also a significant element of a country's competitiveness on the international stage.

Investing in innovative solutions in renewable energy sources emerges as a key transformative factor. Research indicates that states actively investing in renewable technologies not only reduce greenhouse gas emissions but also create new opportunities for economic development. Innovations in the field of renewable energy become a driving force for economic growth, creating new jobs and increasing competitiveness in the global market.

The conclusions drawn from this study suggest that an effective transformation of the energy sector requires an integrated approach, encompassing both energy security and energy policy aspects, supported by active investments in innovative solutions in renewable energy sources. States focusing on these three key areas are more likely to achieve goals related to a low-emission economy, contributing to the global fight against climate change and building a sustainable future for energy.

The conducted research clearly indicates that achieving energy security and goals related to a low-emission economy requires a holistic approach, involving the engagement of the state, collaboration with the private sector, and the activity of individual participants in the energy market. A key element of this approach is investing in comprehensive solutions, including renewable energy sources, especially photovoltaic technologies, which can significantly contribute to reducing the negative impact on the environment. In the context of a successful energy transformation, a full understanding and consideration of all aspects, encompassing both legislative and social dimensions, are necessary. Only through a holistic approach will it be possible to achieve a sustainable and efficient transformation of the energy system.

## Bibliography

- Akomea-Frimpong I., Jin X., Osei-Kyei R., Tumpa R.J. (2023), *A critical review of public-private partnerships in the COVID-19 pandemic: key themes and future research agenda*, "Smart and Sustainable Built Environment", No. 12(4).
- Ali M., Irfan M., Ozturk I., Rauf A. (2023), *Modeling public acceptance of renewable energy deployment: a pathway towards green revolution*, "Economic Research-Ekonomska Istraživanja", No. 36(3).

- Bashir M.F., Pan Y., Shahbaz M., Ghosh S. (2023), *How energy transition and environmental innovation ensure environmental sustainability? Contextual evidence from Top-10 manufacturing countries*, "Renewable Energy", No. 204.
- Borowski P. F. (2019), *Adaptation strategy on regulated markets of power companies in Poland*, "Energy & Environment", No. 30(1).
- Borowski P. F. (2022a), *Digital Transformation and Prosumers Activities in the Energy Sector*, (in:) *Intelligent Systems in Digital Transformation: Theory and Applications* (pp. 129–150), Springer International Publishing, Cham.
- Borowski P. F. (2022b), *Mitigating climate change and the development of green energy versus a return to fossil fuels due to the energy crisis in 2022*, "Energies", No. 15(24).
- Borowski P. F., Karlikowska B. (2023), *Clean Hydrogen Is a Challenge for Enterprises in the Era of Low-Emission and Zero-Emission Economy*, "Energies", No. 16(3).
- Borowski P.F., Czepło F., (2023), *Development of Energy Companies Based on Renewable Energy Sources*, "Organization and Management Series", No. 189.
- Bukowski M., Majewski J., Sobolewska A., Stawicka E., Suchoń A. (2022), *Wybrane ekonomiczne i prawne aspekty wytwarzania energii z instalacji fotowoltaicznych w gospodarstwach rolnych województwa mazowieckiego*, Wydawnictwo SGGW, Warszawa.
- Can M., Ahmed Z. (2023), *Towards sustainable development in the European Union countries: Does economic complexity affect renewable and non-renewable energy consumption?*, "Sustainable Development", No. 31(1).
- Czepło F. (2022), *Realizacja celów polityki energetycznej poprzez odnawialne źródła energii*, „Przegląd Budowlany”, No. 93(9–10).
- Daintith T., Hancher L. (2019), *Energy strategy in Europe: the legal framework* (Vol. 4). Walter de Gruyter GmbH & Co KG.
- Fleta-Asín J., Muñoz F. (2021), *Renewable energy public–private partnerships in developing countries: Determinants of private investment*, "Sustainable Development", No. 29(4).
- Gitelman L.D., Kozhevnikov M.V. (2015), *Energy strategies of industrial enterprises*, (in:) *Ecosystems and Sustainable Development X*, WIT Press, Ashurst Lodge, Ashurst, Southampton SO40 7AA.
- GUS (2021), *Energia ze źródeł odnawialnych*, Warszawa.
- Hdom H.A., Fuinhas J.A. (2020), *Energy production and trade openness: Assessing economic growth, CO2 emissions and the applicability of the cointegration analysis*, "Energy Strategy Reviews", No. 30.
- Jakstas T. (2020), *What does energy security mean?*, (in:) *Energy Transformation Towards Sustainability*. Elsevier, DOI: 10.1016/B978-0-12-817688-7.00005-7.

