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KEY TRENDS IN GOVERNING UKRAINE'S ENERGY SECTOR IN THE CONTEXT OF MILITARY AGGRESSION

Background. *The energy sector of Ukraine is a critical component of the national infrastructure. In Ukraine, this issue is especially relevant under the influence of military aggression, since its facilities in all sectors (from mining to electricity generation and oil refining) are being constantly destroyed. The restoration of the energy sector of Ukraine and its further development require new approaches to its management and the application of new technologies to increase the efficiency of resource use. The purpose of the study is to identify key trends and develop approaches to the intensive use of Ukraine's energy resources using the latest technologies. The task of the study is to determine the prospects for using cogeneration to rebuild the energy sector of Ukraine. The object of the study is approaches to the intensive use of energy resources. The subject of the study: the main tools for rebuilding the energy sector of Ukraine.*

Methods. *The methodological basis of the study is general scientific and special methods of scientific knowledge, in particular, theoretical and methodological analysis of modern literature on the development of the energy sector, and documents of world organizations in the energy sector. The method of analysis and synthesis was used to generalize and provide a unified approach to highlighting the advantages and disadvantages of the above-mentioned tools for rebuilding the energy sector. SWOT and PESTEL analyses were also used to determine the advantages and disadvantages of using cogeneration as a tool for rebuilding the energy sector of Ukraine.*

Results. *The study showed that significant destruction in the energy sector of Ukraine requires the application of new strategies for its development. Damage to electricity generation facilities requires their restoration on the principles of low-carbon technologies, and attacks on oil and gas fields led to the need to restore previously preserved sources of hydrocarbons. It was determined that the use of deposits that were closed due to unprofitability requires the transition to new, more modern technologies, which will allow for an increase in the resource base of hydrocarbons and, using cogeneration of energy, to solve the problem of energy independence and ecology.*

Conclusions. *The introduction of cogeneration in the current conditions and war will allow attracting additional investments to increase the extractable reserves of oil and gas, maintain hydrocarbon production at the current level to increase electricity production, achieve energy stability and autonomy, save fuel, reduce the country's energy dependence, solve environmental safety, etc.*

Keywords: *oil, gas, inactive deposits, liquidated wells, oil and gas industry, production, cogeneration, difficult-to-extract reserves.*

Background

Ukraine's energy sector is a critical component of the national infrastructure, as the sustainability of all social, economic, and defence institutions of the country depends on its functioning. The energy sector is the basis for the development of the national economy. In Ukraine, this issue is especially relevant because of the military aggression, as there is constant destruction of its facilities in all its segments (from mining to electricity generation and oil refining). The reconstruction of Ukraine's energy sector and its further development are based not only on the availability of adequate financing but also require new approaches to its management and the application of new technologies to increase the efficiency of resource use. Modern challenges caused by ongoing political and geopolitical tensions, as well as significant destruction of the energy infrastructure due to military actions, pose a daunting task for the Ukrainian government to restore destroyed facilities and to develop a strategy for the protection and recovery of all segments of the energy sector, taking into account the prospects of European integration.

The purpose of the study is to identify key trends and develop approaches to the intensive use of Ukraine's energy resources using the latest technologies. The objective of the study is to determine the prospects for using cogeneration to rebuild the energy sector of Ukraine.

Literature review. The object of the research is the approaches to the intensive use of energy resources. The subject of the research is the main instruments for the reconstruction of the energy sector of Ukraine.

In economic literature, the issue of forming a modern strategy for developing a sustainable renewable energy sector is actively considered. For example, Sulich and Sołoducho-Pelc (2022) conducted a thorough study of the main directions of transformation of the energy sector development strategies. They found that modern strategies not only prioritize technological solutions but are also based on the sustainable development of the sector and the economy as a whole. Markovska, Taseska and Pop-Jordanov (2009) made an attempt to determine the optimal strategy for its sustainable development based on a SWOT analysis of the energy sector of Macedonia. They recommended the use of natural gas, economically reasonable electricity prices, increased energy efficiency, and the use of renewable energy as the basis for further development of the sector in the country. Papież, Śmiech and Frodyma (2019) analysed the impact of the development of the renewable energy sector on the relationship between electricity consumption and economic growth in the EU countries in 1995-2015. The authors found that the development of the renewable energy sector has a positive impact on economic growth. Dzikuć et al. (2021) considered the issue of abandoning the excessive use of solid fuels. They emphasized that Poland is currently trying to catch up with other EU countries in its economic development, but to do this, it needs to switch to low-carbon technologies. They noticed that a component of such a process should be the transition to renewable energy sources. Strielkowski et al. (2024) examined the main directions of the energy sector transformation in European

countries to reduce harmful emissions within the framework of the Paris Climate Agreement and identified six groups of countries depending on the strategy they use on the path to sustainable development of the sector. One of the main criteria for the analysis was the share of renewable energy in its total production. Lorek, and Lorek (2023) proposed a concept for modernizing the sustainable energy segment, taking into account the EU policy and the principles of sustainable electricity generation. They noted that some factors (energy and economic crises) do not contribute to an effective transition to renewable energy. Liu et al. (2022) highlighted that very often a trilemma arises when building a strategy for the development of the energy sector, that is, a conflict between three challenges: equitable access to energy, energy security, and environmental protection. The authors considered that achieving all three goals simultaneously is impossible, the environment suffers the most, and the countries with the largest greenhouse gas emissions are in no hurry to improve the situation. Juhola et al. (2024) examined the impact of renewable energy on climate change mitigation, as well as the impact of climate risks on energy companies operating in the renewable energy sector. They argued that companies typically ignore these risks because they consider them insignificant.

Another area of research that is popular in the economic literature is the use of cogeneration to build a sustainable energy sector. Particularly, Çakir, Comakli and Yüksel (2012) considered the cogeneration system as one of the ways to save energy, increase energy efficiency, and reduce carbon emissions. Oh et al. (2007) examined the commercial use of cogeneration plants jointly producing electricity and heat to determine their optimal size from an economic perspective. According to the authors, the payback period of the investment and the rate of return are crucial. Also, a popular area of research is the impact of cogeneration on energy sector transformation strategies to increase its sustainability (He et al. 2021; Ma et al.2021; Salehi et al. 2021).

