ПРОБЛЕМИ ЕКОЛОГО-ЗБАЛАНСОВАНОГО РОЗВИТКУ

UDC 620.9
DOI https://doi.org/10.32846/2306-9716/2025.eco.5-62.2.19

PROBLEMS OF POST-WAR USE OF WIND ENERGY IN THE SOUTH OF UKRAINE

Bozhenko A.
Petro Mohyla Black Sea National University
68 Desantnykyv St., 10, 54000, Mykolaiv
voodoo@chmnu.edu.ua

The attacks on Ukraine's energy sector during the war raised the issue of diversifying energy production sources. It is assumed that a large number of small, dispersed sources are much more difficult to attack and destroy than a system of a small number of traditional industrial power plants. This increases the role of alternative energy sources. The most attractive area for wind power projects in Ukraine is the steppe zone. On the one hand the installation of wind farms takes away fertile land that it would be better to use for agriculture, on the other hand the lands of the five regions of the steppe zone are low-productive and, as a result, low-value. Ukraine has begun to take over the wind power experience of Germany, Denmark and other European countries. This prospect seems attractive, but it is necessary to take into account that in the north of Europe and the ocean coast, wind speeds are noticeably stronger than on land and the sea shelf of Ukraine, up to twice as much. In addition to attracting international and state money to the sector, the development of citizen investment is widely considered. We have analyzed hybrid (wind turbine + solar panels) installations from local suppliers. According to preliminary estimates, this solves not as much economic problems, such as making a profit, but rather the problem of diversifying electricity supplies. However, indirectly, the use of wind turbines can strengthen security in industry and housing and communal services of Ukraine and contribute to more sustainable development of the country's economy. Most of the regions of South-Eastern Ukraine are currently in the frontline zone, so they will be considered attractive for investment only after the war. In addition, it is necessary to take into account the recurrence of hostilities in the future and build the most diversified network of wind turbines and other energy sources, which it will be difficult to disable by attacking individual elements. *Key words:* wind energy, the South of Ukraine, hybrid energy systems.

Проблеми післявоєнного використання вітроенергетики в умовах Півдня України. Боженко А.Л.
Стаття присвячена аналізу перспектив розвитку вітроенергетики на півдні України після війни. Атаки на енергетичний сектор України під час війни порушили питання диверсифікації джерел виробництва енергії. Вважається, що велику кількість малих, розосереджених джерел набагато важче атакувати та знищити, ніж систему з невеликої кількості традиційних промислових електростанцій. Це підвищує роль альтернативних джерел енергії. Найбільш привабливим регіоном для проектів вітроенергетики в Україні є степова зона. Зазвичай ставиться питання, що встановлення вітрових електростанцій забирає родючі землі, які краще використовувати для сільського господарства, але землі п'яти регіонів степової зони є низькопродуктивними та, як наслідок, низькоцінними. Україна почала широко використовувати досвід вітроенергетики Німеччини, Данії та інших європейських країн. Ця перспектива видається привабливою, але необхідно враховувати, що на півночі Європи та океанському узбережжі швидкість вітру помітно сильніша, ніж на суші та морському шельфі України. Окрім залучення міжнародних та державних коштів у сектор, широко розглядається розвиток громадських інвестицій. Ми проаналізували гібридні (вітрові турбіни + сонячні панелі) установки від місцевих постачальників. За попередніми оцінками, це в першу чергу вирішує не економічні проблеми, такі як отримання прибутку, а проблему диверсифікації поставок електроенергії. Однак опосередковано використання вітрових турбін може посилити безпеку в промисловості та житлово-комунальному господарстві України та сприяти більш сталому розвитку економіки країни. Більшість регіонів Південного Сходу України зараз знаходяться у прифронтовій зоні, тому вони будуть вважатися привабливими для інвестицій лише після війни. До того ж слід враховувати можливий повтор у майбутньому воєнних дій і розбудовувати максимально диверсифіковану мережу вітрогенераторів та інших енергетичних джерел, яку важко буде надовго вивести з ладу за допомогою атаки на окремі її елементи. *Ключові слова:* вітрова енергетика, Південь України, гібридні електростанції.