- Kazemi M., Tabatabaei S.S., Moslemi N. (2023), *A novel public-private partnership to increase the penetration of energy storage systems in distribution level*, "Journal of Energy Storage", No. 62.
- Lorek M. (2017), *Bezpieczeństwo energetyczne a bezpieczeństwo wewnętrzne państwa*, „Modern Management Review”, No. 24 (3).
- Lu Y., Khan Z.A., Alvarez-Alvarado M.S., Zhang Y., Huang Z., Imran M. (2020), *A critical review of sustainable energy policies for the promotion of renewable energy sources*, "Sustainability", No. 12(12).
- Maka A.O., Alabid J.M. (2022), *Solar energy technology and its roles in sustainable development*, "Clean Energy", No. 6(3).
- Martiniello L., Morea D., Paolone F., Tiscini R. (2020), *Energy performance contracting and public-private partnership: How to share risks and balance benefits*, "Energies", No. 13(14).
- Mikulčić H., Baleta J., Klemeš J.J., Wang X. (2021), *Energy transition and the role of system integration of the energy, water and environmental systems*, "Journal of Cleaner Production", No. 292.
- Młynarski T. (2017), *Bezpieczeństwo energetyczne i ochrona klimatu w drugiej dekadzie XXI wieku: energia-środowisko-klimat*, Wydawnictwo Uniwersytetu Jagiellońskiego, Kraków.
- Mukhtarov S., Aliyev J., Borowski P.F., Disli M. (2023), *Institutional quality and renewable energy transition: Empirical evidence from Poland*, "Journal of International Studies", No. 16(3).
- Mukhtarov S., Mikayilov J.I. (2023), *Could financial development eliminate energy poverty through renewable energy in Poland?*, "Energy Policy", No. 182.
- Nicolli F., Vona F. (2019), *Energy market liberalization and renewable energy policies in OECD countries*, "Energy Policy", No. 128.
- Osman A.I., Chen L., Yang M., Msigwa G., Farghali M., Fawzy S., ... Yap P.S. (2023), *Cost, environmental impact, and resilience of renewable energy under a changing climate: a review*, "Environmental Chemistry Letters", No. 21(2).
- Pamula A. (2013), *Zaangażowanie odbiorców z grupy gospodarstw domowych w zarządzanie popytem na energię*, Wydawnictwo Uniwersytetu Łódzkiego, Łódź.
- Raczkiewicz M. (2020), *Optymalność ekonomiczna farmy fotowoltaicznej do 1 MW w warunkach polskich*, Zakład Statystyki i Prognoz ARE S.A, Warszawa.
- Sachs J.D., Woo W.T., Yoshino N., Taghizadeh-Hesary F. (2019), *Importance of green finance for achieving sustainable development goals and energy security*, "Handbook of Green Finance: Energy Security and Sustainable Development", No. 10.
- Safarzadeh S., Rasti-Barzoki M., Hejazi S.R. (2020), *A review of optimal energy policy instruments on industrial energy efficiency programs, rebound effects,*

*and government policies*, "Energy Policy", No. 139, DOI: 10.1016/j.enpol.2020.111342.

- Sobocińska-Maciejewska M. (2014), *Partnerstwo publiczno-prywatne jako źródło finansowania innowacji realizowanych w systemie zamówień publicznych*, „Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu”, nr 365.
- Sobolewski M. (2017), *Pakiet „Czysta energia dla wszystkich Europejczyków” – nowa inicjatywa w dziedzinie unijnej polityki energetycznej*, „Studia BAS”, nr 3.
- Soliński B. (2011), *Partnerstwo publiczno-prywatne w inwestycjach z zakresu wykorzystania odnawialnych źródeł energii*, „Zeszyt Naukowy Apeiron”, nr 6.
- Steiber A., Alänge S. (2023), *Implications Beyond Silicon Valley. In The Silicon Valley Model: Management for Entrepreneurship*, Springer International Publishing, Cham.
- Taylor B., Sinha G., Ghoshal T. (2006), *Research methodology: A guide to for researchers in management and social sciences*, PHI Learning Pvt. Ltd.
- Wojdalski J., Borowski P.F., Drózd B. (2023), *Przekształcenia w sektorze energetycznym i zakładach produkcyjnych w kierunku zmniejszenia emisyjności*, (w:) Sówka I., Szczepański K., Ślęczka W. (red.), *Ochrona klimatu w Polsce. Wybrane zagadnienia i rozwiązania*, IOŚ PIB, Warszawa.
- Wojdalski J., Niżnikowski R. (2019), *Biogospodarka, pasze, biogaz – wybrane zagadnienia w kontekście zrównoważonego rozwoju*, „Przegląd Hodowlany”, nr 87(2).
- Wojdalski J., Drózd B., Lubach M. (2007), *Factors influencing energy consumption in fruit and vegetable processing plants*, “TEKA Komisji Motoryzacji i Energetyki Rolnictwa – OL PAN”, nr 7.

### **Affiliatons: mgr Filip Czepło**

Polish Photovoltaic Installation  
5 Politechniczna Str.  
05-110 Jabłonna, Poland  
e-mail: filip.czeplo@gmail.com

### **dr hab. inż. Piotr F. Borowski, prof. AFiBV**

Vistula University  
Faculty of Business and International Relations  
3 Stokłosy Str.  
02-787 Warsaw, Poland  
e-mail: p.borowski@vistula.edu.pl