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DEVELOPMENT OF RECOMMENDATIONS AND PROPOSALS FOR INCREASING THE VOLUME OF NEW GENERATING CAPACITIES IN THE FIELD OF RENEWABLE ENERGY SOURCES IN UKRAINE

РОЗРОБКА РЕКОМЕНДАЦІЙ ТА ПРОПОЗИЦІЙ ЩОДО ПІДВИЩЕННЯ ОБСЯГІВ ВВЕДЕННЯ НОВИХ ГЕНЕРУВАЛЬНИХ ПОТУЖНОСТЕЙ У СФЕРІ ВІДНОВЛЮВАЛЬНИХ ДЖЕРЕЛ ЕНЕРГІЇ В УКРАЇНІ

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Abstract. The purpose of this article is to develop recommendations and proposals for increasing the introduction of new generating capacities in the field of renewable energy sources in Ukraine. This includes analyzing the current state of renewable energy, identifying key issues and barriers, and formulating strategic directions and specific measures to stimulate the development of this sector.

The research used the methods of system analysis, expert evaluation, comparative analysis and forecasting. A detailed analysis of the regulatory and legal framework of Ukraine in the field of renewable energy was conducted and the experience of leading countries in this field was studied. The main data for the analysis are obtained from official sources, statistical reports and the results of surveys of key stakeholders.

The study revealed a number of significant barriers to the development of renewable energy in Ukraine, such as the imperfect regulatory framework, limited access to financial resources, insufficient infrastructure development, and technical problems. At the same time, promising areas of development were identified, such as improvement of legislation, development of stimulating financial mechanisms, implementation of modern technologies, development of local electricity markets, and raising public awareness of the benefits of renewable energy.

The scientific novelty of the study consists in a comprehensive approach to the analysis of problems and prospects for the development of renewable energy in Ukraine, in particular, in the identification of new opportunities for increasing the efficiency of the implementation of renewable energy sources. The proposed measures take into account international experience and the specifics of Ukrainian conditions, which makes it possible to make conclusions and recommendations maximally adapted to the real needs and capabilities of the country.

The practical significance of the study lies in the possibility of using the developed recommendations and proposals for the formation of state policy in the field of renewable energy, as well as for practical implementation at the level of individual enterprises and regions. Implementation of the proposed measures will help increase the share of renewable energy sources in the energy balance of Ukraine, reduce dependence on traditional energy sources, improve the environmental situation and increase the energy security of the country.

Key words: renewable energy sources; generating capacity; energy policy; legal framework; Ukraine.

Анотація. Метою цієї статті є розробка рекомендацій та пропозицій щодо збільшення введення нових генерувальних потужностей у сфері відновлювальних джерел енергії в Україні. Це включає аналіз поточного стану відновлюваної енергетики, виявлення ключових проблем і бар'єрів, а також формулювання стратегічних напрямків і конкретних заходів для стимулювання розвитку цього сектора.

У дослідженні використовувались методи системного аналізу, експертного оцінювання, порівняльного аналізу та прогнозування. Було проведено детальний аналіз нормативно-правової бази України у сфері відновлюваної енергетики та вивчено досвід провідних країн у цій галузі. Основні дані для аналізу отримані з офіційних джерел, статистичних звітів та результатів опитувань ключових стейкхолдерів.

Дослідження виявило ряд значущих бар'єрів для розвитку відновлюваної енергетики в Україні, таких як недосконалість нормативно-правової бази, обмежений доступ до фінансових ресурсів, недостатній розвиток інфраструктури та технічні проблеми. Водночас було визначено перспективні напрями розвитку, такі як вдосконалення законодавства, розробка стимулюючих фінансових механізмів, впровадження сучасних технологій, розвиток локальних ринків електроенергії та підвищення обізнаності громадськості щодо переваг відновлюваної енергетики.