Formulation of the problem. Potentially, Ukraine is of some interest in terms of investments in wind energy. This is in line with global trends towards a carbon-free economy and European efforts to reduce the continent's dependence on carbon-fuel-producing countries. To address this issue, it is necessary to research risk factors that affect the payback of such investments and justify their feasibility.

The relevance of research. In the long term, the introduction of alternative energy sources will help make the energy system of Ukraine more independent and resilient to economic and military attacks. It is obvious that wind energy itself will occupy only a narrow niche, but nevertheless, it is useful to study this type of energy as comprehensively as possible in order to maximize the future profit that can be extracted from it.

Connection of the article with important scientific and practical tasks. This work is connected with two important scientific and practical tasks of our time: the environmental task of introducing low-carbohydrate alternative energy sources into the local energy system and the task of increasing the energy security of Ukraine.

Analysis of recent research and publications.

According to Global Wind Energy Council global wind market growth in 2023–2024 was flat, annual wind installations (onshore and offshore combined) increased in the Asia Pacific and Africa & Middle East regions, while Europe, as well as North America and LATAM experienced a decline. However, the situation over the course of a decade is influenced by the factor that Europe has been accelerating renewables development to achieve energy security in the aftermath of Russia's invasion of Ukraine. It is expected that in the near future growth in Europe and China will remain the backbone of global onshore wind development. Altogether they are expected to make up 73% of the total capacity to be built during 2025–2030 [1].

The most attractive for the implementation of wind power projects in Ukraine is the steppe zone. Strong winds in the cold season, in the warm season reduce their strength, but compensate for this decrease with additional local winds – breezes. The presence of powerful seaports and highway networks in the steppe zone simplifies the solution of logistics problems.

Usually the question is raised that the installation of wind farms alienates fertile lands from use, which are more expedient to use in agriculture, but the lands of five regions of the steppe zone are low-productive and, as a result, low-value. These are the Crimea and the regions of Mykolaiv, Kherson, Zaporizhia and Luhansk. The total area of these lands, low-productive for agriculture, but quite suitable and economically profitable for wind farms, is 10,000 thousand hectares = 100 thousand km^2 [2, 3].

Minimum installed capacity utilization factor (CUF):

– 0.31 for onshore wind farms;

– 0.45 for offshore wind farms.

The largest potential for installed capacity and wind power generation are in Dnipropetrovsk, Kherson, Odesa and Zaporizhia regions. Mykolaiv region belongs to the second group of regions in the South and East in this ranking with a wind power capacity potential of 30,043 MW [2, 3].

According to the materials of the newspaper "Українська енергетика" ("Ukrainian Energy") [4], in 2024, up to 44.6 MW of wind power plants were installed in Ukraine, while in 2023 the installed capacity of new wind power plants was 238 MW. According to Konechenkov, the development of wind power in Ukraine is hampered by debt in the electricity market, periodic violations of the government's obligations to renewable energy producers, and the ineffectiveness of the market premium mechanism. Nevertheless, next year Ukraine intends to significantly increase wind generation. These are plans to build specific wind generation facilities with a capacity of more than 800 MW [4].

In order to fully restore the energy sector of Ukraine after the war and integrate it into the energy system of the European Union, it is necessary to exchange experience between universities of different countries. Gottfried Wilhelm Leibniz Universität Hannover, in particular, plans to provide active methodological support to the Mykolaiv region. In order to ensure the use of renewable energy sources, a network of scientists was formed there, uniting the Leibniz Research Center "Energy 2050" (LiFE 2050). For this purpose, interdisciplinary research areas were developed in the field of wind energy, solar energy, electric power, thermal and electrochemical energy, as well as sustainable drive systems [5]. Volker Schöber and Elke Katharina Wittich, within the framework of this line of research, suggest that Ukraine, like other European countries, move away from a centralized energy system, where if one element fails, the entire system is damaged, and perhaps even abandon the idea of restoring the energy system in this form after the war. Instead, they consider it advisable to build a diversified energy system composed of different types of energy installations, including, in particular, solar and wind [5].

