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Summary

Utilizing renewable energy sources in enterprise risk mitigation

Domain: Economic sciences

Discipline: Economics

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1. Introduction - rationale for the choice of topic

Risk is an inherent part of business activity. Achieving success, generating a profit or taking a position on the market means the need to delimit the risk. The concept of risk is thus inscribed in the functioning of enterprises, and the risk itself is determined by a number of internal and external factors¹, including global aspects². When analyzing the determinants of the functioning of an economic entity, the role of energy is often diminished - its cost is treated as insignificant and the security of its supply as obvious. Recent years have shown, however, that sustainable energy acquisition is becoming a global challenge, and Polish enterprises have to take into account a new risk factor - energy risk, which not only reduces their competitiveness in the international arena, but also begins to threaten their existence. It is necessary not only to define and estimate the scale of energy risk in enterprises, but also to propose methods for its mitigation, which was done in the doctoral dissertation.

In order to explain the importance of the issues discussed in the dissertation, one should start with defining the role of energy in the economy. From the beginning of the presence on Earth, man has used various forms of energy, and its use has been the engine of progress. The development of district heating networks and the beginnings of industrial electricity production in the second half of the 19th century were the catalysts of the second industrial revolution. Since then, the global consumption of primary energy³ has been growing continuously⁴, and the development of energy had a huge impact on improving the living conditions of society and could have been one of the factors supporting the growth of the world population in the 20th century. Currently, electricity and heat are used in all sectors of the economy - agriculture, industry, trade, services, but also in heating all types of buildings and powering everyday devices - energy has become an integral part of social life, as well as a stimulus for economic development.

Such an important role of energy meant that ensuring its stable supplies was and is considered one of the determinants of the country's security. When describing this aspect of security, a definition of *energy security* was created - in accordance with the *Energy Law*⁵, it

¹ J. Woźniak, *Risk management conditions in contemporary organization*, in: *Risk map in organization management*, ed. J. Woźniak, W. Wereda, CeDeWu, Warsaw 2018, pp. 17-41.

² WEF, *Global Risks 2019*, World Economic Forum, Geneva 2019.

³ Pursuant to the provisions of Art. 3 point 3 of the *Act of April 10, 1997 - Energy Law*, (Journal of Laws 2006 No. 89 item 625), primary energy is energy contained in primary energy carriers obtained directly from the environment, e.g. coal, crude oil, natural gas, or water, wind, solar, geothermal energy, as well as biomass.

⁴ V. S mil, *Energy Transitions: Global and National Perspectives*, Praeger, 2017.

⁵ *Act of April 10, 1997 - Energy Law*, Journal of Laws of 1997, No. 2006 no. 89 item 625, art. 3 p. 16.

is "the state of the economy that allows to cover the prospective demand of consumers for fuels and energy in a technically and economically justified manner, while maintaining environmental protection requirements." In the event of a threat to the energy security of the state, the term *energy risk* is referred to. Its causes may be⁶ technical aspects - e.g. power units requiring modernization, economic aspects - e.g. rising raw material prices, environmental aspects - increasing air pollution in a country or region, institutional aspects - bureaucracy, corruption, legal instability, inefficient regulatory institutions, ineffective support mechanisms, lack of competition in the market.

The key role of energy in the economy is visible not only at the macroeconomic level, but also at the micro level - obtaining energy has a significant impact on the activities of enterprises, and the service and industry sectors themselves are responsible for a total of 35% of final energy consumption in Poland⁷. Almost every enterprise bears the costs of acquiring energy, and its activity is dependent on its stable supplies. The share of energy in the cost structure of enterprises depends on many factors, and, as it was shown in the doctoral dissertation, in Polish enterprises it may be even a dozen or so percent of revenues. The analysis of energy costs in business activity is the subject of numerous studies, including the European Commission's⁸, and the amount of these costs strongly depends on the industry. For example, in the textile industry, energy costs have been estimated at 8-10% of the total cost of producing a product^{9, 10} in the case of the metallurgical industry it is 16%¹¹, and in the case of the petrochemical industry as much as 50%¹². In services, energy accounts for an average of 4 to 9% of total operating costs¹³. The increase in these costs in recent years, and the planned continuation of this trend in the future, constitute a significant risk factor for enterprises' operations and threaten their profitability. However, forecasts of the scale of this phenomenon

⁶D. Niedzółka, P. Czyżak, *The economic security of power plants*, "E3S Web Conf." 2017, no. 14, art. 01007.

