

ALTERNATIVE ENERGY AS A DRIVER OF TRANSFORMATION PROCESSES IN THE ENERGY SECTORAnna Kholod ^{1*}

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Renewable energy is actively developing both on the global market and within individual regions and countries. Alternative energy sources, particularly solar and wind, guarantee a stable and safe energy supply. Such systems ensure a reliable supply of energy in everyday life and in extreme situations, such as natural disasters or breakdowns in the operation of the energy infrastructure. The transition to alternative energy sources generally contributes to creating a stable, ecologically clean and environmentally friendly energy system, which has many advantages for society. The article aims to study the prerequisites and dynamics of the development of alternative energy. The article found out that the use and introduction of alternative energy sources is an important factor for restoring the ecological balance during the decarbonization of the economy. As of the end of 2022, wind power plants, solar power plants, home solar power plants, and small hydroelectric power plants are gaining popularity. The leaders in the number of new facilities installed from renewable energy sources in Ukraine are the Mykolaiv, Odesa, Kherson, and Zaporizhia regions. The analysis carried out in the article proved that the most common alternative sources in Ukraine and Europe are solar panels, wind power plants and smart energy. The authors systematized the advantages of solar panels, which define them as sustainable and stable energy sources for the future. The work concludes that wind power plants have more limitations due to the nature of the conditions, but with the development of technology, they have become more and more efficient. In addition, a promising direction for developing the modern energy system is using smart energy, which includes artificial intelligence, data analytics, and a system for collecting energy resources. Modern smart energy allows you to provide energy planning effectively and to warn of power outages.

Keywords: sustainable development, alternative energy, solar energy, wind energy, smart energy

АЛЬТЕРНАТИВНА ЕНЕРГЕТИКА, ЯК ДРАЙВЕР ТРАНСФОРМАЦІЙНИХ ПРОЦЕСІВ В ЕНЕРГЕТИЧНОМУ СЕКТОРІАнна Холод ^{1*}

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Відновлювальна енергетика активно розвивається як на глобальному ринку, так і в межах окремих регіонів та країн. Альтернативні джерела енергії, зокрема, сонячна та вітрова, гарантують стабільне та безпечне постачання енергії. Такі системи забезпечують надійне постачання енергії як у повсякденному житті, так і в екстремальних ситуаціях, таких як природні катастрофи або збої в роботі енергетичної інфраструктури. В цілому, перехід на альтернативні джерела енергії сприяє створенню стабільної, екологічно чистої та природозберігаючої енергетичної системи, що має багато переваг для суспільства. Метою статті є дослідження передумов та динаміки розвитку альтернативної енергетики. В статті з'ясовано, що використання та впровадження альтернативних джерел енергії є важливим фактором для відновлення екологічної рівноваги за декарбонізації економіки. Станом на кінець 2022 року популярності набирають вітроелектростанції, сонячні електростанції, домашні сонячні електростанції, малі гідроелектростанції. Лідерами по кількості встановлених нових об'єктів з відновлювальних джерел енергії на в Україні є: Миколаївська, Одеська, Херсонська та Запорізька області. Проведений в статті аналіз засвідчив, що на Україні та Європі найпоширенішими альтернативними джерелами є сонячні панелі, вітрові електростанції та смарт-енергетика. Авторами систематизовано переваги сонячних панелей, які визначають їх як стійкі та стабільні джерела енергії для майбутнього. В роботі зроблено висновок, що вітрові електростанції мають більше обмежень через природні умови, але з розвитком технологій вони стають все ефективнішими. Окрім цього, перспективним напрямком для розвитку сучасної енергетичної системи є використання смарт-енергетики, яка включає в себе застосування штучного інтелекту, аналітики даних та систему збору про енергетичні ресурси. Сучасна смарт-енергетика дозволяє ефективно забезпечувати енергетичне планування, та попереджати по перебої в електропостачанні.