Наукова новизна дослідження полягає у комплексному підході до аналізу проблем та перспектив розвитку відновлюваної енергетики в Україні, зокрема у виявленні нових можливостей для підвищення ефективності впровадження відновлюваних джерел енергії. Запропоновані заходи враховують міжнародний досвід та специфіку українських умов, що дозволяє зробити висновки та рекомендації максимально адаптованими до реальних потреб і можливостей країни.

Практична значимість дослідження полягає у можливості використання розроблених рекомендацій та пропозицій для формування державної політики у сфері відновлюваної енергетики, а також для практичного впровадження на рівні окремих підприємств та регіонів. Реалізація запропонованих заходів сприятиме зростанню частки відновлюваних джерел енергії в енергетичному балансі України, зменшенню залежності від традиційних енергоносіїв, покращенню екологічної ситуації та підвищенню енергетичної безпеки країни.

Ключові слова: відновлювані джерела енергії; генерувальні потужності; енергетична політика; нормативно-правова база; Україна.

INTRODUCTION

In today's world, the global community is actively working to reduce the negative impact on the environment and combat climate change. One of the key directions of this activity is the development of renewable energy sources (RES), which allows to reduce greenhouse gas emissions and reduce dependence on fossil fuels. Ukraine, having significant potential in the field of RES, has also taken important steps in this direction. However, despite the achieved successes, the level of RES development in Ukraine is still insufficient to achieve the ambitious goals of energy independence and environmental sustainability.

The topicality of the topic is due to the need to develop effective strategies and mechanisms for stimulating the introduction of new generating capacities in the field of renewable energy. The current state of the legal framework, infrastructure and financial mechanisms needs improvement to ensure stable and rapid development of this sector [1-3].

This article analyzes the current state of development of renewable energy in Ukraine, identifies the main problems and barriers that prevent the introduction of new generation capacities, and develops recommendations and suggestions for overcoming them. Special attention is paid to the analysis of international experience and the possibility of its adaptation to Ukrainian conditions.

The purpose of the study is the formulation of complex measures that will allow to significantly increase the volume of introduction of new capacities in the field of RES, will contribute to the improvement of the ecological situation and ensure the energy security of Ukraine. Thanks to the proposed recommendations, it is possible to create favorable conditions for attracting investments, introducing modern technologies and developing local electricity markets.

Object of study – renewable energy sources in Ukraine.

Subject of study – processes and mechanisms of introduction of new generating capacities in the field of RES.

FORMULATION OF THE PROBLEM

Ukraine's modern energy sector faces numerous challenges, such as dependence on imported fossil fuels, aging infrastructure, and environmental issues. Taking into account the global trends in the development of renewable energy sources (RES), it is necessary to develop effective strategies to increase the amount of introduction of new generation capacities using RES.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The latest research in the field of renewable energy in Ukraine emphasizes the significant potential of the country in the use of solar, wind and bioenergy. Studies show that Ukraine has sufficient natural resources for the development of RES, but faces problems of regulatory and legal regulation, access to financing and technical barriers. The works [4-7] reveal the main obstacles and opportunities for the development of RES.

SEPARATION OF PREVIOUSLY UNRESOLVED PARTS OF THE OVERALL PROBLEM

Despite numerous studies, the issues of effective stimulation of renewable energy investments, improvement of the legal framework and development of complex mechanisms for supporting the development of renewable energy still remain unresolved. It is also important to take into account local conditions and the specifics of the Ukrainian energy market [8].

PRESENTATION OF THE MAIN MATERIAL

Ukraine has problems related to energy security, ecology and dependence on imported fuels. To solve these problems and achieve sustainable development of the country, it is extremely important to expand the use of renewable energy sources.

To this end, a number of measures and strategies need to be considered. First, it is necessary to create a favorable regulatory environment, including simplification of legislation and procedures for obtaining permits for the development of renewable energy sources. It is also important to provide financial support and stimulate investment through special programs and benefits.