⁷Eurostat, *Energy statistical pocketbook*, <https://ec.europa.eu/energy/en/data/energy-statistical-pocketbook> (access date: 26/05/2021).

⁸European Commission, *Energy costs and EU industrial competitiveness*, "Study Factsheet - Background Study for the European Competitiveness Report 2014", Brussels 2014.

⁹S. Palamutcu, *Electric energy consumption in the cotton textile processing stages*, "Energy" 2010, no. 35, pp. 2945-2952.

¹⁰A. Hasanbeigi, L. Price, *A review of energy use and energy efficiency technologies for the textile industry*, "Renewable and Sustainable Energy Reviews" 2012, no. 16, pp. 3648-3665.

¹¹N. Karali, T. Xu, J. Sathaye, *Reducing energy consumption and CO2 emissions by energy efficiency measures and international trading: a bottom-up modeling for the US iron and steel sector*, "Applied Energy" 2014, no. 120, pp. 133-146.

¹²Z. Geng, J. Bai, D. Jiang, Y. Han, *Energy structure analysis and energy saving of complex chemical industries: A novel fuzzy interpretative structural model*, "Applied Thermal Engineering" 2018, no. 142, pp. 433-443.

¹³M. Jamieson, A. Renaud, *A \$ 3 Billion Opportunity: Energy Management in Retail Operations*, "Schneider Electric White Paper", Schneider Electric, 2014.

in Poland are scarce¹⁴. The stability of energy supply itself is also becoming a growing challenge, as the production capacities of the Polish power system are not sufficient to cover the growing demand¹⁵. This may result in more and more frequent restrictions on energy supplies, which has a number of negative consequences, including loss of potential revenues from the sale of products and services, costs of lost or damaged goods, costs of stopping and starting machines, loss of image, and even a threat to the health of employees and customers^{16,17}. The costs of the daily power loss in the largest Polish service buildings have been estimated at several tens of thousands of zlotys, in industrial facilities they can be much higher. Despite the scale of the phenomenon, most publications on energy shortages focus on the countries of Asia, South America and Africa, and only selected ones discuss this topic in the context of the global north^{18, 19, 20, 21, 22, 23}. Moreover, only a few studies focus on the effects of discontinuities in energy supplies specifically for economic activity^{24,25, 26, 27}. The analysis of energy risk in Polish enterprises is therefore a clear gap in the literature, and the doctoral dissertation helps to fill it.

The study of the energy risk is essential to enable preventive measures and protecting the enterprise against incurring financial losses²⁸. Among the proposed solutions, it is

¹⁴P. Czyżak, A. Wrona, M. Borkowski, *The missing piece of the puzzle. Considerations on Energy Security*, "Instrat Policy Paper" 2021, no. 9.

¹⁵ Polskie Sieci Elektroenergetyczne, *Peak demand coverage forecast for power in 2016-2035*, <https://www.pse.pl/documents/20182/f0b419f3-b8b9-49b9-87e4-490ffcb1cc31?safeargs=646f776e6c6f61643d74727565> (access date: 27.01.2021).

¹⁶A. Castillo, *Risk analysis and management in power outage and restoration: A literature survey*, "Electric Power Systems Research" 2014, no. 107, pp. 9-15.

¹⁷T. Schröder, W. Kuckshinrichs, *Value of Lost Load: An Efficient Economic Indicator for Power Supply Security? A Literature Review*, "Frontiers in Energy Research" 2015, no. 3, p. 55.

¹⁸D. Coll-Mayor, J. Pardo, M. Perez- Donsion, *Methodology based on the value of lost load for evaluating economical losses due to disturbances in the power quality*, "Energy Policy 2012, no. 50, pp. 407-418.

¹⁹C. Growitsch, R. Malischeck, S. Nick, H. Wetzel, *The cost of power interruptions in Germany: a regional and sectoral analysis*, "Ger. Econ. Rev." 2014, no. 13, pp. 307-323.