Ключові слова: сталий розвиток, альтернативна енергетика, сонячна енергетика, вітрова енергетика, смарт-енергетика.

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INTRODUCTION

The issue of energy generation today and in recent years is urgent, requiring a systematic approach and the introduction of alternative energy sources. The advantages of switching to alternative energy sources are undeniable. First, it is the preservation of resources for future generations. This will be facilitated by reduced production and use of limited resources, namely fossil fuels such as coal, oil or natural gas. It also helps to reduce pollution by reducing emissions of greenhouse gases and other harmful substances (solar, wind and hydropower energy sources have a smaller carbon footprint). Dependence on imports decreases, and the price of oil and gas stabilizes. Solar and wind energy sources are available worldwide, helping to reduce dependence on imports and political risks. New opportunities for innovation and energy efficiency are opening up. The development of new technologies and the implementation of energy-saving initiatives, thanks to the transition to alternative energy sources, contribute to reducing energy consumption and increasing its efficient use. Alternative energy sources like solar and wind guarantee a stable and secure energy supply. Such systems can ensure a reliable energy supply in everyday life and extreme situations, such as natural disasters or infrastructure failures. The transition to alternative energy sources generally contributes to creating a stable, ecologically clean and environmentally friendly energy system, which has many advantages for society. The article aims to study the prerequisites and dynamics of the development of alternative energy.

RESULTS

At the beginning of 2021, in Ukraine, as of December 31, according to the data of the National Commission for State Regulation of Energy and Public Utilities, the total capacity of the renewable energy sector reached 9655.9 MW. This figure includes solar installations for private households. It is worth noting that, in general, the pace of development of the industry is quite active, but the most significant increase falls on the industry of domestic solar power stations (Razumkov, 2022). In 2021, its capacity increased by 426.1 MW, 36.4% of the new renewable energy sources commissioned last year (Figure 1).

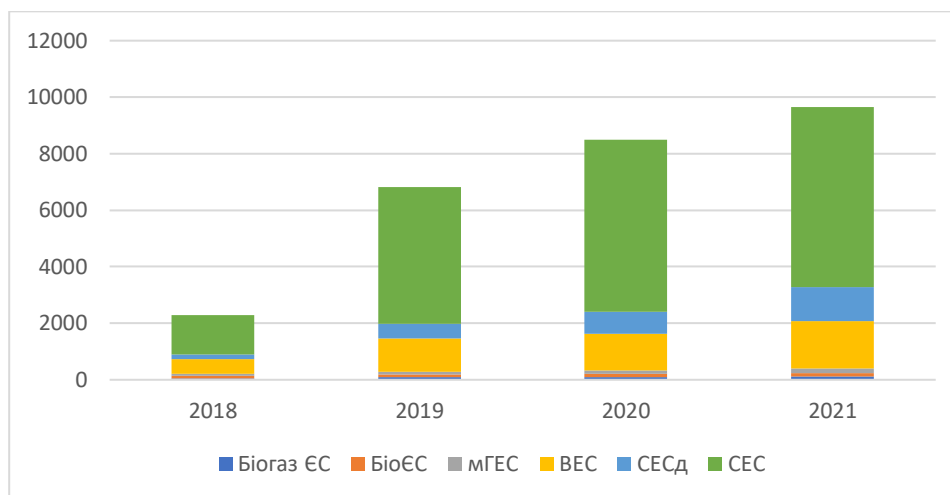


Fig. 1. Dynamics of growth of the installed capacity of renewable energy facilities operating under the "green" tariff, MW

Source: built by the author based on (Razumkov, 2022).