Secondly, it is necessary to develop a network of energy storage facilities and modernize the existing energy infrastructure for efficient storage and transmission of energy from renewable sources to consumers. This may include the reconstruction and improvement of transport systems and energy networks.

From 2018 to 2021, the total installed capacity of renewable energy sources in Ukraine more than quadrupled, growing from 2.3 GW to 9.6 GW. Over half of these capacities are ground-based solar power plants, and another third are wind turbines.

As of the end of 2021, the share of renewable energy sources in the Ukrainian energy system reached 8.1% or 12.8 TWh. This indicates the rapid development of the industry, which is able to effectively replace traditional sources of electricity generation, such as nuclear and thermal power plants. The rest consists of biogas, biomass and small hydroelectric plants [4-7].

However, the war had a significant impact on the development of RES – currently wind and solar generation is less than half of their usual pre-war level. This is due to two main factors:

- firstly, as a result of the Russian invasion, 80% of Ukrainian wind energy capacities were stopped due to direct military actions or to prevent damage to electrical equipment.

- secondly, the decrease in demand for electricity and the high percentage of base generation make it difficult to integrate renewable energy into the energy system, especially solar energy, which amounts to more than 6 GW. Due to a sharp decrease in electricity demand in the country, national dispatchers have been forced to shut down RES generation, especially during generation peaks.

It is the increased level of renewable energy generation that can make Ukraine's power system more flexible and ready for emergency situations – this is due to the fact that solar and wind power plants are decentralized and less vulnerable than basic generation such as nuclear power plants or thermal power plants.

In addition, increasing the capacity of European interconnectors could prevent the loss of a significant amount of energy produced on the basis of RES in the most productive months of the year.

Generating capacities based on renewable energy generation are a reliable stabilizer of the energy system of Ukraine during a military conflict. Their wide distribution throughout the country allows to reduce the risks of losses, which generally contributes to greater flexibility

of the energy system in the most difficult period in the history of independence.

When developing specific recommendations and proposals for increasing the use of renewable energy sources in Ukraine, it is important to take into account the country's needs for renewable energy, the prospects and development potential of this sector, as well as interaction with other energy sectors [9-10].

Widespread implementation of renewable energy sources can significantly improve energy security, reduce emissions of harmful substances into the atmosphere, and reduce dependence on imported fuel. This approach will contribute to the sustainable development of the country and improve the quality of life of citizens.

Modern energy is mainly based on non-renewable energy sources, which, having limited reserves, are exhausted and cannot guarantee the sustainable development of world energy in the long term. The use of these sources is one of the main factors causing the global deterioration of the environment and leading to the energy crisis. Renewable energy is a branch of energy that ensures the production of electrical, thermal and mechanical energy from renewable energy sources, such as solar, wind, geothermal energy, wave and tidal energy, hydropower, biomass and others [2-4].

The American ecologist and founder of the Worldwatch Institute, L. Brown, points to the need to use renewable energy sources instead of fossil fuels to prevent the destruction of the environment, which negatively affects the economy of every country. Research confirms that the solution to this problem lies in the use of renewable energy sources. One of the key tasks is the search for new, efficient and renewable energy sources, taking into account energy security and the preservation of ecological balance. Ukraine must develop renewable energy sources (RES) to ensure energy security and environmental protection. To achieve these goals, the government and private companies must take into account the opportunities and prospects for the development of RES.

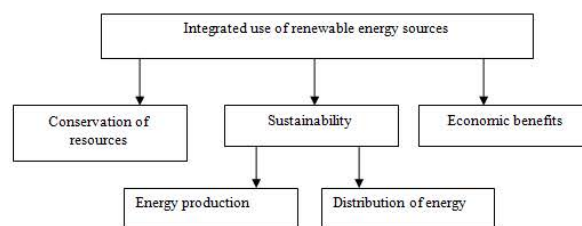


Fig. 1. Integrated use of renewable energy sources

Proposals to increase the volume of introduction of new generating capacities in the field renewable energy sources through their integrated use:

- infrastructure development – in Ukraine, infrastructure needs to be developed to connect new generating capacities to the energy system.

