POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL

2022 ✦ Volume 25 ✦ Issue 4 ✦ 39–54

DOI: 10.33223/epj/156627

Inesa Mikhno[1], Oksana Redkva[2], Viktoriia Udovychenko[3], Oksana Tsimoshynska[4], Viktor Koval[5], Michał Kopacz[6]

Sustainable energy supply management in the mechanical-engineering industry

Abstract: Increasing energy security in the face of rising energy demand and declining funding for fossil fuels has necessitated the diversification of energy supply and the shift to renewable energy. Sustainable management of energy supply is aimed at achieving a low-carbon intensity of production, especially in energy-intensive industries, including the mechanical-engineering industry. The article examines the possibility of shifting the current mechanical-engineering enterprise system and the technical, environmental and economic indicators of production to the new concept of the green economy, which will be an alternative to the further sustainable development of the industry. This article analyzes key approaches to energy conservation. An analytical

✉ Corresponding Author: Michał Kopacz; e-mail: kopacz@min-pan.krakow.pl

[1] National Aviation University, Kyiv, Ukraine; e-mail: inessa.mihno@gmail.com

[2] Technical College of Ternopil Ivan Pul'uj National Technical University Ternopil, Ukraine; ORCID iD: 0000-0002-8246-4305; e-mail: oksanaredkva@ukr.net

[3] Taras Shevchenko National University of Kyiv, Ukraine; ORCID iD: 0000-0003-4588-8149; e-mail: udovychenko.vv@knu.ua

[4] Interregional Academy of Personnel Management, Kyiv, Ukraine; ORCID iD: 0000-0002-2277-3317; e-mail: ovmichailenko@ukr.net

[5] National Academy of Sciences of Ukraine, Ukraine; ORCID iD: 0000-0003-2562-4373; e-mail: victor-koval@ukr.net

[6] Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Kraków, Poland; ORCID iD: 0000-0001-6475-8206; e-mail: kopacz@min-pan.krakow.pl

model has been developed for calculating the energy risk of the mechanical-engineering enterprise and has built a context diagram of mechanical-engineering production, taking into account the environmental impact and the possibility of energy modernization, which allows the setting of strategic goals to ensure the sustainability of energy supply in the mechanical-engineering industry and develop the main principles of efficient enterprise activities in the context of increased risk. It has been proven that one of the criteria for increasing the profitability indicator is the adaptability of enterprises to external conditions and increasing alternative options for obtaining energy from our own autonomous sources.

Keywords: energy supply management, energy resources, mechanical-engineering sector, sustainability

Introduction

One of the most resource-intensive manufacturing industries is the mechanical-engineering industry, which is now a promising area of development in many countries with a large range of resources and goods and the possibility of constant improvement (David et al. 2020). The strategic development of the mechanical-engineering sector in developing countries primarily requires modernization and regular improvement while these processes require significant financial outlays, which are limited and difficult to find and are faced with increasing risks and global trends in innovations, and with growing competition.

Due to the greening of the manufacturing industry and digitalization, more and more mechanical-engineering enterprises focus on eco-friendly and resource-saving production systems that should ensure the development of the economically effective economy. The infrastructure of the mechanical-engineering industry forms the material foundation for the technological modernization of the national economy.

With the outbreak of the military conflict in Ukraine, significant mechanical-engineering facilities were either damaged or shut down, complicating further development without restructuring and reconstruction. A lot of operating Ukrainian enterprises are faced with limited production and resources and a difficult marketing situation. It encouraged the top managers of enterprises to seek additional resources and reserves to improve their situation. Environmental and economic indicators were low because of high resource intensity and the use of outdated technologies, which had a negative result and environmental impact, in other words, they were unprofitable (Shvets et al. 2013). One of the strategic goals of every enterprise in recent years has been to find alternative reserves and innovations to preserve natural resources and adopt "green technologies" to global standards. On average, 20% of expenditures of Ukrainian enterprises accounted for energy resources, while this percentage reached about 10% in developed countries indicating the possibility to reduce them.

Given the above mentioned points, one of the most important factors that can improve the value of the environmental and economic indicators of the mechanical-engineering industry in

Ukraine is energy, the crisis of which became substantial in 2022 and reached a continental scale due to the worsening situation between countries and the resource dependence on suppliers.

The increase in global energy prices was the impetus to find new solutions worldwide, adopt "green technologies", change the values system and supply chains and reduce energy consumption.

In Ukraine, the problem of energy use emerged along with the problem of military conflict and the constant instability of energy supply at nuclear thermal power plants and other energy facilities, while mechanical-engineering enterprises of strategic importance to the country were not able to restore obsolete equipment and change technology.

This article is aimed at exploring the sustainability of the management of the energy supply in the mechanical-engineering industry as a strategic area of Ukraine's development, which has significant importance to improving the current situation and requires reconstruction in the postwar period.

The methodical approaches to the development of mechanical engineering that were used earlier may not be relevant for Ukraine in the post-war period and require further development in the field of environmentally friendly engineering in the context of the effective management of the energy supply.