The location of the facilities of alternative energy sources differs according to the renewable energy source (RES) and corresponds to the natural potential of a particular region. The location of wind power plants in the southern and south-eastern regions, on the coast of the Azov and Black Seas, is approximately 85%, but even under such conditions, solar generation is much more widespread, because about 60% of industrial solar power plants are concentrated in the southern and south-eastern regions of Ukraine. As of the beginning of 2022, Dnipropetrovsk Oblast – 1350,06 MW, Kherson

Oblast – 1139,65 MW, and Mykolaiv Oblast – 1121,16 MW are the leaders among all regions of Ukraine in terms of total installed renewable energy capacity. All these regions account for more than 37,3% of all RES capacities in Ukraine. Considering the annual increase, we can highlight the largest number of new facilities from renewable energy sources for 2021. Mykolaiv Oblast - 16.7 MW, Odesa Oblast – 149,1 MW, Kherson Oblast - 145 MW and Zaporizhzhya Oblast – 98,8 MW (Khomenko et al., 2022; Renewable, 2023). An interesting fact worth noting is that these four regions, in particular, occupy leading positions in terms of installed wind power capacity (Figure 2).



Fig. 2. Installed renewable energy capacity by regions of the mainland of Ukraine, (2021, MW).

Source: built by the author based on (Khomenko et al., 2022).

The European Union has several internal documents that determine the vector of development of a certain energy industry. The first goal, aimed at the RES development rate, was set back in 1997. According to the plan, by 2010, the share from renewable sources was supposed to increase by 12%. The green tariff was first introduced in Germany in 1991. Within a few years, other countries, such as Sweden, Italy, Switzerland, Denmark and others, began introducing a similar policy. In 2009, Europe decided to move from declared plans to mandatory implementation. By 2020, 20% of energy consumed in the EU should come from renewable sources, as Directive 2009/28/EC established. At the beginning of 2004, the share of RES was 8.5%, and by 2018, the share had increased to 18% (Figure 3) (Chygryn et al., 2023a; Chygryn et al., 2023b; Khomenko et al., 2023).

Each EU country, in addition to the Directive, has its own specific goals and strategies for the transition to alternative energy sources. At the same time, the progress of implementation depends on the level of development in this country. For example, the first place was taken by Sweden, which showed a result of 49% by 2020, by which time it exceeded its goal and now receives more than 54% from RES. It is worth noting that, in addition to Sweden, 11 more countries have achieved their goals by 2020, namely: Bulgaria, Greece, Denmark, Estonia, Italy, Cyprus, Latvia, Lithuania, Finland, Croatia and the Czech Republic. In 2018, the European Union revised the Directive and set new goals, namely the provision of at least 32% of energy from renewable sources by 2030 (Bondarenko et al., 2019; Geletukha et al., 2016). In this context, energy includes not only electricity, but also transport fuel, heating and others.

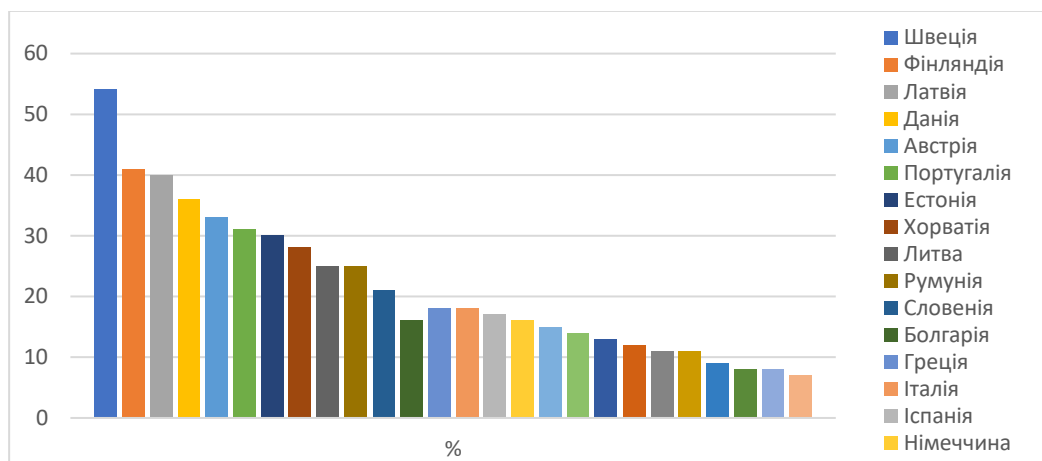


Fig. 3. Share of energy from renewable sources in EU countries
Source: built by the author based on (Bondarenko et al., 2019; Geletukha et al., 2016)