The work of many scientists, both domestic and foreign, is dedicated to the study of the problems in the energy sector and the innovative and investment development of the energy sources. Thus, the issues of energy investment by regions of the world were revealed in the work of Stepanova.The author proved the importance of investing in the energy sector for the entire developed world and identified the priorities of this process, the ways to solve Ukraine's energy dependence, taking into account existing world best practices. In the research by Hernego and Lyakhova (2021) dedicated to the investments in alternative energy in Ukraine, it was proven that increasing the potential of alternative energy in Ukraine is associated with the possibility of attracting financial resources from various sources. Based on a study of practical aspects of financing renewable energy sources, the features of financing the potential for the development of alternative energy in Ukraine are revealed, and the factors that determine it are identified. Babina identified and systematized the features of innovation and investment activities in the development of alternative energy sources and substantiated ways to implement world best practices in innovation and investment activities for the development of alternative energy sources in Ukraine (Babina, 2020). The author has improved the economic and mathematical modelling of the development of alternative energy sources, which allows for creating multivariate forecasts for the development of alternative energy sources by regions of Ukraine, as well as to develop a framework for the development of alternative energy sources. Samoilenko (2018) considered the innovation and investment frameworks for the development of the energy market of Ukraine, and established the need to implement regulatory benchmarking as a measure that allows for determining the reference level of efficiency of an energy company in several key aspects, such as operational and investment activities, and in such factors as reliability, costs, and losses. In particular, Sobolev and Zatonatska (2024) focused on the main directions of further development of the energy sector of Ukraine within the framework of the implementation of the state strategy. The authors proposed their own definition of the energy sector, which was based on such components as the main segments of energy demand and the energy supply segment. The authors concluded that the successful implementation of Ukraine's national energy strategy requires further improvement of the regulatory environment, expansion of economic support instruments, and intensification of international cooperation. Another area of research that is popular in the scientific literature is the use of cogeneration to build a sustainable energy sector. Thus, Khodakivskyi and Karpenko attempted to determine the effectiveness of the implementation of cogeneration in the conditions of modernization and redundancy of the heat supply system (Khodakivskyi and Karpenko, 2025). The analysis of the efficiency of centralized and decentralized heating systems, including Power-to-Heat technologies, conducted by the authors, showed that distributed generation systems, electrification of heat supply, and the introduction of renewable energy sources can significantly reduce greenhouse gas emissions and increase the reliability of energy infrastructure. Andreev et al. (2015) conducted a thorough study dedicated to the analysis of low-power power generating units used in the conversion of existing boiler houses into mini-CHP plants. Their work presented comparative features of gas piston engines and gas turbine plants for small power generating facilities, and assessed the possibilities of implementing cogeneration principles. The researchers carried out feasibility studies on the implementation of a superstructure based on GPA, focusing on the impact of gas prices on the project's payback period, which is extremely important in today's conditions of energy instability. Stepanov and Resident (2023) determined the impact of the ratio of gas and electricity prices on the economic efficiency of combined heat and power generation using natural gas. They showed that using a cogeneration plant to cover one's own electrical needs is economically feasible if the ratio of prices for electricity and natural gas is more than 2.4. The authors confirmed that cogeneration is economically feasible, but has significant investment payback periods. However, despite significant scientific achievements in this area, not all issues related to the formation of Ukraine's energy sector during the military aggression have yet been resolved, which makes this area of research relevant.

Methods

The methodological basis is a combination of general scientific and special methods. A theoretical and methodological analysis of modern scientific literature on the problems of energy sector transformation, as well as official documents and analytics of international organizations in the field of energy, was applied. To generalize approaches and identify discussion fields, methods of analysis and synthesis, induction and deduction, comparative and systemic approaches were used. The empirical part is based on statistical methods for processing time series: construction of indices, calculation of chain and basic growth/decline rates, moving averages, as well as the ratios

"investment → production" for oil and gas. To preliminarily identify the relationship between the dynamics of capital investment and actual production volumes, the correlation approach and elastic estimates (in percentage changes year-on-year) were applied. Institutional and political-economic analyses were used to interpret the obtained quantitative results in the context of military risks and regulatory constraints. The assessment of strategic directions for reconstruction was carried out through two complementary frameworks, including SWOT analysis and PESTEL analysis of the implementation of cogeneration, taking into account the conditions of wartime and post-war recovery. Additionally, elements of the scenario approach and case analysis were applied. The source database includes official statistics, specialized government publications, as well as analytics from international organisations and industry research reviews.

Limitations. Due to the martial law and increased confidentiality requirements, official statistics after 2022 have significant limitations. The calculations used an agreed assumption regarding the proportional distribution of investments between the gas and oil segments. At the same time, the lack of quarterly data and possible structural gaps in reporting do not allow for drawing unambiguous cause-and-effect conclusions. The obtained results of correlation and elastic estimates are considered indicative. To increase the reliability of the conclusions, methodological triangulation was used, involving a combination of quantitative and qualitative approaches.

Results

In the modern world, the concept of the green economy is actively developing, which involves the transformation and further development of the energy sector according to a new scenario focused on renewable energy, reducing greenhouse gas emissions, waste, and environmental protection. Ratification of the Paris Climate Agreement of December 12, 2015 and implementation of relevant measures by its signatories would provide several significant positive effects by 2040: increasing electricity production from renewable energy sources (RES) to 37% in the overall electricity production structure; using RES for new capacities at 60% and increasing their competitiveness; increasing the number of electric vehicles to 150 million units, etc. If these projections come true, CO2 emissions from the global energy sector will grow by an average of 0.5% annually, compared to an average of 2.4% since 2000. This indicates the need for a more active transition to carbon-neutral development, in particular, through the transformation of the energy sector of the economy. The fundamental principle of decarbonising the energy sector is the transition from traditional energy production and consumption systems based on fossil fuels, such as oil, natural gas, and coal, to the expansion of renewable energy sources, the implementation of non-traditional sources, as well as the improvement of energy transmission and storage systems.

Renewable energy sources play a key role in shaping a new energy paradigm that not only meets the requirements of environmental sustainability but also stimulates significant economic shifts. In Ukraine, as it combats difficult challenges due to military aggression, the implementation of strategies for transitioning to renewable energy sources can promote economic growth, reduce dependence on imported energy resources, increase energy security, and create new jobs.

According to forecasts by the International Renewable Energy Agency, the global transition to renewable energy sources by 2030 could add more than $4 trillion to the world economy and create more than 20 million new jobs. At the same time, to achieve the baseline scenario by 2030, global investments in renewable energy sources must increase significantly, meaning at least threefold. These trends are also reflected in the development of the global renewable energy market (Fig. 1).