– connection to European power grids – Ukraine must connect its energy systems to European power grids to ensure stable energy supply.

– development of new technologies – Ukraine needs to develop new technologies for the production of energy from RES, such as solar and wind energy.

– cooperation with international organizations – Ukraine should cooperate with international organizations to obtain financial and technical assistance in the development of RES [6-7].

– development of incentive and incentive programs – it is necessary to develop incentive programs for private companies engaged in the development of RES.

– development of long-term energy security plans – it is necessary to develop energy security plans to ensure stable energy supply and environmental protection.

– development of education and training programs – it is necessary to develop education and training programs for RES specialists.

– development of innovation programs – it is necessary to develop innovation programs to stimulate the development of new technologies and products in the field of RES.

– development of energy efficiency programs – it is necessary to develop energy efficiency programs to reduce energy consumption and energy production from traditional sources.

– development of environmental protection programs – it is worth developing environmental protection programs to ensure the safety and cleanliness of air, water and land.

The development of recommendations and proposals for increasing the volume of introduction of new generating capacities in the field of RES in Ukraine can help the government and private companies to develop infrastructure, technologies and programs to ensure a stable and ecologically clean energy supply.

Forecasting the development of wind energy in Ukraine using the Holt method

Based on previous studies, it was chosen to build predictive parameters using the Holt method for the following types of energy: wind energy

Holt's method is used to forecast time series when there is an upward or downward trend in the values of the time series. And also for series when the data is not for a complete cycle (for example, for an incomplete year for a monthly forecast). Constant smoothings in Holt's method ideologically play the same role as constants in simple exponential smoothing. The Holt method is used to forecast time series when there is a tendency to increase or decrease the values of the time series. The main dependencies and regularities of the Holt method are as follows:

Exponentially smoothed series:

$$L_t = k \cdot Y_t + (1 - k) \cdot (L_{t-1} - T_{t-1}),$$

where L_t – smoothed value for the current period;

k – coefficient of smoothing of the series;

Y_t – current values of the series;

L_{t-1} – smoothed value for the previous period;

T_{t-1} – trend value for the previous period.

Definition of the trend:

$$T_t = b \cdot (L_t - L_{t-1}) + (1 - b) \cdot T_{t-1},$$

where T_t – trend value for the current period;

b – trend smoothing factor;

L_t – exponentially smoothed value for the current period;

L_{t-1} – exponentially smoothed value for the previous period;

T_{t-1} – trend value for the previous period.

Building a forecast using the Holt method:

$$\hat{Y}_{t+p} = L_t + p \cdot T_t,$$

where $\hat{Y}_{t+p}$ – forecast by the Holt method on p period;

L_t – exponentially smoothed value for the last period;

p – serial number of the period for which the forecast is made;

T_t – the trend for the last period.

Constant smoothing in the Holt method ideologically plays the same role as the constant in simple exponential smoothing. They are selected, for example, by going through these parameters with some step. Algorithms that are less complex in terms of the number of calculations can also be used. The main thing is that you can always choose such a pair of parameters that gives a high accuracy of the model on the test set, and then use this pair of parameters in real forecasting.

The main thing is that you can always choose such a pair of parameters that gives a high accuracy of the model on the test set, and then use this pair of parameters in real forecasting. In the Holt model, the smoothing parameters characterize the degree of adaptation of the model to changes in a number of observations. They determine the speed of the model's response to changes occurring in development. The more they are, the faster the model reacts to changes. Of course, their value is larger for stable series, and smaller for unstable ones. Different forecasting methods use a different approach to their determination. They can be taken as fixed, and the best value can be determined by the selection method so that the forecast error one step ahead is the smallest. An alternative to this approach is the dynamic change of smoothing parameters. In evolution and simplex planning methods, the adaptation parameters are constantly changing at each step. Multiple values are generated for the smoothing parameter.