Germany has been an EU leader in wind utilisation, PV, solar thermal installations and biofuel production for decades [6]. A stable and predictable policy framework has created conditions favourable to renewable energy sources (RES) growth. One of the most important economic benefits of wind power is that it reduces the exposure of economies to fuel price volatility. This benefit is so sizable that it could easily justify a larger share of wind energy in most European countries, even if wind were more expensive per kWh than other forms of power generation.

In 2025, according to Federal Network Agency, a large number of wind turbines are still being installed across Germany. The Federal Ministry for Economic Affairs reports that many new wind turbines have already been approved across the country and are now entering the construction phase. There's good news from the solar energy sector as well: Germany has already reached the halfway mark in its goal to expand solar capacity to 215 gigawatts by 2030 [7].

In addition to attracting international and government funds to the sector, the development of citizen investment is under consideration [8]. Citizen investment into wind energy is conducive to public acceptance and can contribute to closing the renewable energy investment gap, while promoting corporate social responsibility. The findings of [8] show that the risk of loss and the expected annual return on investment are the main attributes determining investment decisions, but secondary criteria, such as the project location and ownership characteristics, also affect willingness to invest. Respondents living within 10 km of a wind farm or expressing support for wind energy are significantly more likely to consider investing.

In order to actively attract residents to use solar and wind installations, it is usually necessary to use financial incentives from the state, such as tax cuts, green tariffs, etc. Such stimulation methods have their drawbacks. Thus, previously in Ukraine there were foreign solar battery parks that were fully owned by an external investor, could be removed and dismantled by him at any time, but the bulk of their income was the green tariff. In fact, their income came from the budget of Ukraine. However, further experiments with such forms of stimulation are possible to find the most optimal ones.

Highlighting previously unsolved parts of the general problem to which this article is devoted. The article is devoted to insufficiently studied aspects of wind energy development in the south of Ukraine, such as a comparative analysis of the experience and prospects for the development of wind energy in the countries of the European Union and Ukraine, taking into account local circumstances.

The novelty of the study. The authors have analyzed the economic risks and prospects for the mass use of wind turbines of different capacities in the south of Ukraine.

Methodological and general scientific significance. The methodological or general scientific significance of the work lies in the definition, clarification and theoretical substantiation of a set of issues related to improving the accounting and analysis of data on wind characteristics when making decisions about installing wind generators in a selected area.

Description of the study. Currently, the energy system of Ukraine is being reformed. After the war, investments from a number of European countries are planned. This creates the need to continue studying this industry in relation to the South of Ukraine. In order to predict the possible results of post-war investments, we analyzed data from sources [9, 10]. Total offshore wind capacity installed, under construction, consented, planned, on 30 June 2011 [9] we compared with the number of offshore wind farms operating worldwide as of June 2024, by country [10]. The results are presented in Table 1 and Fig. 1.

By comparing and ranking these data, we found a strong correlation between the number of projects in 2011 and the number of completed projects with the number of actual wind farms with turbines larger than 10 MW in 2024. This number is approximately two to three orders of magnitude less than the number of initial projects. It seems unlikely that thousands of wind energy projects will emerge for Ukraine, although it may be an exception to this trend.

It is worth mentioning that the wind capacity of the territory and water area of Ukraine is around two times less than in the best areas of northwestern Europe. For example, Fig. 2 shows that according to calculations by the Globalwindatlas system [11], the Mean Power Density indicator at an altitude of 100 m in the Elbe delta is 880 W/m^2, and at the confluence of the Bug estuary with the Dnieper estuary – 443 W/m^2. This is just one example, we have analyzed the map of the EU and Ukraine as a

Table 1

Total offshore wind capacity (installed, under construction, consented, planned), on 30 June 2011 compared to the number of offshore wind farms operating worldwide as of June 2024, by country

Country	Number of projects in 2011	Actual number of operating wind farms in 2024 (over 10 MW)
United Kingdom	48,596	39
Germany	31,247	30
Norway	11,394	5
Sweden	8,279	4
Spain	6,804	1
France	6,000	4
Netherlands	5,992	11
Greece	4,889	0
Finland	4,249	1
Ireland	3,780	1
Italy	2,700	1
Denmark	2,471	16
Belgium	1,857	11
Estonia	1,000	0
Poland	0,900	0
Portugal	0,478	1
Latvia	0,200	0
Malta	0,095	0