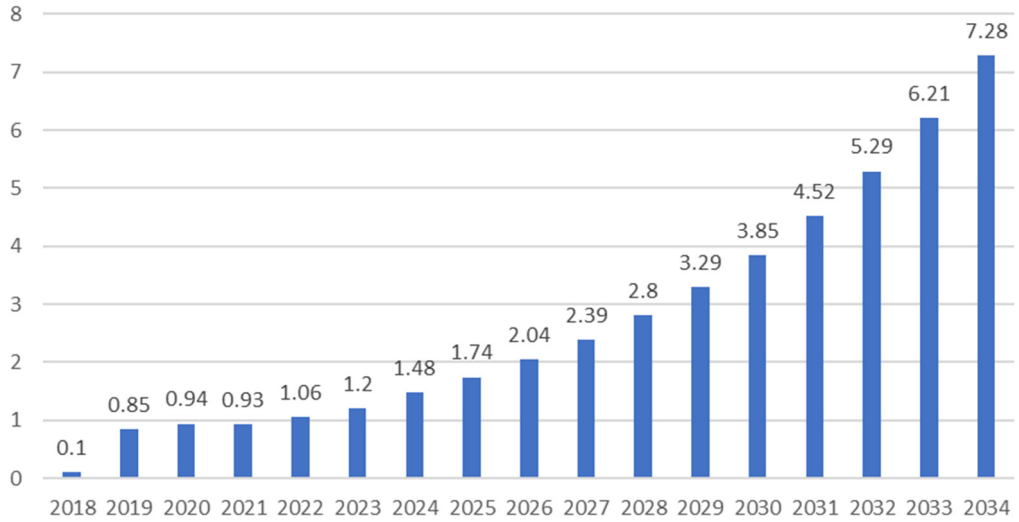

Fig. 1. Global renewable energy market (trillions of U.S. dollars)

Source: compiled by the author based on data from Precedence Research 2025 and Grand View Research 2024. Forecast starting from 2025.

If in 2018 the volume of this market was only 0.1 trillion USD, then according to forecasts for 2025, this figure will reach 1.74 trillion USD. The global renewable energy market is expected to reach $7.28 trillion USD by 2034, with a compound annual growth rate of 17.23% between 2025 and 2034. This shows evidence of significant demand for clean energy in various sectors of the global economy.

Ukraine is actively seeking integration into the European Union, and the practices of the EU member states in the field of renewable energy are an important guide for us. It should be noted that the transition to energy transformation is an important step to ensure sustainable development and stability of Ukraine's energy system in the future. However, the implementation of this policy is impossible without overcoming the consequences of military destruction

caused by russia's armed aggression. As a result of this destruction, the energy infrastructure (Fig. 2) and the country's economic base suffered significantly, which complicates the process of transitioning to renewable energy sources and increasing energy efficiency. Therefore, the recovery of damaged energy infrastructure facilities is an important stage in the context of the overall energy transformation, which should ensure not only the sustainability of the energy system but also create conditions for sustainable socio-economic development.

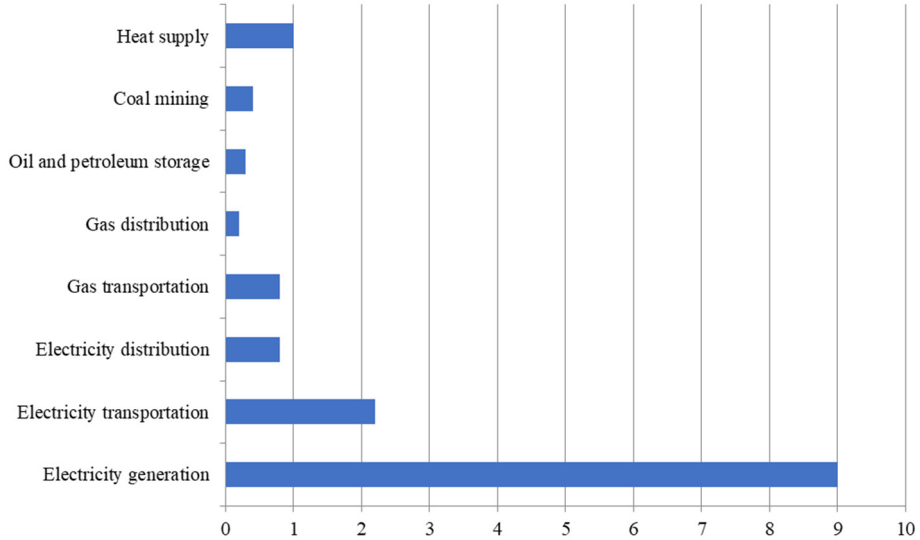

Fig. 2. Direct losses of Ukraine's energy sector as a result of the armed conflict (billions of U.S. dollars)

Source: compiled by the author based on data from Report on Direct Damage to Infrastructure from Destruction as a Result of russia's Military Aggression against Ukraine (as of November 2024).

Total direct damage from destruction due to military aggression as of November 2024 is estimated at 14.6 billion USD. This reflects the scale of the destruction, particularly in the electricity generation and transmission sector, which is most vulnerable to shelling and attacks by the aggressor. Damages caused to energy facilities amount to over 12 billion USD, with a significant portion of them occurring at large generation facilities. Massive missile strikes on thermal and hydroelectric power plants resulted in damage or destruction of a significant number of turbines, generators, and auxiliary equipment. One example is the destruction of the Kakhovka hydroelectric power plant in June 2023, which caused losses in excess of $0.6 billion USD. Critical damage was sustained by thermal generation facilities: as a result of massive shelling, several key thermal power plants and CHP plants were destroyed or put out of action, such as Burshtynska TPP, Ladyzhynska TPP, and Trypilska TPP.

Gas transportation and distribution suffered losses estimated at USD 0.8 billion and USD 0.2 billion, respectively. Damage to gas pipelines and gas distribution stations has caused a chronic gas shortage, which is particularly acute at the level of industrial enterprises and the population, particularly in the winter. Given the critical importance of this infrastructure for the country's energy security, its restoration is an important task to ensure a stable energy supply. The storage of oil and petroleum products suffered losses of USD 0.3 billion, and the coal mining industry lost USD 0.4 billion. Part of the coal mining industry, in particular mines and quarries for coal extraction, is located in territories where active hostilities are taking place or which have already been captured by the enemy. This significantly limited access to the necessary resources for thermal power plants that use coal as their main fuel. As a result, Ukraine has become significantly dependent on imported energy sources, which increases the vulnerability of energy infrastructure and creates additional risks to the country's energy security. Additionally, electricity generation facilities from renewable sources also suffered serious losses. A significant portion of solar and wind generation capacity was located in temporarily occupied territories, resulting in the loss of 13% of solar generation capacity and almost 80% of wind generation capacity. Constant shelling of energy facilities has led to the destruction or serious damage of more than 20% of renewable capacity. Current direct losses for the renewable energy segment are estimated at $0.3 billion USD (as of November 2024).