Today, the issue of alternative energy sources is acute for Ukraine because, after the beginning of the full-scale invasion of the aggressor country, mass shelling began. Ukrainians were left without light, heat, and water due to hitting critical infrastructure facilities. The time of repair works depended on the frequency and duration of shelling in the settlement and the scale of the damage. As noted above, the country's main concentration of installed renewable energy facilities is in Ukraine's southern and south-eastern regions, where active hostilities are underway. According to various expert estimates, by August 2022, 30–40% of RES power plants in these regions, or about 1,120–1,500 MW of installed capacity, were damaged. According to the Ukrainian Wind Energy Association, since the beginning of the full-scale invasion of russia into Ukraine, more than 3/4 of the wind energy capacities have been lost, that is, out of a full 1,673 MW, about 1,462 MW of Ukrainian wind turbines have been stopped. At the same time, in the Kherson region, 5 wind turbines installed at the Myrne, Siva and Novotroitska wind power plants cannot function due to destruction. (Husar, 2021).

Statistics on the spread of renewable energy sources in the European Union raise questions about the availability of qualified workers at each station. Figure 5 presents the statistics of persons employed in renewable energy using solar photovoltaic, wind, and hydropower technologies.

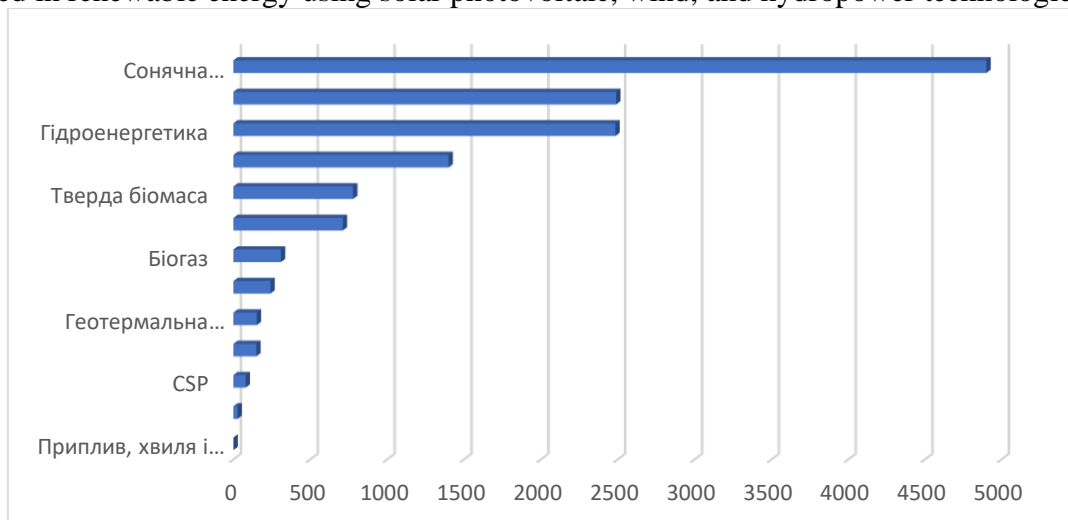


Fig. 4. Global renewable energy employment by technology, 2022
Source: built by the author based on (Chygryn et al., 2023a)

The statistical data analysis on the development of alternative energy in Ukraine and Europe made it possible to identify the three most common alternative energy sources: solar panels, wind power plants, and smart energy. Solar panels (photoelectric modules) can convert solar radiation into

electricity. By design, they are rigid and flexible. Among the advantages of solar panels, the following can be highlighted (table 1).