1. Literature review

The transformation of the energy sector into a key market has imposed political and economic impacts, leading to dependencies between countries, state subsidies, permanent research and new technologies. In Poland, one of the European countries bordering Ukraine, there have been many types of financial support for alternative energy sources, such as preferential fees, grants, and loans, which were widely used by businesses to quickly improve and upgrade existing technologies (Cader et al. 2021; Koval et al. 2019). Furthermore, they reduced the dynamics of the 2022 energy crisis compared to countries with only traditional fossil energy resources and outdated mechanical-engineering technology.

At the same time, the number of photovoltaic systems – one of the methods of promoting low-carbon energy production – has increased in Poland in recent years, which has been actively supported by the state due to special development programs and promotion among businesses to improve the technical and environmental indicators of enterprises (Olczak and Komorowska 2021). The use of photovoltaic systems as an additional way to obtain energy improves the overall energy efficiency of a building by reducing energy consumption from fossil fuels and can reduce energy dependence on traditional energy resources for both small and large enterprises (Sawicka-Chudy et al. 2018).

Unfortunately, there are difficulties in introducing alternative energy-effective technologies and energy sources that would increase profits in the long term; this also applies to developing

countries with economic and political uncertainties. However, the use of energy efficient technologies and energy sources can lead to higher carbon reductions in the future (Olczak and Komorowska 2021).

When analyzing small mechanical-engineering enterprises, the use of expensive decision support systems in small systems can be unprofitable, and NPV for lithium-ion technology is much higher than for hydrogen technology; for example, the NPV output of the 1 MWh and 1 MW storage system is –4.85 million EUR for hydrogen, and NPV for lithium-ion is –0.23 million EUR, which indicates the prospects for lithium-ion technology in order to upgrade existing energy systems (Komorowska et al. 2022).

Steam generation and waste hot fluid, which can be used in mechanical-engineering enterprises, can also serve as a source of additional energy when using modern automatic control systems and the organic cycle (Kaczmarzewski et al. 2019; Matuszewska and Olczak 2020).

The growth of renewable energy sources in Poland and government support in the implementation of low-carbon development ideas shows positive long-term effects, attracts investment in promising areas of Ukraine's development, improves the situation on the energy market and creates additional energy reserves (Dzikuć et al. 2022).

With the number of photovoltaic energy producers growing in Poland, this technology is promising for further development in Ukraine where one will develop a new concept of environmental and economic security during reconstruction and it is expected that this would result in the rapid growth and large flow of foreign investment.

2. Research methodology and results

The increasing dependence on energy carriers has actualized the issue of public energy security, requiring an urgent solution in numerous countries. Russia's military and energy aggression has triggered the adoption of new technologies, not only in the defense sector but also in manufacturing. Therefore, mechanical-engineering enterprises have become one of the objects for the introduction of green technologies that have recently become popular in developed countries where the issue of financing was relegated to second place in favor of environmental problems (Latysheva et al. 2020).

The largest mechanical-engineering countries in terms of the market share are China, the USA and Germany, the revenues of which in the mechanical-engineering industry are shown in Figure 1.

Economic activities of mechanical-engineering enterprises in Ukraine take place at a substantial level of uncertainty in the environment of their functioning, which is characterized by systematic changes in the legal field, the unbalanced economic policy of the state, the weakness of the financial sector, the decline in high-tech production, as well as increasing international competition and pressure on the national market. These factors causes significant threats to me-

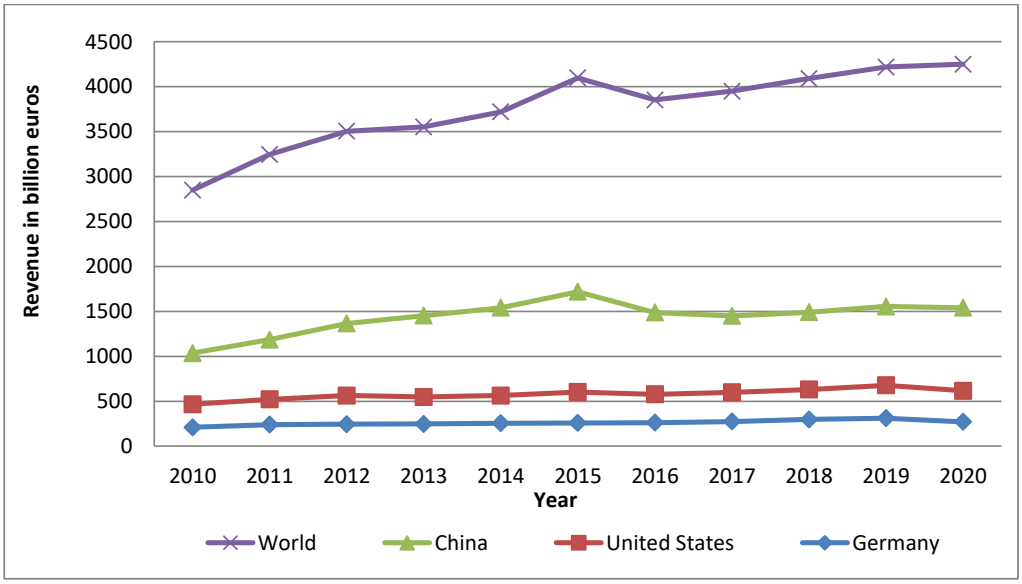

Fig. 1. Revenues of the mechanical-engineering industry (European Commission 2022)

Rys. 1. Przychody w przemyśle maszynowym

chanical-engineering enterprises, which requires the construction of an efficient economic-security management system. The imperfection of the current economic-security system of most mechanical-engineering enterprises does not contribute to active counteraction to the implementation of internal and external dangers and, consequently, results in the development of crisis processes. The economic-security management system of mechanical-engineering enterprises can be defined as one of the functional areas of management, in other words, as a process of planning, organization, motivation and control required to achieve the goals of the efficient functioning of any business entity.