Despite the serious destruction caused by the war and the need to restore a significant part of the energy infrastructure, it is important to note that the existing infrastructure has long required modernization. It is outdated and worn out, which complicates the efficient use of resources and increases risks to energy security. Therefore, along with the restoration of damaged facilities, it is necessary to direct efforts to the development and implementation of innovative solutions and investment changes in the management of the energy sector. This will not only ensure the stability of the energy sector but also contribute to its long-term modernization and efficiency improvement.

Ukraine's oil and gas industry consists of three main sectors: hydrocarbon exploration and production, hydrocarbon transportation and storage, as well as processing and distribution. Each of these sectors plays an important role in the country's energy independence, but the hydrocarbon exploration and production sector occupies a key position. It is the structural element, as it ensures the growth of resources, stability, and development of the entire oil and gas industry, and therefore the energy security of the state. Analysis of data on oil production in Ukraine in recent years indicates a negative trend of decreasing production volumes, which became even more pronounced after the start of russia's armed aggression.

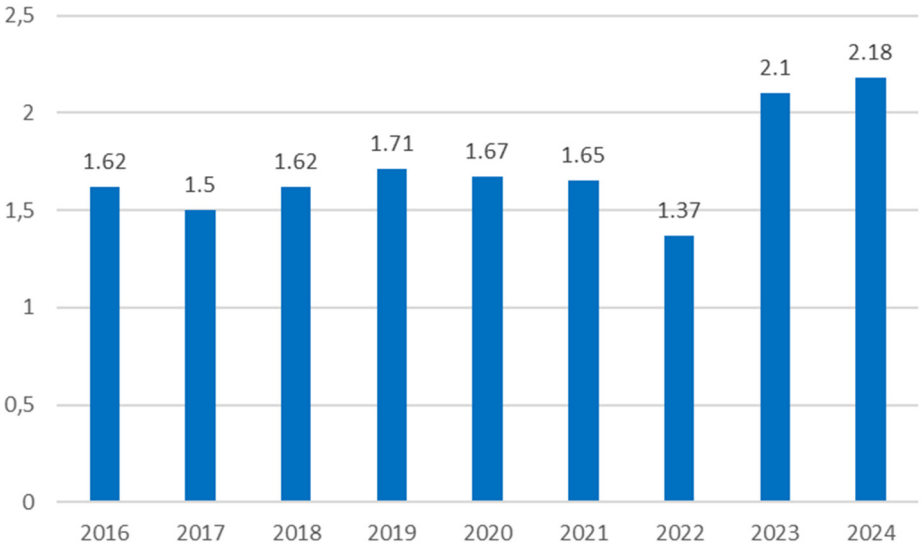

Fig. 3. Dynamics of oil production (million tons)

Source: compiled by the author based on data from the State Statistics Service 2024 of Ukraine and open sources.

According to the data in Fig. 3, in 2016, oil production was at the level of 1.62 million tons; however, in 2022, it decreased to 1.37 million tons, which indicates a significant reduction in extractable resources. The negative impact of russian aggression, particularly in the territories where oil and gas fields are located, has complicated the process of hydrocarbon extraction. Although oil production increased to 2.1 million tons in 2023 and 2.18 million tons in 2024, it cannot fully compensate for the losses caused by both the long-term trend of declining production and the destruction caused by the war.

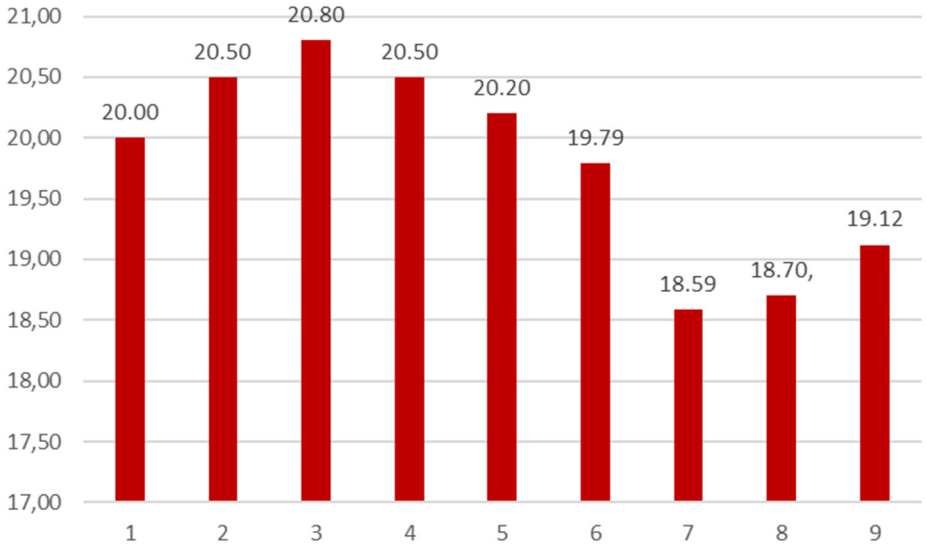

Fig. 4. Dynamics of gas production (billion m³)

Source: compiled by the author based on data from the State Statistics Service of Ukraine 2024 and open sources. Since 2022, gas and condensate production have been reported as a single indicator.

Analysis of data on gas production in Ukraine in recent years also indicates negative trends. According to the dynamics shown in Fig.4, in 2016 the volume of production was 20 billion m³, but by 2022 it decreased to 18.59 billion m³. The steady decline is due to a number of factors, including infrastructure problems, equipment wear and tear, and, of course, military operations. 2023 was marked by a slight increase in production to 18.7 billion m³, which continued into 2024 (19.12 billion m³). However, this growth cannot compensate for the shortage of gas in gas storage facilities. As of early spring 2025, about 5 billion m³ of gas remained in the underground storage facilities of the gas transportation system of Ukraine, and in February 2025, it was necessary to urgently purchase 0.5 billion m³, while 0.8 billion m³ was required. It should be noted that for the stable passage of the 2025–2026 winter season, Ukrainian underground storage facilities need to accumulate at least 12.8 billion m³ of gas, including 4.6 billion m³ of so-called buffer gas, necessary to maintain pressure in storage facilities. Despite all the efforts of the oil and gas complex, this is impossible in conditions of constant shelling. Only import remains.

It should be noted that the systemic stagnation observed in the oil and gas industry negatively affects the economy of Ukraine, since the industry has a significant share in the country's GDP. At the same time, a decrease in production

leads to a decrease in energy independence, as the country becomes more dependent on energy imports, which, in turn, increases the vulnerability of the national economy to external economic and political factors. In such conditions, the role of the state in creating and implementing innovative changes in the oil and gas industry becomes particularly important. It should become the main driver of the industry's development, creating conditions for the inflow of investments and stabilization of hydrocarbon production. Innovations in exploration and production, the use of the latest technologies and drilling methods, as well as improving infrastructure for transporting and storing hydrocarbons, can become key factors in ensuring the stable development of the industry and increasing the country's energy independence in the face of global changes in energy markets.