Table 1. Advantages of implementing solar panels

Benefits	Contents
Environmental friendliness	Solar panels do not use fuel, so they do not produce harmful emissions. Thus, they reduce the impact on air pollution and reduce the likelihood of climate change.
Independence	Solar panels are arranged in such a way that they do not require additional resources. Solar energy is free and renewable, with a dependency on the sun that allows for stable access to energy.
Economically profitable investment	Solar panels are expensive, but they are self-sustaining, because they work constantly and their operation significantly reduces electricity costs.
Network independence	Solar panels can provide electricity even in remote places where there is no access to electricity grids. This is especially useful in rural areas or areas far from cities.
Technological development	The use of solar panels promotes technological development and innovation. Research in this field is helping to improve the efficiency of solar panels, reduce their cost, and make them more accessible to everyone.

Source: built by the author based on (Smart, 2023)

All these advantages are aimed at promoting the use of solar panels as a sustainable and stable energy source for the future.

Wind power plants are power structures that convert the wind's kinetic energy into electrical energy. The advantages of wind power plants are listed in Table 2.

Table 2. Advantages of the implementation of wind power plants

Benefits	Contents
Renewable energy	Wind is an endless and free source of energy. Therefore, wind power plants use energy that has a process of constant renewal, this helps to reduce dependence on fossil fuels and the burning of hydrocarbons.
Environmental friendliness	Wind power plants are quite an ecological method, because they do not pollute the atmosphere with harmful gases and other things. They do not contribute to the greenhouse gas effect, air quality reduction or climate change. The use of wind energy can help in the fight against global warming.
Independence from international crises	Because wind is a local resource, countries developing wind energy do not need to import expensive petroleum products or natural gas. This reduces the country's vulnerability to geopolitical conflicts.
Regional development	Placing wind farms can contribute to the development of remote and rural areas. The construction of stations provides jobs for local residents and contributes to the development of the local economy.
Flexibility	Wind farms can be located in a variety of areas, including coastal areas, deserts, and remote mountainous areas. This makes it possible to make the most of the wind potential in a specific region.

Source: built by the author based on (Na Chasi, 2018; Chygryn et al., 2021)

Despite these advantages, wind farms have limitations and challenges due to wind inconsistencies and potential impacts on nature and local fauna. However, as technology advances and efficiency improves, wind farms are becoming increasingly attractive sources of energy.

Smart energy is a promising direction of the development of the modern energy system. It uses innovative technologies to optimize energy supplies, increase energy efficiency and reduce negative impacts on the environment. Smart energy allows you to ensure energy needs are met as accurately as possible and increases the efficiency of energy system control. It includes using smart technologies,

namely: artificial intelligence, a system for collecting and analyzing data on energy resources. Implementing smart energy and creating "smart" houses and microgrids is gaining popularity daily. The essence of a "smart" house is that it is equipped with special systems that should automatically monitor and regulate the use of energy in the house. For example, smart sensors react to human movements in the room and turn on the light, in the absence - turn it off for optimal energy savings (Pimonenko et al., 2021; Khalatur et al., 2021).

Microgrids are a small-scale energy supply system that combines energy production and consumption. They can contain various energy sources such as solar panels, wind turbines, energy storage batteries, etc. Smart technologies enable optimising the flow of energy in the microgrid, ensuring a stable and efficient energy supply. In addition, smart energy also provides support for distribution networks and consumer management. Thanks to modern technologies, energy companies can provide energy planning considering consumers' needs, warn of possible interruptions in energy supply and regulate network load to prevent overloads (Chygryn et al., 2023b).

The development and implementation of smart energy requires significant investment and cooperation between government agencies, energy companies and research institutions. However, these costs are justified by the benefits of smart energy to all consumers: reducing dependence on traditional energy sources, increasing the stability and reliability of energy systems, saving resources, and reducing emissions into the atmosphere.

Today, many countries and companies are implementing smart energy as a strategic development direction. After looking at the statistics on the Google Trends website, we can see the spread of this topic by the search query "smart energy" (Figure 5).