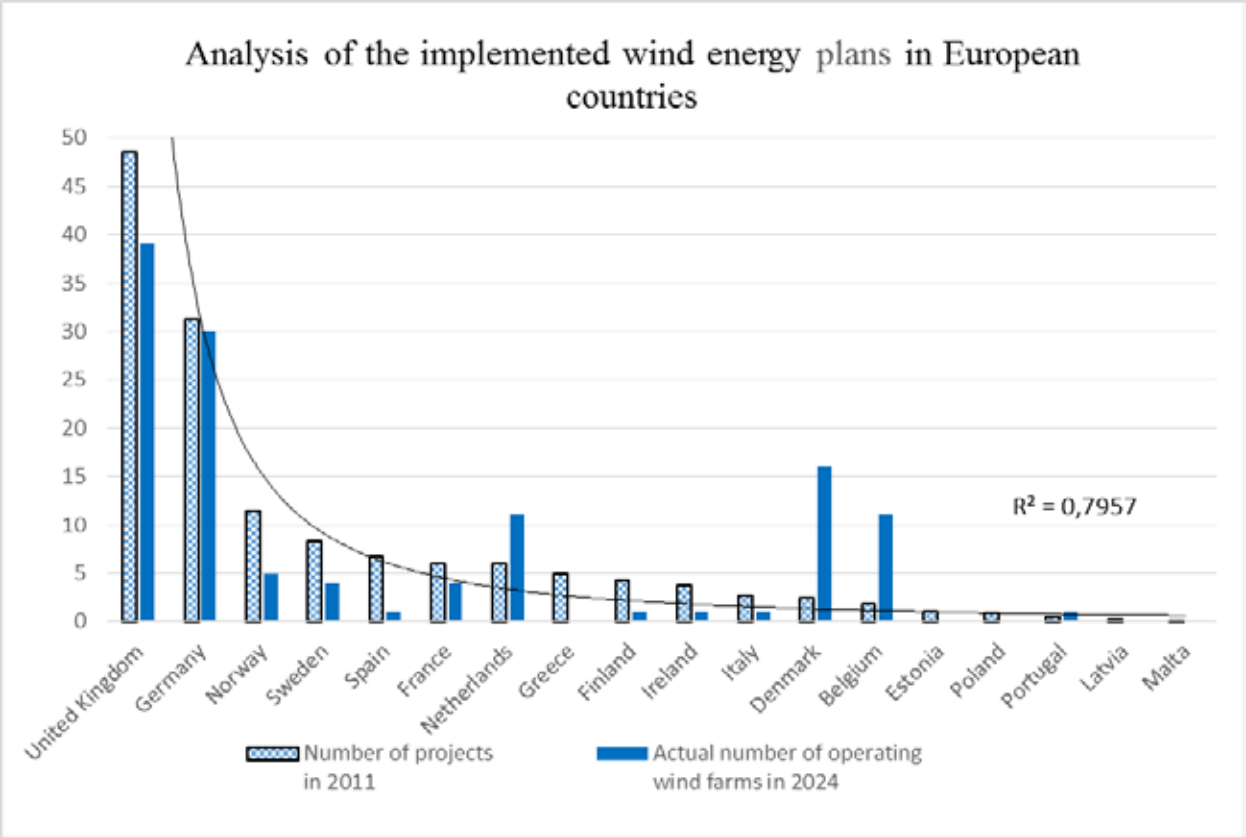

Fig. 1. Total offshore wind capacity (installed, under construction, consented, planned), on 30 June 2011 compared to the number of offshore wind farms operating worldwide as of June 2024, by country

whole, and there are many other examples of differences in the potential of possible locations for wind farms. Thus, we must admit that Ukraine as a whole has a significantly lower wind potential than European countries bordering on oceans, larger seas or clusters of seas.

It is also worth considering that turbines with a capacity of over 10 MW are very large and expensive, which means that damage to even one of them with a drone or other weapon will have a significant effect. At the moment, targeted attacks by Russian FPV drones on wind turbines in the Mykolaiv region have already been recorded, hitting the nacelle – the main element of the turbine, which contains the electric generator, braking system and transmission [12]. In this regard, we believe it is more rational to install smaller and less powerful machines in Ukraine and place them in such a way that damage to one machine does not immediately disable the entire wind farm.