Overall, despite some recovery in 2023–2024, the general trend towards a decrease in hydrocarbon production threatens the country's energy security, which requires comprehensive measures to attract significant investments to the industry (Fig. 5).

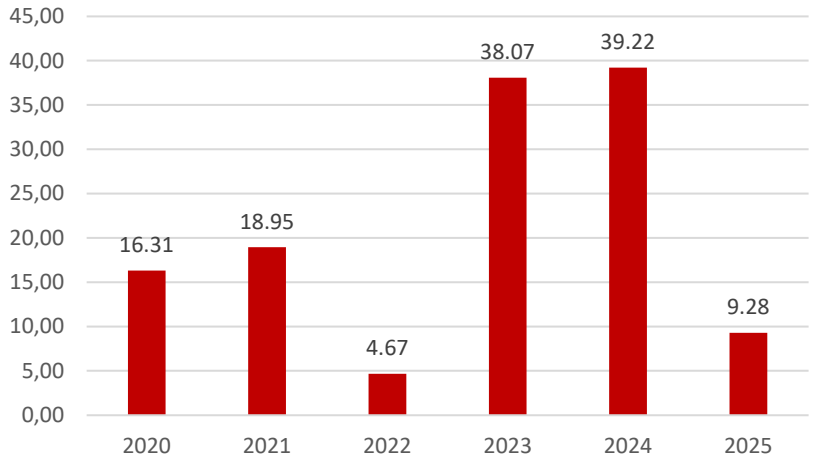

Fig. 5. Capital investments in oil, gas, and condensate production, billion UAH

Source: compiled by the author based on data from the State Statistics Service of Ukraine 2025.

Our analysis of capital investments in oil, gas, and condensate production in Ukraine shows significant fluctuations, indicating the serious challenges the industry has faced amid the armed conflict and economic difficulties. In 2020, capital investments in the sector amounted to UAH 16.306 billion, representing a relatively stable level. In 2021, investments increased to UAH 18.951 billion.

(+16.2%), indicating some improvement in the conditions for the development of the oil and gas industry, likely due to a more stable economic situation and partial recovery from the COVID-19 pandemic. However, in 2022, investments decreased sharply to UAH 4.672 billion (–75.3%). This significant reduction is explained by the beginning of russia's armed aggression against Ukraine, which caused large-scale destruction of infrastructure, particularly in the oil and gas sector. Not only did physical facilities suffer from shelling and combat operations, but investors also became more cautious due to the sharp increase in risks, which negatively affected the volume of capital investment. However, in 2023, there has already been a significant increase in capital investments to UAH 38.07 billion (+714.6% compared to 2022), which indicates the state's efforts to restore the industry and attract new financial resources to stabilize oil and gas production. This growth resulted from government support and investment incentives, as well as efforts to adapt to new conditions and the urgent need to restore critical energy infrastructure. In 2024, capital investments continued to grow, reaching UAH 39.221 billion (+3.0 %). This trend is a positive signal for the industry and demonstrates its capacity to develop despite ongoing challenges. However, data for the first quarter of 2025 – showing capital investments of UAH 9.282 billion compared to the same period in 2024– indicate a potential slowdown in investment growth, creating risks for the stability of the industry's development in the short and medium term.

Our analysis of the dynamics of capital investments in oil and gas production in Ukraine relative to the actual indicators of hydrocarbon production allows us to trace a clear relationship between the volume of invested resources and the performance of the industry (Table 1).

Table 1

Dynamics of changes in investments and oil and gas production in Ukraine

Year	Total investments, billion UAH	%	Investments in gas, billion UAH	Investments in oil, billion UAH	Gas production, billion m³	%	Oil production, million tons	%
2020	16.306	–	15.16	1.145	20.2	–	1.675	–
2021	18.951	+16.2	17.63	1.32	19.79	–2.0	1.65	–1.5
2022	4.672	–75.3	4.35	0.33	18.59	–6.1	1.37	–15.7
2023	38.07	+714.6	35.4	2.6	18.7	+0.6	2.1	+53.6
2024	39.221	+3.0	36.5	2.7	19.12	+2.3	2.18	+3.8

Source: compiled by the author based on data from the State Statistics Service of Ukraine.

In 2020, the total volume of capital investments in oil, gas, and condensate production amounted to UAH 16.306 billion. At the same time, there was a clear imbalance in the distribution of funds: oil received UAH 1.145 billion (7 % of the total amount); gas accounted for UAH 15.16 billion (93 %). This confirms the state's strategic focus on supporting the gas production sector, whereas the oil sector remained relatively secondary in terms of investment. The lack of official detailing by industry sector after 2020 is explained by the confidentiality requirements of the Law of Ukraine "On Official Statistics" dated August 16, 2022, No. 2524-IX. However, if we conditionally apply the ratio of 93% (gas) to 7% (oil) for the following years, we can trace the following patterns:

- In 2021, investments increased to UAH 18.951 billion. This means that the gas production sector could have accounted for about UAH 17.6 billion, while the oil sector for only UAH 1.3 billion. This imbalance logically explains why oil production grew only symbolically (+0.2%), while gas showed a more noticeable increase (+2.5%).
- In 2022, the total volume of investments fell sharply to UAH 4.672 billion (-75.3 %). Applying the previous ratio, gas would account for about UAH 4.35 billion, and oil would account for less than UAH 0.33 billion. This decline was reflected in production: oil fell by 15.7%, and gas by 9.5%. Thus, the investment deficit immediately affected production volumes, and in the oil and gas balance, it was the oil segment that suffered the greatest losses.
- In 2023, investments recovered to UAH 38.07 billion (+714.6 %). Under the conditional distribution, gas got UAH 35.4 billion; oil got UAH 2.6 billion. In the same year, oil production increased by 53.6%, and gas production by only 0.6%. This difference is explained by the fact that even a small additional inflow of funds into the oil sector (from UAH 0.3 to 2.6 billion) had an instant effect, while gas production, due to high inertia and a long investment cycle, reacts much more slowly.
- In 2024, investments increased by another 2.9%, reaching UAH 39.221 billion. Following the same proportion, gas received about 36.5 billion UAH and oil 2.7 billion UAH. As a result, oil production increased by 3.8% and gas by 2.3%. This demonstrates that a gradual increase in investment in wartime conditions still allows for the stabilization of production, although the effect is different for different sectors of the industry.