²⁰M. de Nooija, C. Koopmans, C. Bijvoet, *The value of supply security: The costs of power interruptions: Economic input for damage reduction and investment in networks*, "Energy Economics" 2007, no. 29, pp. 277-295

²¹London Economics, *The Value of Lost Load (VoLL) for Electricity in Great Britain*, OFGEM and DECC, London 2013.

²²F. Trengereid, *Quality of supply regulation in Norway*, "Proceedings of 17th CIRED" 2003, Round Table BETA 2-6.

²³E. Leahy, RSJ Tol, *An estimate of the value of lost load for Ireland*, "Energy Policy" 2011, no. 39, pp. 1514-1520.

²⁴SM Harish, GM Morgan, E. Subrahmanian, *When does unreliable grid supply become unacceptable policy? Costs of power supply and outages in rural India*, "Energy Policy" 2014, no. 68, pp. 158-169.

²⁵K. Kim, Y. Cho, *Estimation of power outage costs in the industrial sector of South Korea*, "Energy Policy" 2017, no. 101, pp. 236-245.

²⁶P. Linares, L. Rey, *The costs of electricity interruptions in Spain. Are we sending the right signals?*, "Energy Policy" 2013, no. 61, pp. 751-760.

²⁷J. Reichl, M. Schmidthaler, F. Schneider, *The value of supply security: The costs of power outages to Austrian households, firms and the public sector*, "Energy Economics" 2013, no. 36, pp. 256-261.

²⁸K. Jajuga, *Risk management*, PWN Publishing House, Warsaw 2009, p. 40.

recommended to invest in renewable energy sources (RES)²⁹ - e.g. solar or wind energy, which allow achieving energy self-sufficiency, making companies independent of rising energy prices or its potential unavailability, bringing additional financial and image benefits. The topic of the use of renewable energy in enterprises is discussed in an increasing number of scientific literature. The potential for using renewable energy sources is assessed as particularly high in commercial facilities^{30,31} but also in industry^{32, 33} and office buildings^{34, 35}. Some companies in Poland have already decided to use this potential, and examples include Mercedes-Benz³⁶, KGHM³⁷, the Dino Group³⁸ or Żabka Polska³⁹. However, there are still few examples, and detailed economic analyzes of individual projects are not available, which is an unquestionable gap in the literature, addressed in part by this work.

There are very few works linking RES with the issue of energy risk - typically, these topics are treated separately, which makes it difficult to assess the potential of RES as a risk mitigation tool. Among this type of work, one can mention the publication of I. Henriques and P. Sadorsky from 2010, showing how companies can reduce their exposure to energy risk using the principles of sustainable development⁴⁰. However, there is no current literature comprehensively applying the above considerations to the Polish case, and this gap is filled by the doctoral dissertation.

²⁹These are sources whose resources are not depleted by exploitation and / or are being renewed. [after:] F. Krawiec (ed.), *Renewable energy sources in the light of the global energy crisis*, Difin, Warsaw 2010, p. 16.

³⁰A. Colmenar-Santos, S. Campiñez-Romero, C. Pérez-Molina, F. Mur, *An Assessment of Photovoltaic Potential in Shopping Centers*, "Solar Energy" 2016, no. 135, pp. 662-73.

³¹JH Braslavsky, JR Wall, LJ Reedman, *Optimal distributed energy resources and the cost of reduced greenhouse gas emissions in a large retail shopping center*, "Applied Energy" 2015, no. 155, pp. 120-130.

³²MA Butturi, F. Lolli, MA Sellitto, E. Balugani, R. Gamberini, B. Rimini, *Renewable energy in eco-industrial parks and urban-industrial symbiosis: A literature review and a conceptual synthesis*, "Applied Energy" 2019, no. 255, art. 113825.

³³F. Bandejas, M. Gomes, P. Coelho, J. Fernandes, *Towards net zero energy in industrial and commercial buildings in Portugal*, "Renewable and Sustainable Energy Reviews" 2020, no. 119, art. 109580.

³⁴NT Mbungu, RM Naidoo, RC Bansal, MW Siti, DH Tungadio, *An overview of renewable energy resources and grid integration for commercial building applications*, "Journal of Energy Storage" 2020, no. 29, art. 101385.