At the same time, it is worth mentioning the market of not only medium-power but also low-power wind turbines. For example, we analyzed hybrid (wind turbine + solar panels) systems from Alteco, using information from their website [13] (Table 2, Figure 3) as of 2025. For convenience, it is indicated here how many LED lamps can operate thanks to these installations.

We have determined that there is a close relationship between the increase in price and the capacity of the installation. Nevertheless, for domestic use, these installations can be considered quite expensive, and their advantage is primarily not in the ability to save money, but in the diversification of sources of personal energy consumption.

Conclusion

1. The attacks on Ukraine's energy sector during the war raised the issue of diversifying energy production sources. It is assumed that a large number of small, dispersed sources are much more difficult to attack and destroy than a system of a small number of traditional industrial power plants. This strengthens the role of alternative energy sources, including wind turbines, the advantages of which were usually considered in terms of ecology and a carbon-free economy. Now it is becoming clear that they also make the energy system less dependent on blackmail from states that supply oil and gas. The small productivity of such installations has one positive feature – the destruction of such a single installation deprives the system of a correspondingly small amount of necessary capacity.

2. Ukraine has begun to learn from the wind power experience of Germany, Denmark and other European countries. This prospect seems attractive, but it is necessary to take into account that in the north of Europe and the ocean coast, wind speeds are noticeably stronger than on land and the sea shelf of Ukraine, on average about