In general, the growth of capital investment in oil and gas production shows a positive correlation with production volumes, but this effect depends on the scale of investment and the existing challenges. We have come to the conclusion that in Ukraine, we can observe: the dominance of the gas sector, as about 90% of all investments were directed specifically to gas production, while oil remained underfunded. This led to a long-term decline in oil production, despite the overall growth in investments in 2021. The analysis reveals several key patterns: ***high sensitivity of oil production*** – even a small increase in investments in the oil segment (for example, from UAH 0.33 billion in 2022 to UAH 2.6 billion in 2023) produced a rapid effect, resulting in a sharp increase in production (+53.6%); ***inertia of gas production*** – the gas industry reacts slowly even to substantial increases in investments, which can be explained by the long cycles required for drilling new wells, developing infrastructure, and commissioning new capacities; ***war as a key factor*** – the sharp decline in investments in 2022 and the subsequent reduction in production confirm that military actions and the destruction of infrastructure remain the decisive factors behind the stagnation of the industry; ***strategic need*** – to restore Ukraine's energy independence, it is essential to balance investments between the oil and gas sectors, with a special emphasis on modernization and innovation. This approach would help reduce the investment lag in gas production and enhance the overall efficiency of investments in the oil and gas sector. For stable development and sustainable production growth, it is necessary to attract investment, promote innovation within the industry, and continue the restoration of critical infrastructure.

At the beginning of Ukraine's independence, significant volumes of associated petroleum gas (APG) were lost through flaring due to technological imperfections in collection and preparation systems, as well as the remoteness of the fields from the main gas infrastructure. In the absence of economic incentives and against the backdrop of relatively cheap electricity from nuclear power plants, cogeneration projects were considered secondary. From an economic point of view, this meant lost profits: instead of converting APG into commercial electrical and thermal energy, there was a direct destruction of the resource without a multiplier effect on GDP and local budgets. Nowadays, taking into account military risks, capacity shortages, and high volatility of fuel markets, cogeneration is becoming a priority vector of investment. Its key advantage is high fuel efficiency due to the simultaneous production of electricity and useful heat, which reduces specific fuel consumption and the cost of energy for industry and district heating, and power utilities. Additional economic effect is formed by: reducing system balancing costs through distributed sources close to consumption; reducing network losses and capital-intensive investments in its transmission; "monetizing" previously lost APG. From an energy security perspective, decentralized cogeneration increases resilience to attacks on mainline infrastructure and reduces dependence on imports.

Cogeneration technology is not new to Ukraine, but its large-scale implementation has remained limited for a long time. In practice, the use of cogeneration units was concentrated mainly in large cities based on thermal power plants (TPPs), where they served as manoeuvring capacities with the ability to quickly respond to fluctuations in demand. Such stations operated mainly on traditional fuels such as coal, natural gas, or fuel oil. According to data until 2021, the share of cogeneration in the structure of electricity production in Ukraine was about 27% of the total generation volume. However, this dynamics did not have stable growth in 2016-2021, which indicates the lack of systemic investment support and proper state policy for the development of the industry. After the start of russia's large-scale aggression, the situation became even more complicated: the availability of statistical data has declined, and energy infrastructure has suffered significant damage. At the same time, official data from the National Commission for State Regulation of Energy and Utilities (NCRECU) for 2023 indicate a significant drop: electricity production from cogeneration TPPs decreased by 4.1% compared to 2022 and by 37.3% compared to 2021 (TEK, 2021). This decline reflects both wartime destruction and chronic underfunding of the industry's modernization. In such a situation, cogeneration takes on particular importance from an economic point of view. Firstly, it is a tool for increasing energy efficiency: simultaneous production of heat and electricity allows achieving a fuel utilization ratio of 80-90%, which significantly exceeds the performance of traditional generation. Secondly, the development of cogeneration technologies can reduce dependence on energy imports, since cogeneration plants can be built closer to consumers,

using local resources. Thirdly, they form an investment-attractive segment in the war and post-war period: investments in cogeneration are less capital-intensive than the construction of large thermal power plants or hydroelectric power plants, but provide a faster economic effect due to flexibility and decentralization.

However, the situation with cogeneration does not look hopeless. Thus, in 2024 alone, 68 cogeneration plants with a total electrical capacity of 77 MW were put into operation; in the first five months of 2025, 29 plants with an electrical capacity of 377 MW and a thermal capacity of 1,625 MW were qualified. Experience shows that some installations do not meet the criteria for high efficiency. The main reasons are too low electricity production, as well as the use of outdated equipment with low efficiency, sometimes over 50 years old. To increase efficiency and obtain the status of highly efficient cogeneration, the State Agency for Energy Efficiency and Energy Saving of Ukraine recommends that owners of such installations conduct energy audits, implement accurate energy accounting systems, consider switching to alternative fuels, prepare feasibility studies for modernization, and seek financing through available financial programs (Ukraine and the EU, 2025). Thus, the further development of cogeneration capacities in Ukraine requires technical modernization, a targeted innovation and investment strategy, and international investment support.

State innovation and investment policy in the energy sector is gaining particular importance in the current conditions of military challenges and transformational dynamics of the Ukrainian economy. It forms the basis for implementing the economic growth strategy, ensuring the integration of scientific and technological achievements into production processes and creating the prerequisites for increasing the competitiveness of the national economy. An energy sector capable of rapid adaptation and implementation of innovative technologies, including in the cogeneration segment, is becoming a key factor in sustainable development. Investments in the modernization and development of such technologies increase energy efficiency and create a multiplier effect for related industries, stimulating socio-economic changes. So, to determine the strategic priorities for the innovative development of Ukraine's oil and gas industry in the face of military threats and global energy transformation, it is advisable to use the SWOT analysis tool kit. This allows for a comprehensive assessment of the industry's internal strengths and weaknesses, as well as external opportunities and threats that will determine the prospects for its further evolution (Table 2).