Fig. 5. Distribution of the smart energy search query in the world
Source: built by author with help Google Trends

With the help of Google Trends, an analysis of search queries in the web environment was carried out for three key words: Smart Grid, Sustainable Development and Renewable Energy (Figure 6).



Fig. 6. List of selected search requests
Source: built by author with help Google Trends

Figure 7 shows the statistics of the popularity of search queries worldwide for 5 years. Analysis of statistics for all categories shows the most popular search query "Renewable Energy", which had

the highest figures in April 2022. The lowest popularity is observed in the "Smart Grid" category.

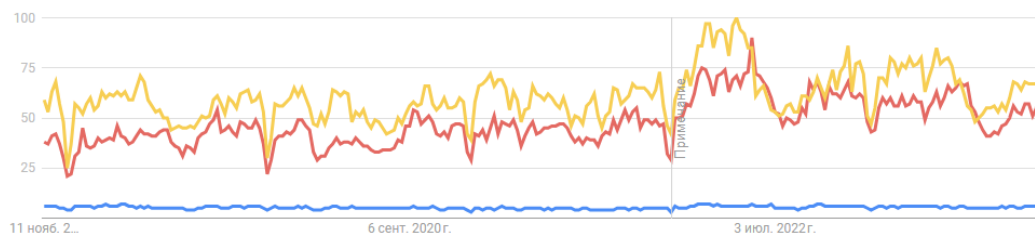


Fig. 7. Dynamics of the popularity of selected search queries in the world

Source: built by author with help Google Trends

So, according to the given statistics, the number of searches for "Renewable energy" and "Sustainable development" shows a slight difference. They have both sharp increases in demand for these requests and sharp drops. While the "Smart grid" has quite low statistics, it almost does not change. After looking at this graph, we can see constant statistics with only small deviations. In the category "Science", the analysis results are shown in Figure 8. No sharp changes and no special differences were found compared to the general statistics. A slight difference is the latest data from "Renewable Energy", which rose in October 2023. Meanwhile, the search query "Sustainable Development" shows a downward trend.

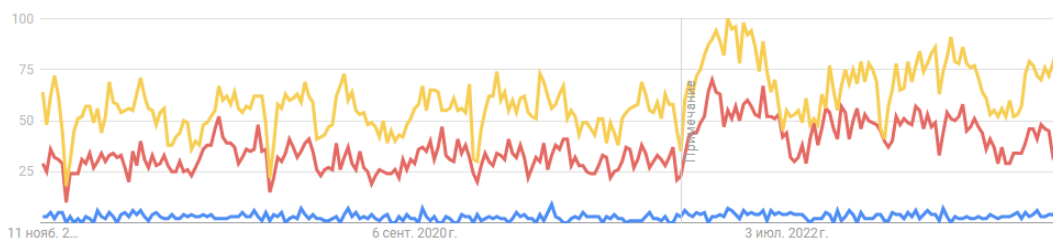


Fig. 8. Dynamics of the popularity of selected searches by category "Science"

Source: built by the author with the help Google Trends

Looking at the statistics for the category "Business and Industry" (Fig. 9), we can see the low dynamics of "Sustainable Development", which almost equalled the lowest dynamics for the request of "Smart Grid".

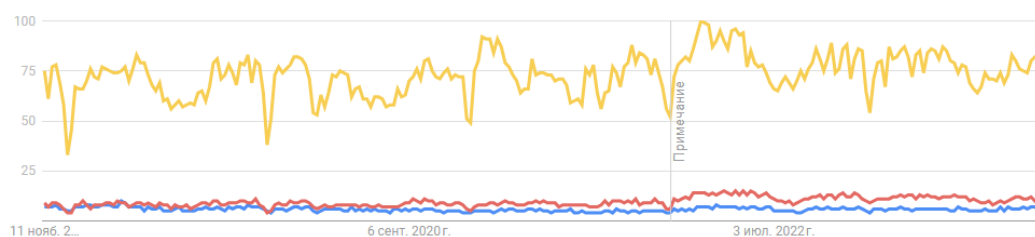


Fig. 9. Dynamics of the popularity of selected searches by category "Business and industry"