As can be seen from the constructed schedule regarding the installed capacity of wind energy in Ukraine, the following results of the construction of the forecast model were obtained: by 2026, an increase in the amount of installed capacity of wind energy is predicted to the level of 2500 MW, which confirms that special attention should be paid in Ukraine to the intensification of the development of new generation capacities in the field of wind energy.

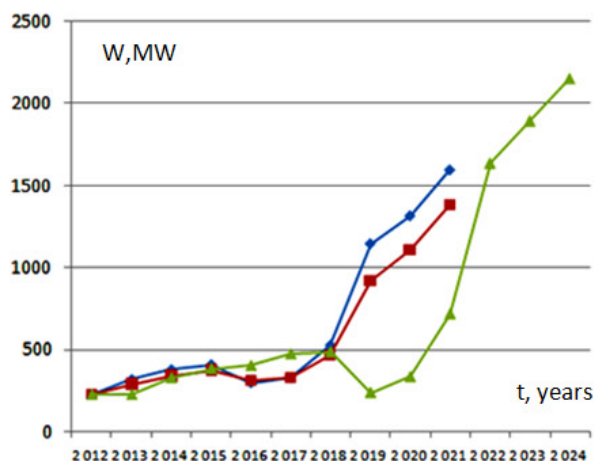


Fig. 2. Forecasting the dynamics of the development of the installed capacity of wind energy in Ukraine according to the Holt method:

- ▲— $\hat{Y}_{t+p}$ Series with forecast model, MW;
- ◆— Wind energy, installed capacity, MW;
- L_t exponentially smoothed series, MW

DISCUSSION OF THE OBTAINED RESULTS

The results of the study showed that the main barriers to the development of RES in Ukraine are the imperfection of the regulatory and legal framework, limited access to financial resources and insufficient infrastructure development. The proposed recommendations include the improvement of legislation, the development of stimulating financial mechanisms, the introduction of modern technologies and the development of local electricity markets.

CONCLUSIONS

The conclusions of the study indicate the need for an integrated approach to the development of RES in Ukraine. Implementation of the proposed measures will contribute to the growth of the RES share in the country's energy balance, reduction of dependence on traditional

energy sources, improvement of the environmental situation and increase of energy security.

The development of renewable energy sources (RES) is a key direction for the energy sector of Ukraine, taking into account the need to increase energy independence, reduce environmental impact and integrate into European energy markets. In the course of the study, it was found that the main obstacles to the development of RES in Ukraine are the imperfect regulatory framework, limited access to financial resources and insufficient infrastructure development.

The proposed recommendations cover the following main areas:

1. Improvement of the legislative framework – it is necessary to create a stable and transparent legal environment that will stimulate investments in RES. It is important to ensure long-term and clear rules for investors and develop mechanisms to protect their interests.

2. Development of financial instruments – to attract investments in RES, new financial mechanisms should be developed and implemented, such as "green" bonds, special credit lines and state guarantees for investors. This will help reduce financial risks and increase the attractiveness of the sector for private investors.

3. Implementation of the latest technologies – support for innovation and development of new technologies in the field of RES are extremely important for increasing efficiency and reducing energy production costs. This includes the development of infrastructure for energy storage and distributed energy systems.

4. Development of local electricity markets – decentralization of energy production and the creation of local electricity markets will contribute to increasing the reliability of energy supply and reducing dependence on centralized systems.

The implementation of these measures will contribute not only to the increase in the share of RES in the energy balance of Ukraine, but also to the improvement of the environmental situation, the creation of new jobs and the increase of energy security. A comprehensive approach to the development of RES will ensure the sustainable development of the energy sector and contribute to the integration of Ukraine into the European and world energy markets.

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