The Elbe delta

The place where the Bug estuary flows into the Dnieper estuary

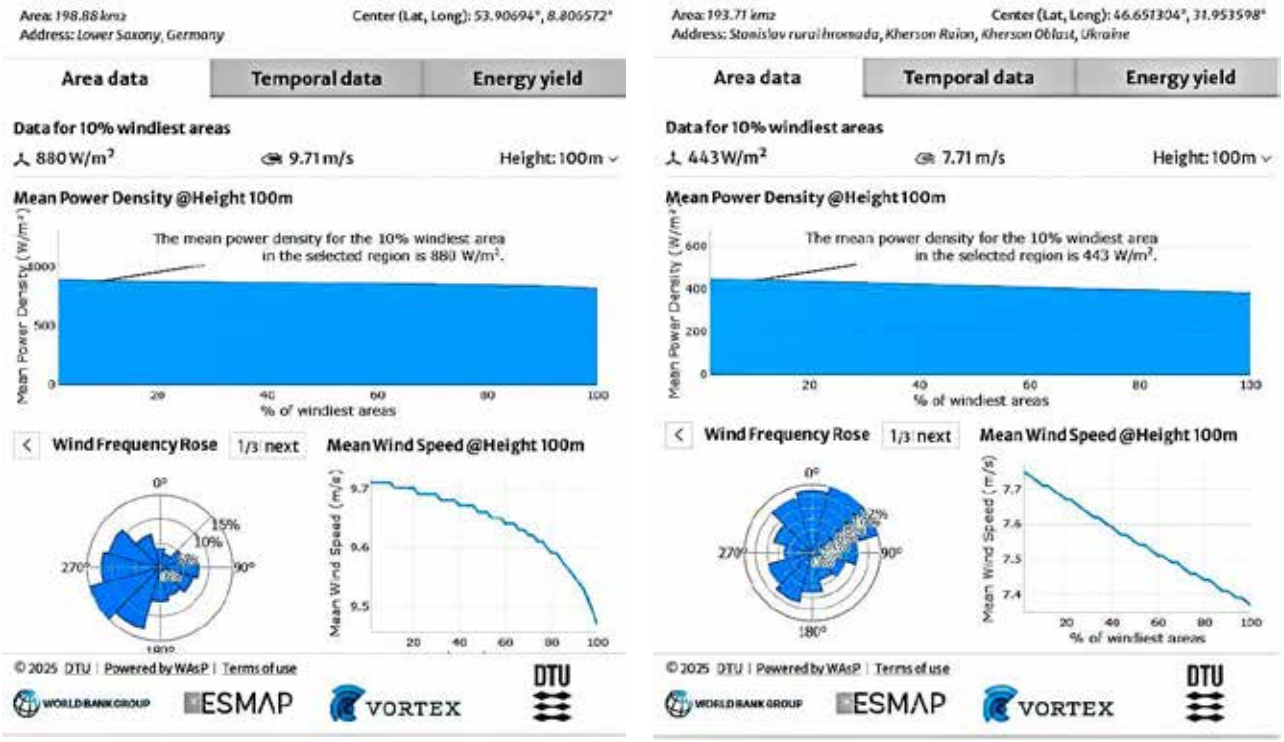

Fig. 2. Comparative analysis of the wind potential of the Elbe delta and the confluence of the Bug estuary with the Dnieper estuary using data from Globalwindatlas

Table 2

Analysis of hybrid (wind turbine + solar panels) systems from Alteco

№	Type of hybrid power plant	Cost *, $	LED lamp Power, W	Number of lamps operating simultane-ously	Approximate operating time in winter, hours per day	Electricity consumption, kWh per month
1	Autonomous solar station 3 kW	**2858**	9	5	7	**9,8**
2	Autonomous solar station 5 kW	**5500**	9	5	7	**9,8**
3	Wind turbine generator for home use 0.8 kW – Offer 1	**5 937,00**	9	5	5	**7**
4	Wind turbine generator for home use 1.6 kW – Offer 2	**8 882,68**	10	8	8	**19,8**
5	Wind turbine generator for home use 4 kW – Offer 3	**21 056,06**	10	15	8	**37,2**
6	Wind-solar station 0.8 / 2 kW – Offer 1	**10042,08**	10	6	8	**14,9**
7	Wind-solar station 1.6 / 2 kW – Offer 2	**14097,68**	10	8	8	**19,8**
8	Wind-solar station 4/3 kW – Offer 3	**26291,68**	10	30	8	**74,4**

twice as much. Ukraine still has wind potential worthy of use, especially if we adopt Germany's experience in using the most diverse types of electrical installations.

3. According to preliminary estimates, the implementation of wind turbines of different capacities into the energy system of different regions of Ukraine solves not as much economic problems, such as making a profit, but the problem of diversifying electricity supplies. However, indirectly, the use of wind turbines can strengthen security in industry, housing, and communal services of Ukraine and contribute to more sustainable development of the country's economy.