Source: built by author with help Google Trends

So, after considering the dynamics of the popularity of the selected search queries, namely: Smart grid, Sustainable Development and Renewable Energy, we can draw a conclusion. The most popular query despite fluctuations in the number of queries in different categories is "Renewable Energy". The search query "Sustainable Development", which, although it showed a rather low dynamic in the "Business and Industry" category, nevertheless showed a positive, rather high dynamic in the general

category, comes in second place. Regarding the search query "Smart grid", we can emphasize the rather low dynamics, which in any of the presented categories does not show a positive growth trend compared to other queries.

Smart energy is a step forward towards sustainable development and ensuring energy security. The Smart Energy group of companies, part of the Smart Holding investment group, was selected for review as an example of implementing projects on this topic. Smart Energy is implementing projects for the exploration and industrial development of hydrocarbon deposits. Smart Energy Group is represented by the public British company Enwell Energy with assets in the Poltava Region (Representative Regal Petroleum Corporation Limited) and Kharkiv Region (ToV "Prom-Energo Product"), as well as the gas production company PrJSC "Ukragazvydobutok", which operates in Kharkiv region (Fig. 10). In 2020, Arkona Gas-Energy LLC, which was purchased by a British company and operates in the Poltava region, joined the group (Na Chasi, 2018).

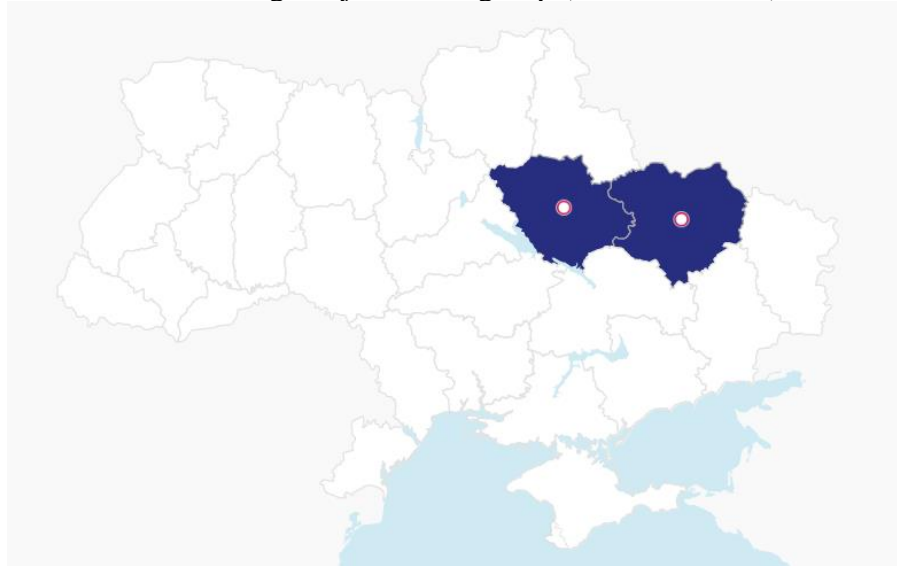


Fig. 10. Smart Energy group assets map
Source: built by the author based on (Na Chasi, 2018)

The main mission of the company is investing in the energy security of Ukraine. As stated on the official website, they create a business that implements the best global standards of production, organization of business processes and personnel management. The main values of the company are openness, mutual respect, responsibility and trust, they make it possible to build a culture of success and efficiency on a daily basis, resistant to external factors and a changing environment. The company's strategy can be formed as follows: ensuring the growth of hydrocarbon production in two ways - organic and inorganic. Growth can be ensured organically through the expansion of investment activity in existing deposits, including the development of certain narrow-sector directions (Dobrowolski et al., 2022). Inorganically, growth can be achieved through mergers and acquisitions.