³⁵P. Bailera, E. Lisbona, E. Llera, B. Peña, LM Romeo, *Renewable energy sources and power-to-gas aided cogeneration for non-residential buildings*, "Energy" 2019, no. 181, pp. 226-238.

³⁶GramWZielone.pl, *the Mercedes factory in Jawor will be powered by wind energy*, <https://www.gramwzielone.pl/energia-wiatrowa/32068/fabryka-mercedesa-w-jaworze-zasili-energia-wiatrowa> (access date: 10.01.2021).

³⁷GramWZielone.pl, *The first KGHM solar farm*, <https://www.gramwzielone.pl/energia-sloneczna/104333/pierwsza-farma-fotowoltaiczna-kghm-najnowoczesniejsza-w-polsce> (access date: 10.01.2021).

³⁸GramWZielone.pl, *Polish supermarket chain already has 100 photovoltaic installations*, <https://www.gramwzielone.pl/energia-sloneczna/103571/polska-siec-supermarketow-ma-juz-100-instalacji-fotowoltaicznych> (access date: 10.01.2021).

³⁹ForHandlu.pl, *Żabka has opened a shop entirely powered by green energy*, <https://www.dlhandlu.pl/detal-hurt/wiadomosci/zabka-otworzyla-sklep-calkowicie-zasilany-zielona-energia,93139.html> (access date: 10.01.2021).

⁴⁰I. Henriques, P. Sadorsky, *Can environmental sustainability be used to manage energy price risk?*, "Energy Economics" 2010, no. 32, pp. 1131-1138.

It is worth paying attention to the timeliness of the topics discussed. The energy sector is undergoing a dynamic transformation both in Poland and in the entire European Union, which has an unprecedented impact on the activities of Polish enterprises. Polish companies must take part in the EU energy transformation in order to remain competitive on the common market.

2. Goals, thesis and hypotheses of the work

The subject of the dissertation is the analysis of the potential of renewable energy sources in minimizing the risk of Polish enterprises. The author set two main **goals**. The first one is to draw attention to the problem of the occurrence of energy risk in Polish enterprises and to develop a model allowing for the quantification of this risk. The second goal is to show the benefits of using renewable energy sources through the prism of their potential to reduce the risk of business operations. Both goals were achieved by assessing the scale of energy risk with the use of a valuation model, and by assessing the potential and profitability of investing in renewable energy sources in exemplary enterprises.

The dissertation proved the following **thesis**: the use of renewable energy sources allows to reduce the risk of enterprises' activity. The **research hypotheses** were also verified:

1. Generating energy plays a key role in the activities of enterprises;
2. Energy prices in Poland will rise, increasing operating costs and posing a risk to the profitability of enterprises;
3. Limitations of energy supply cause noticeable financial losses for business owners, constituting a significant risk factor. These limitations will occur more and more often due to the condition of infrastructure or the manner of conducting the national energy policy;
4. The use of renewable energy sources in an enterprise allows for the stabilization of the price level of obtaining energy and ensures energy independence;
5. Investing in renewable energy sources allows not only to reduce the energy risk, but may also bring additional financial benefits.

3. Research methodology

A number of research methods were used to verify the thesis and hypotheses. The dissertation was divided into two stages corresponding to two goals - the first, focusing on defining and estimating the scale of energy risk in enterprises, and the second, introducing mechanisms to mitigate this risk with the use of renewable energy sources.

First, the risk in business activity was defined and classified, dividing the risk factors into those resulting from the internal environment and the immediate and further external environment. Particular attention was paid to global risk factors that have an increasing impact on the activities of enterprises. The basic elements of the risk management process were also discussed, in particular preventive actions that could be taken. Then, the energy risk was defined and its significance in the activities of Polish enterprises was shown. The amount of financial outlays incurred by enterprises in connection with the need to obtain energy was assessed and the first research hypothesis was confirmed. The enormous costs associated with the potential loss of power in enterprises from various sectors of the economy were also indicated. A proprietary model of energy risk valuation was proposed, taking into account the forecasts of energy price increases and the probability of potential discontinuity of energy supplies in the future. Based on numerous data sources, a proprietary energy price forecast for 2040 was prepared. In the verification of the factors influencing the energy price, econometric models were used - vector autoregression (VAR) and error correction (ECM), and Granger causality was also investigated⁴¹. The performed analyzes confirmed the second and third research hypotheses, pointing to the enormous scale of energy risk in Polish enterprises.