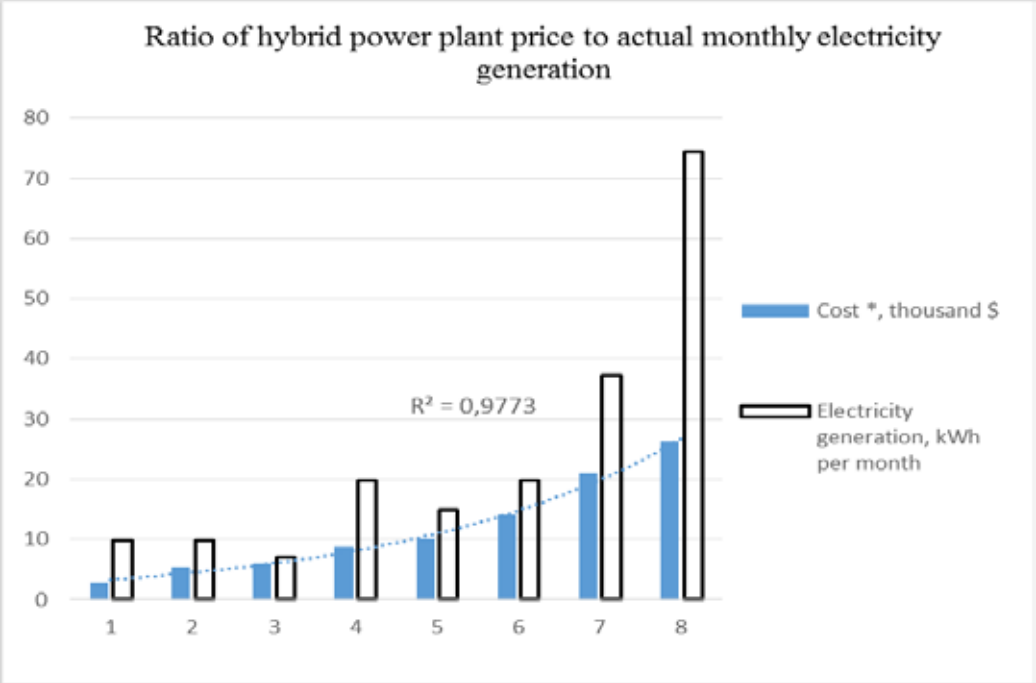

Fig. 3. Analysis of hybrid (wind turbine + solar panels) systems from Alteco

Prospects for the use of research results. In the future, the development of wind energy in Ukraine will be determined primarily by the conditions of the end of the war. The arrival of investments and the choice of location of new wind farms will depend on this. Most regions of the South-East of Ukraine are now in the frontline zone, so they will be considered attractive for investment only after the outcome of the war, which will make them much safer. The materials of the article can be used when making decisions on these issues.

References

1. Feng Z., Global Wind Energy Council. Global Wind Report. *Global Wind Energy Council site*. URL: https://www.gwec.net/reports/globalwindreport (date of access: 31.08.2025).
2. *POWER Data Access Viewer. Prediction Of Worldwide Energy Resource*. URL: https://power.larc.nasa.gov/ (date of access: 31.08.2025).
3. Атлас енергетичного потенціалу відновлюваних джерел енергії України / ред. С. Кудря; Інститут відновлюваної енергетики НАН України. Київ, 2020. 82 с.
4. Зінченко Н. В Україні цьогоріч знизилися темпи встановлення вітрових електростанцій. *Українська енергетика*. 2024. 12 груд. URL: https://ua-energy.org/uk/posts/v-ukraini-tsohorich-znyzylysia-tempy-vstanovlennia-vitrovykh-elektrostantsii (date of access: 31.08.2025).
5. Hanke-Rauschenbach R., Schöber V., Leibniz Universität Hannover. Transformation der Energiesysteme: Ein kompakter Überblick zur Energieforschung an der Leibniz Universität Hannover. 2022. *Https://repo.uni-hannover.de*. URL: https://repo.uni-hannover.de/bitstreams/3bfa9967-0411-440a-a68d-c920d736868b/download (date of access: 31.08.2025).
6. Krohn S. (editor), Morthorst P.-E., Shimon A. The Economics of Wind Energy. A report by the European Wind Energy Association. 2009. *EWEA site*. URL: https://www.ewea.org/fileadmin/files/library/publications/reports/Economics_of_Wind_Energy.pdf (date of access: 31.08.2025).
7. Germany rapidly expanding wind power. *Deutschland.de*. 2025. 4 лип. URL: https://www.deutschland.de/en/news/germany-rapidly-expanding-wind-power (date of access: 04.07.2025).
8. Mechanisms to promote household investment in wind energy: A national experimental survey / J. le Maitre та ін. *Renewable Energy*. 2024. Т. 220. URL: https://doi.org/10.1016/j.renene.2023.119557.
9. 17 EU COUNTRIES PLANNING MASSIVE OFFSHORE WIND POWER. Press Release. *UWEA site*. 29.11.2011. URL: http://uwea.com.ua/article/17-stran-es-zaplanirovali-krupnomasshtabnoe-razvitie-offshornoj-vetroenerge/ (date of access: 31.08.2025).
10. Fernández L. Number of offshore wind farms operating worldwide as of April 2025, by country. *Statista*. 21.04.2025. URL: https://www.statista.com/statistics/264257/number-of-offshore-wind-farms-worldwide-by-country/ (date of access: 31.08.2025).
11. *Globalwindatlas site*. URL: https://globalwindatlas.info (date of access: 31.08.2025).
12. Новини. *Миколаївські новини, № 25*. 2025. 18 черв. С. 2.
13. *Alteco: Official site*. URL: https://alteco.in.ua (date of access: 01.04.2025).

Дата першого надходження рукопису до видання: 07.10.2025
Дата прийнятого до друку рукопису після рецензування: 21.11.2025
Дата публікації: 15.12.2025