Regarding the company's gas production, which is presented in Figure 11, you can see a clear increase from 2011 to 2021.

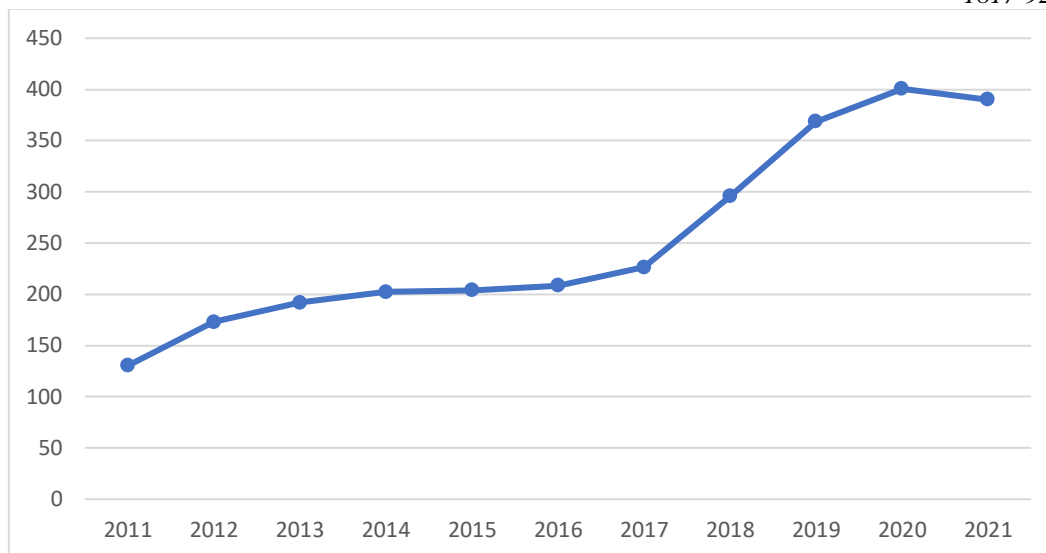


Fig. 11. Dynamics of gas production

Source: built by the author based on основі (Smart, 2023)

CONCLUSIONS

Based on the research on renewable and non-renewable energy sources, it was found that using and implementing alternative energy sources is an important factor for preserving ecology and developing our planet. As of the end of 2022, renewable energy sources are gaining more and more popularity, namely wind power plants, solar power plants, home solar power plants, and small hydroelectric power plants. The leaders in the number of new facilities installed from renewable energy sources for 2021 in Ukraine are Mykolaiv, Odesa, Kherson and Zaporizhzhia regions.

For Ukraine, after the start of a full-scale invasion, the issue of alternative energy sources is urgent and extremely necessary. Alternative energy sources can prevent new blackouts that occur due to hitting critical infrastructure facilities. When introducing alternative energy sources, the advantages of their use should be considered. This opens up new opportunities for innovation and helps reduce environmental pollution.

According to European Union statistics, the most common alternative sources in Ukraine and Europe are solar panels, wind power plants and smart energy. Solar panels have a number of advantages that define them as sustainable and stable energy sources for the future. Wind farms have more limitations due to the nature of the conditions, but with the development of technology they are becoming more and more efficient. An important direction for the development of the modern energy system is the use of smart energy. These technologies use innovations that increase the level of energy efficiency and reduce the negative impact on the environment. Smart energy includes the use of artificial intelligence, data analytics and a system for collecting energy resources. The system of "smart" houses is becoming more and more popular and allows you to automatically control the use of energy in the house. Modern smart energy allows you to effectively provide energy planning and to warn of power outages. The implementation of smart energy is a very expensive investment that will work for the long term. The introduction of alternative energy sources is a promising way to ensure the energy security of the country and preserve the environment.

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