The construction of a system of ensuring, organizing and managing the economic security of mechanical-engineering enterprises requires analysis of the basic parameters of their activities and functional objectives of security, taking into account the social, economic and environmental aspects.

European countries are currently undergoing a transformational period accompanied by the establishment of a new green economic system based on the concept of improving public welfare. Thus, each area of production activity is facing changes and is in a constant dynamic state (Davis-Sramek 2021; Morea et al. 2021).

The general concept of changes in developed countries is shown in Figure 2.

Most areas of society are influenced by global trends in resource and environmental preservation based on the increasing responsibility of each individual for his or her own economic activities (Trachenko et al. 2021). The concept of public consciousness is based on general edu-

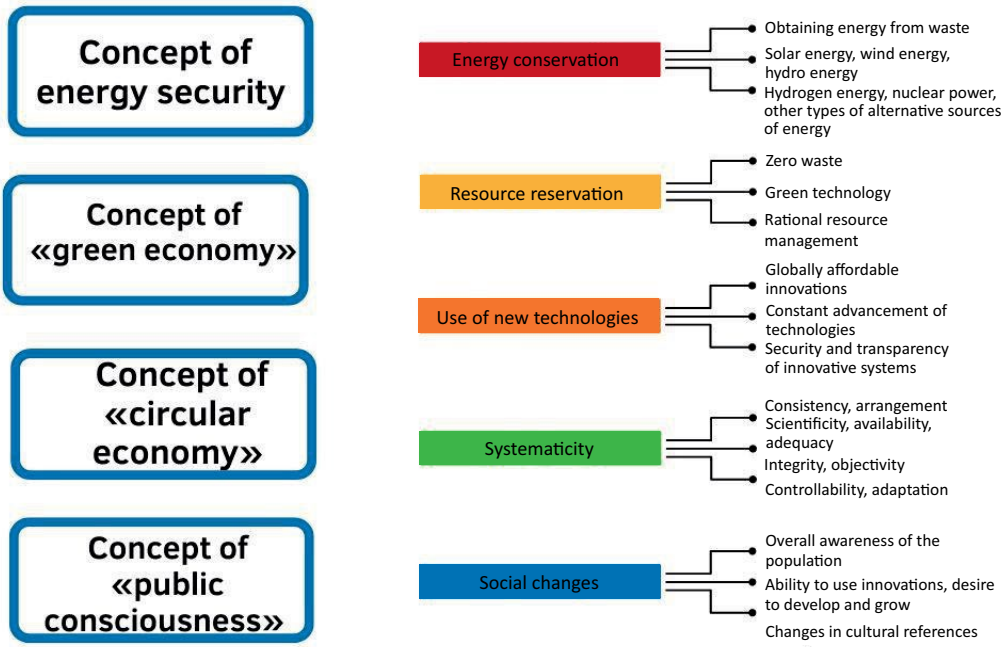

Fig. 2. The transformation of general concepts to different areas of social production in developed countries

Rys. 2. Transfery kluczowych podejść do różnych obszarów produkcji w krajach rozwiniętych

cation, cultural improvement, a careful attitude to the environment and the constant adoption of innovations aimed at optimizing existing material flows (Milčiuvienė et al. 2019).

One of the components of the concept of the circular economy is a resource preservation strategy, which also includes energy conservation principles, as a component of the general approach to rational nature management.

Figure 2 analyzes general approaches to energy conservation that should be implemented within mechanical-engineering enterprises as a production sector with overconsumption of energy sources. The energy conservation approach is based on the principle of increasing the share of the use of renewable energy sources as an alternative to traditional mineral resources that are unevenly distributed in the world and with limited reserves, which makes these resources the object of economic policy of particular countries and goods, the market of which is affected by the foreign policies of different nations.

Taking into account the key approaches shown in Figure 4, we can understand the necessity to upgrade Ukrainian enterprises with a high level of energy consumption, which is possible only with the availability of finance and state support for green economy projects.