Table 2

SWOT analysis of the implementation of innovations in the oil and gas industry of Ukraine

Strengths	**Weaknesses**
Experience. Ukraine has many years of experience in the production, transportation, and processing of oil and gas, which provides a basis for implementing innovations. International support. Active cooperation with international partners and organizations provides the opportunity to obtain modern technologies and investments. Resources. The presence of our own oil and gas reserves, including unconventional ones, which can be used more efficiently with the help of the latest technologies. Developed infrastructure. Oil and gas infrastructure, although damaged, is still ready for modernization in a relatively short period of time. Investments. In the context of war with russia, the governments of Ukraine and the United States signed a mineral agreement that will allow attracting foreign capital to develop the industry.	Import dependence. High dependence on energy imports, especially in times of war, complicates the stability of supply. Outdated infrastructure. A significant part of the infrastructure needs modernization, which requires significant financial investments. Economic constraints. Limited financial resources due to war and economic crisis, which limit opportunities for innovation. Security risks. Military actions and the constant threat of attacks on energy infrastructure. Occupation. Some of the oil and gas fields are located in occupied territories or directly in the combat zone.
Opportunities	**Threats**
Investments in fields written off from the State Balance Sheet. Re-liquidation of inactive fields and wells for re-production of oil and gas. Cogeneration. The construction of cogeneration plants will combine the oil and gas and energy industries and reduce dependence on imported energy resources. Investment in renewable energy sources. The development of renewable energy sources within the oil and gas industries will reduce dependence on traditional energy resources in their extraction and processing. International assistance and grants. Obtaining international assistance and grants for the restoration and modernization of infrastructure. Development of new technologies. Introduction of modern technologies for the extraction and processing of energy resources, which will increase efficiency and safety.	A prolonged war. Continued military operations, constant destruction of infrastructure will significantly complicate the implementation of innovations and the development of the industry. Cybersecurity threat. Increased vulnerability to cyberattacks, which can lead to infrastructure disruptions. Market volatility. The instability of global energy markets, fluctuations in oil and gas prices can affect the economic stability of the industry.

The conducted SWOT analysis demonstrates a complex and at the same time multi-vector picture of the development of the oil and gas industry of Ukraine. Despite its existing strengths, such as its own resources, many years of experience, and international support, the industry remains vulnerable due to outdated infrastructure, limited financial resources, and military risks. At the same time, opportunities associated with the re-licensing of inactive fields, the development of cogeneration, and the integration of renewable energy sources open up prospects for modernization and reduced dependence on imports. Threats posed by war, cyberattacks, and instability in energy markets underscore the need to strengthen public policy and create flexible innovation and investment mechanisms. Therefore, the strategic course should be aimed at maximizing the use of existing opportunities and neutralizing threats, which will create conditions for long-term energy security and economic sustainability of the state.

In modern conditions, which determine the priority areas for the development of the state's energy independence, it is necessary to focus efforts on the level of diversification of its sources and on the existing capabilities of our land. One of the sources of innovative development of the oil and gas industry is its closer connection with the energy sector,

which is currently in an extremely difficult situation. One of these areas that allows for the most effective use of one's own energy potential is cogeneration plants (cogeneration), which is a process that combines the production of electrical and thermal energy.

Innovative approaches to implementing cogeneration systems include:

- decentralization, changes in social and economic reforms in the state;
- development of technological and digital technologies;
- saving certain resources due to the implementation of modern technologies;
- use of low-pressure gas from certain fields and wells;
- use of oil refining products;
- use of renewable energy sources that have the ability to be constantly renewed.

Investment approaches for implementing cogeneration systems include:

- state support programs that provide conditions for energy transformation;
- organization of public-private partnerships that provide for their joint financing;
- participation in international grant programs that provide funds for the implementation of such initiatives;
- community support programs that provide for the modernization of individual complexes.

In order to form the conceptual foundations for the implementation of innovative cogeneration technologies based on depleted and liquidated fields (wells) of Ukraine in the context of military challenges, it is advisable to use the PESTEL analysis methodology. This approach allows for a systematic assessment of key environmental factors (political, economic, social, technological, environmental, and legal) that determine the possibilities and limitations of implementing the relevant process. The results of the analysis are integrated into Table 3, which reflects the impact of the external factors on the prospects for the implementation of cogeneration projects in the oil and gas industry of Ukraine in wartime conditions.

Table 3

PESTEL analysis of the implementation of cogeneration in depleted and liquidated fields (wells) of Ukraine in wartime conditions

Political Factors	Continuous destruction of the infrastructure of the oil and gas, and energy industries which makes stable operation and the possibility of implementing innovations impossible. Occupation of part of the oil and gas fields, coal and peat deposits, which are the main source of electricity production. Support of the authorities for the purpose of internal development and transition to European energy markets. The need to reform legislation to integrate into international law, to implement the mineral agreement concluded with the United States.
Economic Factors	Limited financial resources and low investment attractiveness due to the war. War and economic sanctions affect the stability of markets and the cost of energy resources, which affects the implementation of innovative projects. High dependence on gas imports and price fluctuations in European energy hubs increases vulnerability to external economic impacts.
Social Factors	The population's need for a stable supply of electricity. The need for highly qualified personnel to implement innovations and new technologies. High public support for the development of Ukraine's energy independence.
Technological Factors	Implementation of modern technologies for oil and gas production. Modernization of oil and gas infrastructure, including the re-liquidation of inactive fields and wells for the re-production of oil and gas.
Environmental Factors	Significant public support for the elimination of environmental pollution related to oil spills and gas emissions into the environment. The need to adapt to climate change and reduce greenhouse gas emissions.
Legal Factors	Reforming and implementing changes to the legislation of Ukraine regarding hydrocarbon production and obtaining special permits for subsoil use. Reforming legislation to integrate and harmonize with European legislation, which will promote transparency and attract investment. Ensuring legal protection of investments and compliance with international agreements, including mineral agreements with the United States.

As the PESTEL analysis shows, the key barriers to the implementation of cogeneration technologies are political instability, infrastructure destruction, and limited financial resources. At the same time, the opportunities are dominated by high public support for energy independence, the potential for using depleted wells, and the need to adapt to European standards. This creates the prerequisites for attracting both domestic and foreign investments, especially in the context of post-war reconstruction. Thus, cogeneration based on depleted deposits can become one of the strategic directions for modernizing the Ukrainian energy sector and strengthening its economic sustainability.

The key challenge remains overcoming the systemic asymmetry between the need to increase the resource base and safely increase production, and existing institutional and legal restrictions. Resolving this "inequality" requires an urgent government initiative from relevant bodies with a package of solutions that simultaneously:

- harmonize Ukrainian legislation with European legislation (permitting procedures, environmental standards, guarantees of energy origin, etc.);
- launch financial instruments to accelerate investments (long-term loans from IFOs, partial CAPEX compensation, accelerated depreciation, "green" and transitional PPAs for electricity and heat contracts for cogeneration, etc.);
- provide regulatory predictability for private investors (stable rules for access to resources, transparent auctions, standardized connection agreements, etc.).