The use of renewable energy sources has been proposed as the most advantageous method of mitigating energy risk. The concept of renewable energy sources was introduced, making the necessary classification and discussing the characteristics of each of the types of renewable energy used today, as well as outlining the current role of renewable energy sources in the global economy. The specific features of renewable energy sources that distinguish them from conventional sources, as well as the opportunities and threats resulting from their use, were indicated in relation to the second objective of the doctoral dissertation. The factors influencing the current development of renewable energy in Polish enterprises were explained, in particular institutional factors - legal regulations, energy policy, activities of state and private institutions, which have a key impact on the profitability of using renewable energy in business activities⁴².

Then, the potential of using renewable energy sources in selected Polish enterprises was assessed, taking into account technical, spatial, economic and institutional conditions and using

⁴¹ CWJ Granger, *Investigating Causal Relations by Econometric Models and Cross-spectral Methods*, "Econometrica" 1969, no. 37 (3), pp. 424-438.

⁴²P. Czyżak, *Institutional components of economic security of prosumers*, in: *Components of economic security of enterprises*, edited by: K. Kuciński, CeDeWu, Warsaw 2018.

tools for evaluating energy demand (EnergyPlus)⁴³ or 3D design tools (Sketchup⁴⁴ and Skelion⁴⁵). Using the linear mixed-integer program (MILP)⁴⁶, an economically optimal mix of renewable energy technologies was proposed, allowing for the elimination of energy risk in the surveyed enterprises. A profit and loss account and a cash flow analysis were carried out for the proposed RES investments, assessing their profitability. The financial results of enterprises were compared in scenarios assuming taking measures to mitigate energy risk with the "status-quo" scenario and it was shown that investing in RES may not only eliminate this risk, but also provide companies with additional revenue streams. Thus, the last two research hypotheses were verified, the thesis of the dissertation was confirmed and the second of its goals was achieved.

4. Main results

The obtained results made it possible to verify the research hypotheses and the main thesis. These results can be summarized as follows:

1. Energy is essential to running a business. By examining the importance of energy costs in the cost structure of enterprises, it has been proven that energy costs currently account for from 1-2 to even several percent of the revenues of Polish companies and reach several dozen million zlotys annually in the largest Polish enterprises.
2. On the other hand, for economic entities, the key factor is the very stability of energy supplies, which until recently was considered a certainty, but has been questionable for several years. When power is not available, Polish enterprises are exposed to thousands of zlotys of daily losses resulting from production stoppages, inability to heat or cool buildings, unavailability of communication channels, damage to machines or products. Each kilowatt-hour of lost energy generates several zlotys of losses. For example, in the largest service buildings, this means the daily cost of a power failure of PLN 80,000 PLN.
3. The role of energy risk in the functioning of business entities will increase in the future. The energy price forecast showed a very high increase in the trading component of the tariff in the medium term - between 2020 and 2030 on average by 128%. This translates into a significant increase in final energy prices for institutional consumers - in the

⁴³ EnergyPlus , <https://energyplus.net/> (access date: 15/11/2020).

⁴⁴ Sketchup , <https://www.sketchup.com/> (access date: 19/12/2020).

⁴⁵ Skelion , <http://skelion.com/> (accessed 12/19/2020).

⁴⁶T. Ommen , WB Markussen , B. Elmegaard , *Comparison of linear, mixed integer and non-linear programming methods in energy system dispatch modeling* , "Energy" 2014, no. 74, pp. 109-118.

period 2020-2040, the total cost of energy for the smallest consumers increases by 54%, and for large enterprises it is even 97%.