Based on the analysis of energy production and consumption from renewable energy sources, we can draw attention to the positive trend in 2022 and the increasing share of the use of renewable energy sources in both Ukraine and Europe, which proves positive trends (the trend

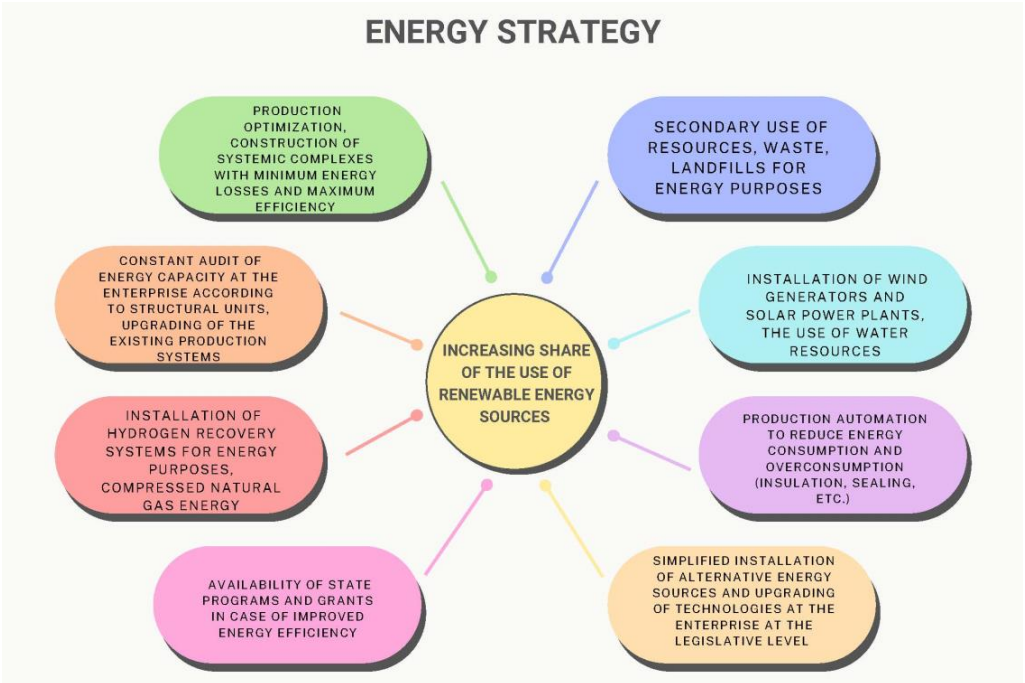

Fig. 3. Key approaches to energy conservation in mechanical-engineering enterprises given the concept of green economy

Rys. 3. Kluczowe podejścia do wykorzystania energii w przedsiębiorstwach przemysłu maszynowego w świetle „zielonej gospodarki”

line is growing) and the efficiency of technologies reducing the energy dependence on traditional energy sources.

However, the outbreak of hostilities has resulted in a dangerous situation around nuclear power plants in Ukraine, which shows the inefficiency of the existing safety systems and market mechanisms (Song and Moon 2020).

Additional risk factors are created for mechanical-engineering enterprises when only using external energy channels and in the case of the lack of their own alternative methods of producing energy. This risk factor refers not only to Ukraine but also to the whole world given the uneven distribution of resources, oligopoly on the energy market and the manipulations of certain countries to meet their own goals.

With Ukraine currently facing the decrease in real GDP, the closure of mechanical-engineering enterprises, increased expenses for the defense sector and the reduction in real wages (by 83% compared to January 2022 and December 2021 – this percentage increased during the hostilities), the re-equipment of mechanical-engineering enterprises is possible only in the case of orders for the defense sector. Enterprises should be modernized with the focus not on environmental preservation but on changing production goods that are currently relevant for consumption.

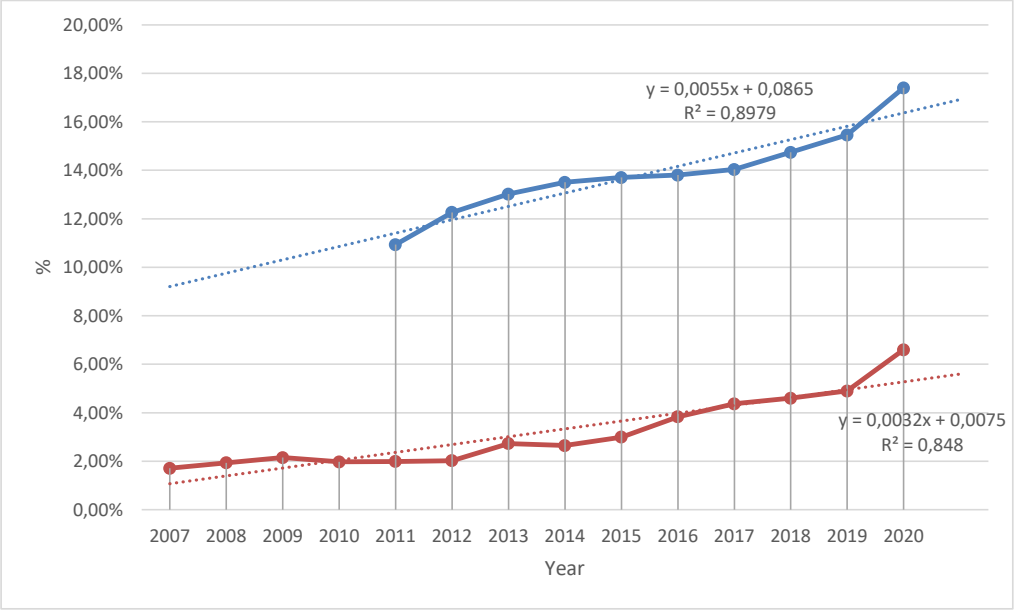

Fig. 4. Energy consumption in Europe and Ukraine from renewable energy sources (European Commission 2022)