After the active phase of the war ends, the priority will be the re-privatization/recapitalization of "dormant" assets and the targeted scaling of distributed high-efficiency cogeneration based on APG and low-pressure gas as the fastest way to increase energy efficiency, reduce import

dependence, and stabilize local energy balances. At the same time, seismic exploration and reassessment of resources in the continental part should be launched, including infrastructure modernization of gas collection and preparation. According to estimates by a number of reputable experts, Ukraine's potential allows it to increase natural gas production up to ≈55 billion m³/year in the medium term, provided that security is stabilized, the market is liberalized, and investments in exploration and production are scaled up. To implement this trajectory, an Energy Recovery Investment Fund with a clear mandate is needed: co-financing exploration, modernization of gas collection/processing infrastructure, and development of cogeneration projects (including heat contracts for communities and industry). Thus, an economically viable combination of (1) legal harmonization, (2) long-term investments, and (3) technological modernization, relying on highly efficient cogeneration and the prospect of offshore projects, is capable of ensuring a sustainable recovery of the energy sector, increasing production, and strengthening Ukraine's energy security.

Discussion and conclusions

The economic literature examines in detail the issue of energy sector transformation strategies used in the modern world. The main goal of such transformations is to achieve sustainable development of the sector, transition to low-carbon technologies, and promote environmental protection. One possible direction is the use of cogeneration using various technologies. Resolving these issues in the current conditions and war will allow attracting additional investments to increase recoverable oil and gas reserves, maintain hydrocarbon production at the current level to increase electricity production through cogeneration, achieve energy sustainability and autonomy, save fuel, reduce the country's energy dependence, address environmental safety, etc.

In general, the processes of forming strategies for managing the transition to a sustainable energy environment must take into account important socio-economic and political issues:

(1) Energy and financing. Appropriate strategies for transforming the energy sector include transparent long-term business planning, approaches to ensuring flexibility and balancing the system, as well as issues of increasing investment. Transparent step-by-step planning will ensure stability and efficient management with safe conditions for stakeholders in a liberalized and balanced energy market. Another important issue is the policy of attracting large amounts of investment needed in the energy sector. It is extremely important to guarantee security and transparency for investors and organizations financing renewable energy projects. This, in turn, can reduce the cost of renewable energy sources and the overall cost of the system.

(2) Stakeholders and government regulation. When planning the phase-out of fossil fuels and the transition to renewable energy sources, it is necessary to consider the need to involve key government stakeholders and relevant decision-making mechanisms. Involving a wide range of experts in decision-making on the use of appropriate policy instruments will ensure the harmonization of socio-economic processes at all levels of the economy. In particular, state institutions form and approve regulatory legal acts and development strategies for countries and industries in the field of sustainable development, decarbonization, stimulation of green investments, etc. At the same time, the state, through the implementation of environmental innovations, renewable energy sources, environmental management and audit systems, and the business sector, provides appropriate measures for sustainable environmental policy. Providing information about decarbonization processes and the specifics of implementing alternative energy at the level of individual communities and households, as well as providing them with green credits and benefits, will also contribute to reducing CO2 emissions. Examples from European countries demonstrate that institutions involving key stakeholders can improve the implementation of such a process at the political level.

(3) Transformation and industrial policy. Sustainable transformation of the energy industry has long-term consequences. This includes the consequences that disproportionately affect territories and populations, the impact of the energy transition on the economy as a whole, and how they can be regulated. What is relevant here is the implementation of a systemic policy on retraining and compensation payments to employees laid off in connection with the transformation policy. Changes in the energy sector will provide a comprehensive set of new opportunities and jobs for the personnel laid off, for example, from coal-based power plants and mines. Another aspect that needs to be taken into account concerns socio-economic issues, in particular the rise in energy prices for end consumers. As this may disproportionately affect vulnerable households and energy-intensive industries, this issue should be given special attention to avoid social hardship. Strategic coordination of industrial and energy sector policies is important here: which areas have been negatively affected; do they remain potentially viable in the future, and how can they be kept internationally competitive? It is recommended to introduce mechanisms for compensation and/or exemption from energy fees and taxes for enterprises in certain energy-intensive industries. It is also extremely important to increase state preferences for electricity productivity and modernization. This will help energy companies compete internationally, and this is especially important for companies that still use outdated technologies and do not receive financing.

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КЛЮЧОВІ ТЕНДЕНЦІЇ В УПРАВЛІННІ ЕНЕРГЕТИЧНИМ СЕКТОРОМ УКРАЇНИ В КОНТЕКСТІ ВОЄННОЇ АГРЕСІЇ

Вступ. ***Енергетичний сектор України є критичним компонентом національної інфраструктури. В Україні це питання є особливо актуальним під впливом військової агресії, оскільки відбувається постійне руйнування об'єктів у всіх секторах (від видобувного до генерації електроенергії та нафтопереробки). Відновлення енергетичного сектору України та його подальший розвиток вимагають нових підходів до управління та застосування нових технологій для підвищення ефективності використання ресурсів. Метою дослідження є визначення основних трендів і розроблення підходів до інтенсивного використання енергетичних ресурсів України із застосуванням новітніх технологій. Завданням дослідження є визначення перспектив використання когенерації для відбудови енергетичного сектору України. Об'єкт дослідження – підходи до інтенсивного використання енергетичних ресурсів. Предмет дослідження – основні інструменти для відбудови енергетичного сектору України.***

Методи. ***Методологічною основою дослідження є загальнонаукові та спеціальні методи наукового пізнання, зокрема й теоретико-методологічний аналіз сучасної літератури з питань розбудови енергетичного сектору, документів світових організацій в енергетичній сфері. Метод аналізу та синтезу використано для узагальнення та єдиного підходу до висвітлення переваг і недоліків зазначених інструментів для відбудови енергетичного сектору. Також застосовано SWOT- і PESTEL-аналіз для визначення переваг і недоліків використання когенерації як інструменту відбудови енергетичного сектору України.***

Результати. ***Дослідження показало, що значні руйнування в енергетичному секторі України вимагають застосування нових стратегій його розбудови. Пошкодження об'єктів генерації електроенергії потребує їхнього відновлення на принципах низьковуглецевих технологій, а атаки на родовища нафти та газу призвели до необхідності відновлення попередньо законсервованих джерел вуглеводнів. Визначено, що використання родовищ, що були законсервовані через нерентабельність, вимагає переходу на нові, сучасніші технології, що дасть змогу наростити ресурсну базу вуглеводнів і за допомогою когенерації енергії розв'язати проблему енергонезалежності й екології.***

Висновки. ***Впровадження когенерації в умовах сьогодення і війни дозволить залучити додаткові інвестиції для приросту видобувних запасів нафти і газу, підтримання видобутку вуглеводнів на поточному рівні з метою приростання виробництва електроенергії, досягнення енергетичної стійкості й автономності, економії палива, зменшення енергетичної залежності країни, забезпечення екологічної безпеки тощо.***

Ключові слова: ***нафта, газ, недіючі родовища, ліквідовані свердловини, нафтогазова галузь, видобуток, когенерація, важковидобувні запаси.***

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