4. Additionally, in the years 2033-2040 there will be a shortage of the required excess capacity in the National Power System. The percentage of uncovered energy demand in Polish enterprises grows from 0.24% in 2033 to 11.92% in 2040, which may result in significant financial losses.
5. In all service categories, the energy risk by 2030 is several times higher than the current annual electricity expenditure. For the largest shopping centers in Warsaw, the risk is estimated at PLN 853 million by 2040. The scale of risk for the largest Warsaw office buildings is as much as PLN 144 million by 2040. In the case of industrial facilities, the energy risk scale by 2030 is up to 5 times the current expenditure for energy, by 2040 the risk reaches hundreds of millions of zlotys.
6. In the face of the presented scale of energy risk, enterprises must take remedial measures. Achieving energy self-sufficiency with the use of renewable energy sources has been proposed as the most effective risk minimization strategy.
7. The analysis of the renewable energy potential in selected enterprises has shown that investing in renewable energy sources may not only reduce the energy risk, but also provide companies with additional revenue streams.
8. In an industrial facility located in a sparsely built-up area, it is technically possible to achieve energy self-sufficiency, which means a complete elimination of energy risk. Thanks to the possibility of selling surplus energy, an investment in renewable energy in an industrial facility is characterized by a positive net present value (NPV) of PLN 8.8 million even before savings on current and future energy costs are taken into account. The investment costs amount to PLN 37 million, and the facility is capable of generating significant revenues from the sale of surplus energy. From 2024, the investment brings a positive net profit, and from 2032, a positive discounted cash flow - the invested capital is fully returned after 12 years. Taking into account that in the period 2021-2040, the energy costs at today's prices would amount to PLN 43.2 million and increasing this value by the energy risk estimated at PLN 37.5 million, it turns out that undertaking the proposed investment brings an economic benefit of PLN 89.5 million .
9. In the case of the investigated commercial enterprise located in a densely built-up urban area, the potential for using renewable energy sources is smaller, but the facility is still able to minimize the energy risk by becoming independent from energy supplies from

the national power system in critical summer months, as well as by stabilizing energy purchase costs. The investment costs PLN 77.3 million and allows to reduce electricity bills by PLN 88.8 million in the period 2021-2040, assuming constant energy prices - the use of renewable energy sources allows for a profit of PLN 11.5 million even without taking into account the risk energy. The latter is estimated at PLN 104.3 million, and by implementing the proposed project, the owners of the facility will record savings of as much as PLN 115.8 million.

The conducted research allowed to **confirm the thesis - it can be said with certainty that the use of renewable energy sources allows to reduce the risk in enterprises**, in particular the component of this risk related to energy. Moreover, RES bring with them additional advantages - including image improvement, marketing potential, and in many cases they can not only bring savings, but also constitute new revenue streams.

5. Final remarks

The doctoral dissertation is an original contribution to the literature. The author undertook a comprehensive analysis of the subject of energy risk in enterprises. Previous publications focused primarily on selected risk components - e.g. the impact of discontinuities in energy supplies on enterprises, and an undoubted gap in the literature was a comprehensive view of the issue of energy risk in business activities, along with a discussion of the potential of remedial actions. Moreover, while there are individual studies in foreign literature that attempt to approach this subject, none of them takes into account the specific features of the Polish energy market - including the unprecedented scale of the risk of discontinuity of energy supplies and an increase in its already high prices. The dissertation fills the gap in the domestic literature, as well as deepening and synthesizing the available foreign literature.

The discussed research forms the basis for a number of further scientific considerations. The proposed model of energy risk estimation can be applied to a number of different examples - enterprises from other sectors or, for example, public institutions. The risk model can be updated as well as supplemented with new components (e.g. increasing risk of natural disasters causing more and more frequent failures of the power grid). Likewise, the analysis of the potential of remedial actions can also be extended to other objects and examples.

Recommendations resulting from the conducted research include: the need to stabilize the legislative situation in the field of energy; the need to provide attractive forms of financing

investments in renewable energy; increasing the availability of reliable analyzes, research, forecasts and scenarios that would allow entrepreneurs to estimate energy risk and take remedial actions in advance; educating and expanding knowledge among entrepreneurs about risk factors that have a growing impact on business activity; the need for the government to estimate the overall impact of energy risk on the competitiveness of the Polish economy, which may rapidly decrease in the coming years; increasing the availability of data necessary to conduct analyzes - including, for example, information on energy consumption profiles in Polish enterprises. The pool of recommendations resulting from the research carried out is therefore extremely wide and it should be expected that in the near future the issue will become a subject not only of scientific discussion, but also of public and political discussion.

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