Rys. 4. Zużycie energii ze źródeł odnawialnych w Europie i Ukrainie

The energy risk coefficient for a particular enterprise can be calculated using the formula:

$$R = \frac{V_z}{V_z + V} + \frac{L}{L_a + L} + \frac{\Delta D_k}{\Delta D_{Ri}} + \frac{E_z}{E_z + E} \tag{1}$$

where:

- V – equity capital,
- V_z – borrowed capital,
- L_a – current assets,
- L – current liabilities,
- ΔD_k – the average square amplitude of energy price fluctuations of a particular company (or a country) on the stock market from its average value for the analyzed period,
- ΔD_{Ri} – the average square amplitude of fluctuations of the average price of energy resources on the global stock market from its average value for the analyzed period,
- E_z – energy consumed by the enterprise from external sources,
- E – energy produced by the enterprise (alternative energy sources).

Table 1 shows the performance of the private machine-parts-production enterprise before (2019) and after (2021) manufacturing modernization.

Table 1. The performance of the private machine parts production enterprise before 2019 and after 2021 manufacturing modernization

Tabela 1. Wyniki prywatnego przedsiębiorstwa produkującego części do maszyn przed 2019 i po modernizacji produkcji w roku 2021

Indicator	Before modernization	After modernization
Capacity [%] (efficiency factor)	54	87
Equity capital [%]	100	81
Average square amplitude of energy-price fluctuations of a particular company [UAH per MW·hour]	278	279
Equipment safety – percentage of risk-free situation (data from device instructions)	74	96
Average lifetime of products	5 years (1 year warranty)	8 years (2 year warranty)
Energy produced by the enterprise	0	800 Watt per sq.m. (20 sq.m.)
Production profitability [%]	4.8	9.7

Source: RGS Ukraine LLC 2022.

Table 1 shows that despite the crisis and the large number of stress factors, the enterprise began to operate more efficiently after the reconstruction, which was generally due to the replacement of equipment with more innovative and efficient alternatives and the reduced expenses for energy needs. Therefore, one should carry out prompt modernization with increases in resource autonomy at mechanical-engineering enterprises.

The availability of borrowed funds poses an additional risk to the enterprise in case of an unpredictable situation because of the inability to freely dispose of financial resources and the dependence on external sources of funds, so maximum autonomy and stability is desirable for mechanical-engineering companies.

Comparing the energy-risk coefficients of companies (or countries), we can draw conclusions about the further development of the company and define the need to create its own energy-production systems.

When the coefficient $R >= 2.8$, we can say that the enterprise (or country) is risky, so it is necessary to change the energy, economic and environmental policy of the enterprise to reduce its dependence on external sources and stabilize the situation, which can lead to unpredictable expenses and uncertainty.

When optimizing enterprise activities, one should initially reduce the impact of risk factors on the enterprise and increase corporate reserves (diversify activities), which can be described by the model of improving the financial stability of the enterprise.

Examples for Ukraine in the recovery in the postwar period include Switzerland, Germany and Poland, who actively adopt alternative energy sources, and the 2022 hostilities have become the impetus to speed up the finding of new options to solve the problem of energy resources. For example, the significant use of photovoltaic power plants in Poland has become an alternative

in the face of the growing worldwide energy crisis and is one of the options to be used within mechanical-engineering enterprises.

The less risky zone of financial stability can be seen in enterprises with their own energy production and a large autonomy coefficient, which indicates the need to install cutting-edge automated systems aimed at optimizing the company's own resources and install autonomous systems for producing alternative (low-carbon) energy.

When constructing a context diagram for a mechanical-engineering enterprise given environmental indicators, one should take into account the need for financial resources that can create a reserve fund in the long term due to the adoption of green technologies and can also reduce the risk of dependence on external influence factors (Fig. 5).

The roofs of production and non-production premises of mechanical-engineering enterprises should be used to install photovoltaic systems as an alternative method of obtaining energy for the enterprise's own needs.

The main strategic goals to ensure the sustainability of energy supply in mechanical engineering include:

1) the construction of autonomous modern energy systems in mechanical-engineering enterprises based on the principles of green economy;

2) the establishment of stable functional relations with companies producing clean energy and the availability of alternative flows of energy resources;

3) the optimization of own capacities that use enterprise resources for energy production (air, water, thermal energy, etc.) based on the modernization of technologies and the adoption of innovations (increasing the efficiency of other production systems in order to obtain energy);

4) the rapid exchange of information and technologies in the industry and the constant updating of existing systems to reduce risk factors and increase the sustainability of the energy supply;

5) the permanent control of enterprise operations, auditing and production optimization;

6) the creation of a map of measures to minimize the consequences of risk situations and instructions to counteract their occurrence;

7) increasing the financial autonomy of the enterprise and the creation of a reserve fund and energy accumulation structures;

8) the creation of information security at the enterprise by improving the functioning of information and the operating systems of the enterprise;

9) participation in grant and state programs promoting green economy and the involvement of investors in the modernization of the enterprise;

10) the development of local energy conservation plans based on the principles of digitalization and automation.

When shifting from the external crisis to stability, the optimal shift for the enterprise is the one that will not affect environmental and economic indicators and production capacity, i.e.:

$$U(R1;S1;k1) \approx U\left(R2;S2;k2\right) \approx U\left(R3;S3;k3\right) \approx \ldots \approx U\left(Rn;Sn;kn\right) \rightarrow U\left(R1;S1;k1\right) \qquad (2)$$

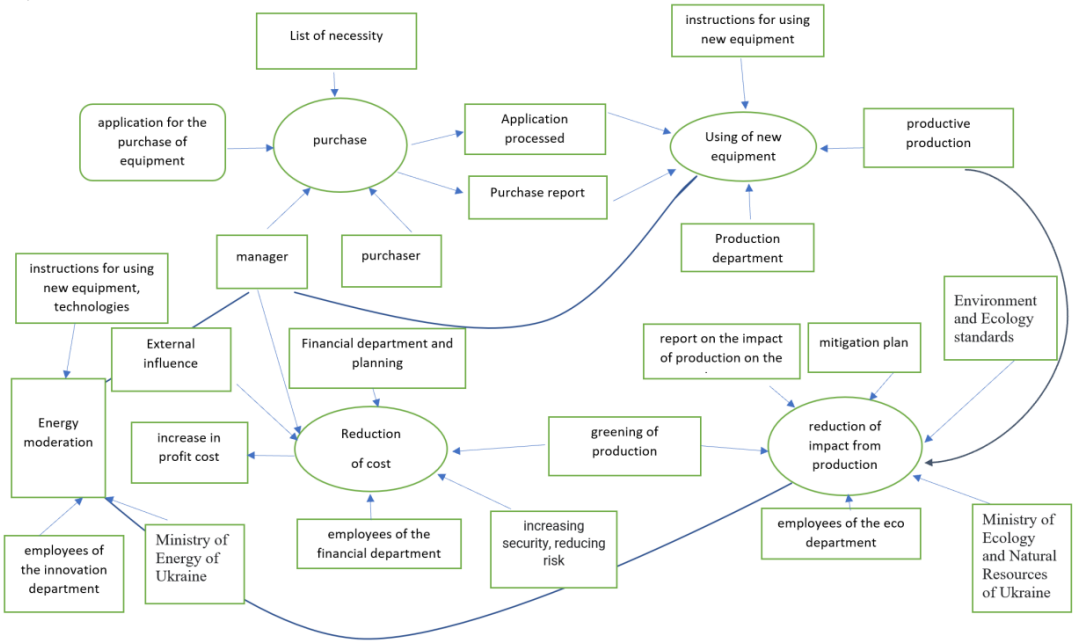

Fig. 5. Context diagram of mechanical engineering production given the environmental impact and the possibility of energy modernization

Rys. 5. Schemat ideowy dla przedsiębiorstwa sektora maszynowego z uwzględnieniem wpływu na środowisko i możliwości modernizacji energetycznej

Where the zero state of the production system (U), which depends on the energy market situation ($S1$) with the risk ($R1$) and the coefficient of the use of own renewable energy sources ($k1$), should be approximately equal to the state of the system with the increased external risk $R2$, the average price of used energy sources ($S2$) and the coefficient of the use of own renewable energy sources ($k2$) in Case 2, etc. to n.

In other words, the system should be stable at a certain time interval and be able to return to the zero point without negative impacts on the production performance or on environmental and economic results. In this case, the variable indicator of the use of own renewable energy sources should be higher when the energy market fluctuations are large while the risks increase to reduce negative impacts on mechanical-engineering enterprise activities (Zhu et al. 2021).

The modeling of components of the economic-security management system of the mechanical-engineering enterprise is a range of processes capable of adapting the system to changes and providing appropriate protection against potential threats to operations of the production system. Information support in the economic-security management of mechanical-engineering enterprises is not only a set of information sources and economic parameters but also covers the approval of processes of grouping and processing collected data to make efficient managerial decisions.

Therefore, based on the creation of its own photovoltaic center with the possibility of adding other sources of alternative energy production, one can achieve the stabilization of the situation in the face of external market fluctuations and the change in risks for this enterprise.

The security system of mechanical engineering enterprises should perform two main functions: operative information and preventive.

A crucial requirement for the management system of mechanical-engineering enterprises is its flexibility, as its organizational structure should provide a prompt response to changes in the external environment and be able to adapt quickly to them.

The key criteria for assessing the efficiency and reliability of the management system include:

- sustainable development, preservation and multiplication of material values of mechanical -engineering enterprises and the high level of product competitiveness;
- the use of innovative technologies in production activities;
- the inviolability of commercial information and all resources;
- the prompt prevention of crisis situations and the neutralization of negative factors affecting the activities of the mechanical-engineering enterprise.

Consequently, the management system of the mechanical-engineering enterprise is the set of various measures aimed at protecting its interests from the negative external impact.

Thus, the establishment of the economic-security management system of the mechanical-engineering enterprise is a complex and multidimensional process affecting its sustainable development and protection from threats and dangers.

Mechanical-engineering enterprises regularly require technical re-equipment and the reconstruction of basic facilities, changes in the strategic set of business areas, changes in the business philosophy, as well as the choice of such an organizational management structure that will meet the requirements of the above-mentioned factors. Therefore, the determining factor in the economic-security management of mechanical-engineering enterprises is adaptability, which includes organizational support of the enterprise's behavior under conditions defined by changes in internal and external environments.

Conclusions

The energy crisis is caused by both natural and political mechanisms, one of which is the strategic foreign policy of countries with reserves of energy resources and creating market fluctuations. This results in energy danger and affects all macroeconomic indicators of countries dependent on energy imports.

Mechanical-engineering enterprises are energy-intensive, so it is necessary to develop a range of measures to reduce energy dependence on external sources, which are primarily based on production optimization, the use of enterprises' own potential, and the adoption of innovations. However, when drawing up Ukraine's reconstruction plan, one should optimize production, up-

grade existing facilities or totally replace them in accordance with environmental and economic standards of the EU and use cutting-edge technologies, which will significantly reduce the use of resources and increase the productivity of enterprises.

One of the options to reduce the energy crisis risk is to develop autonomous energy-generation systems at the mechanical-engineering enterprise based on the use of its own facilities (waste production, steam, etc.) and the construction of a photovoltaic system designed on the principles of implementing the concept of the green economy.

In order to create favorable conditions for work, each enterprise should become as autonomous as possible and not use centralized energy resources or use them as little as possible. This will improve the independence of enterprises from military operations and create conditions for further work. At the same time, finite energy resources will be saved, and solar energy, which will be transformed with the help of photovoltaic cells, will have a positive effect on ecology. Currently, there are many manufacturers of photovoltaic cells, but the cheapest of them are located in China. For Ukraine, the production of photovoltaic cells is also promising and can become a new area of income.

On the basis of the study, it was concluded that the profitability of the enterprise increases by 9.7% when using autonomous energy generators that use alternative sources of energy production. In turn, this also reduces risks for enterprises by 22%, which is extremely important for stable operation. This leads to a decrease in the cost of production and an increase in the competitiveness of the product on the market by 9%, which is also due to its environmental friendliness as this is currently popular in many developed countries.

When assessing the sustainability of energy supply management in mechanical engineering, one should take into account dependencies on factors of external influence (risks) and minimize them by implementing the concept of social consciousness and the green economy at the enterprise due to the optimization of production processes and the adoption of innovative energy conservation and generation technologies.

References

Cader et al. 2021 – Cader, J., Olczak, P. and Koneczna, R. 2021. Regional dependencies of interest in the "My Electricity" photovoltaic subsidy program in Poland. *Polityka Energetyczna – Energy Policy Journal* 24(2), pp. 97–116, DOI: 10.33223/epj/133473.

David et al. 2020 – David, T.M., Silva Rocha Rizol, P.M., Guerreiro Machado, M.A. and Buccieri, G.P. 2020. Future research tendencies for solar energy management using a bibliometric analysis, 2000––2019. *Heliyon* 6(7), DOI: 10.1016/j.heliyon.2020.e04452.

Davis-Sramek, B. 2021. Corporate "green gold": State policy implications for wind and solar energy buyers. *Business Horizons* 64(3), pp. 347–360, DOI: 10.1016/j.bushor.2021.02.002.

Dzikuć et al. 2022 – Dzikuć, M., Piwowar, A. and Dzikuć, M. 2022. The importance and potential of photovoltaics in the context of low-carbon development in Poland. *Energy Storage and Saving* 1(3), pp. 162–165, DOI: 10.1016/j.enss.2022.07.001.

European Commission 2022. *Eurostat*. [Online] https://ec.europa.eu/eurostat [Accessed: 2022-10-25].

Kaczmarzewski et al. 2019 – Kaczmarzewski, S., Olczak, P. and Halbina, A. 2019. Issues of photovoltaic installation size choice for a hard coal mine. *E3S Web of Conferences* 123, DOI: 10.1051/e3sconf/201912301014.

Komorowska et al. 2022 – Komorowska, A., Olczak, P., Hanc, E. and Kamiński, J. 2022. An analysis of the competitiveness of hydrogen storage and Li-ion batteries based on price arbitrage in the day-ahead market. *International Journal of Hydrogen Energy* 47(66), pp. 28556–28572, DOI: 10.1016/j.ijhydene.2022.06.160.

Koval et al. 2019 – Koval, V., Sribna, Y., Mykolenko, O. and Vdovenko, N. 2019. Environmental Concept of Energy Security Solutions of Local Communities Based on Energy Logistics. *19th International Multidisciplinary Scientific GeoConference SGEM 2019*, 19(5.3), pp. 283–290, DOI: 10.5593/sgem2019/5.3/S21.036.

Latysheva et al. 2020 – Latysheva, O., Rovenska, V., Smyrnova, I., Nitsenko, V., Balezentis, T. and Streimikiene, D. 2020. Management of the sustainable development of machine-building enterprises: A sustainable development space approach. *Journal of Enterprise Information Management* 34(1), pp. 328–342, DOI: 10.1108/JEIM-12-2019-0419.

Matuszewska, D. and Olczak, P. 2020. Evaluation of Using Gas Turbine to Increase Efficiency of the Organic Rankine Cycle (ORC). *Energies* 13(6), DOI: 10.3390/en13061499.

Milčiuvienė et al. 2019 – Milčiuvienė, S., Kiršienė, J., Doheijo, E., Urbonas, R. and Milčius, D. 2019. The Role of Renewable Energy Prosumers in Implementing Energy Justice Theory. *Sustainability* 11(19), DOI: 10.3390/su11195286.

Morea et al. 2021 – Morea, D., Fortunati, S. and Martiniello, L. 2021. Circular economy and corporate social responsibility: Towards an integrated strategic approach in the multinational cosmetics industry. *Journal of Cleaner Production* 315, DOI: 10.1016/j.jclepro.2021.128232.

Olczak, P. and Komorowska, A. 2021. An adjustable mounting rack or an additional PV panel? Cost and environmental analysis of a photovoltaic installation on a household: A case study in Poland. *Sustainable Energy Technologies and Assessments* 47, DOI: 10.1016/J.SETA.2021.101496.

RGS Ukraine LLC 2022. [Online] https://rgs-ukraine.com.ua/ [Accessed: 2022-09-12].

Sawicka-Chudy et al. 2018 – Sawicka-Chudy, P., Rybak-Wilusz, E., Sibiński, M., Pawelek, R., Cholewa, M. and Kaczor, M. 2018. Analysis of possibilities and demand for energy in a public building using a tracking photovoltaic installation. *E3S Web of Conferences* 49, DOI: 10.1051/e3sconf/20184900096.

Song, J. and Moon, Y. 2020. Security Enhancement Against Insiders in Cyber-Manufacturing Systems. *Procedia Manufacturing* 48, pp. 864–872, DOI: 10.1016/J.PROMFG.2020.05.124.

Shvets et al. 2013 – Shvets, V.Y., Rozdobudko, E.V. and Solomina, G.V. 2013. Aggregated methodology of multicriterion economic and ecological examination of the ecologically oriented investment projects. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* 3, pp. 139–144.

Statista 2021. Global Mechanical Engineering Revenue. [Online] https://www.statista.com/statistics [Accessed: 2022-11-05].

Trachenko et al. 2021 – Trachenko, L., Lazorenko, L., Maslennikov, Y., Hrinchenko, Y., Arsawan, W. and Koval, V. 2021. Optimization modeling of business processes of engineering service enterprises in the national economy. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* 4, pp. 165–171, DOI: 10.33271/nvngu/2021-4/165.

Zhu et al. 2021 – Zhu, L., Fang, W., Rahman, S.U. and Khan, A.I. 2021. How solar-based renewable energy contributes to CO_2 emissions abatement? Sustainable environment policy implications for solar industry. *Energy & Environment*, DOI: 10.1177/0958305X211061886.

Inesa Mikhno, Oksana Redkva, Viktoriia Udovychenko,
Oksana Tsimoshynska, Viktor Koval, Michał Kopacz

Zarządzanie dostawami energii w przemyśle maszynowym w aspekcie zrównoważonego rozwoju

Streszczenie

Coraz większe wymagania związane z bezpieczeństwem energetycznym, następujące w obliczu rosnącego zapotrzebowania na energię i malejącego finansowania paliw kopalnych, doprowadziło do konieczności dywersyfikacji dostaw energii i przechodzenia na nowe – alternatywne źródła energii. Zarządzanie dostawami energii w świetle wymogów zrównoważonego rozwoju ma na celu osiągnięcie niskiej emisyjności produkcji, zwłaszcza w branżach energochłonnych, w tym inżynierii mechanicznej – przemyśle maszynowym. W artykule przeanalizowano możliwość zmiany funkcjonowania przedsiębiorstw z branży maszynowej w kierunku nowej koncepcji „zielonej gospodarki" oraz wpływ tych zmian na produkcję oraz powiązane z nią wskaźniki techniczne, środowiskowe i ekonomiczne. Może to stanowić alternatywę dla osiągania dalszego zrównoważonego rozwoju tej branży. W artykule przeanalizowano kluczowe podejścia do zarządzania źródłami energii. Opracowano model analityczny do obliczania ryzyka energetycznego przedsiębiorstwa z branży maszynowej oraz zbudowano diagram kontekstowy z uwzględnieniem wpływu na środowisko, jak i możliwości modernizacji energetycznej, dla określenia strategicznych celów i zapewnienia ciągłości dostaw energii, a także kluczowych zasad efektywnej energetycznie działalności w analizowanej branży, w świetle rosnącego ryzyka tych dostaw. Wykazano, że jednym z kryteriów poprawy wskaźników zyskowności staje się zdolność adaptacji przedsiębiorstw do warunków zewnętrznych oraz zwiększenie dostępu do alternatywnych źródeł energii, w szczególności własnych.

Słowa kluczowe: zarządzanie dostawami energii, zasoby energetyczne, sektor inżynierii mechanicznej, zrównoważony rozwój