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# ECOTRANSFORMATION OF THE UKRAINIAN ENERGY SECTOR

*The research has been focused on analyzing the stages of formation of Ukraine's energy sector and its transformation in the context of full-scale military aggression from Russia. Considering the significance of energy for national security and economic growth, the article is emphasized the perspectives for green development during wartime. Specifically, it is examined the readiness of the energy sector to implement renewable energy sources and green technologies in the context of global challenges and the need to reduce dependence on traditional energy sources. The research is highlighted the interrelation between consumer-conscious development and stimulating innovation in the energy sector during crises. The relevance of the research is driven by global trends, climate changes, and the necessity for reforms in the energy sector. The hypothesis is suggested that the war may serve as a catalyst for implementing green development strategies and transitioning to renewable energy sources. The methodology is included an analysis of the stages of formation and the current state of the energy sector during military actions, as well as its preparedness for the implementation of environmentally friendly technologies. The results of the research are confirmed that the conscious development of consumers, focused on supporting green initiatives, it can be a key factor in the development of the renewable energy sector in the conditions of geopolitical uncertainty.*

*Keywords:* energy sector, energy security, renewable energy sources, decarbonization.

**JEL Classification:** F29, Q40, Q42, Q48.

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# ЕКОТРАНСФОРМАЦІЯ ЕНЕРГЕТИЧНОГО СЕКТОРА УКРАЇНИ

*Дослідження зосереджене на аналізі етапів формування енергетичного сектора України та його трансформації у контексті повномасштабної воєнної агресії з боку росії. З урахуванням важливості енергетики для національної безпеки та економічного зростання акцентовано увагу на визначенні перспектив зеленого розвитку під час війни. Зокрема, проаналізовано стан готовності енергетики до впровадження відновлюваних джерел енергії та зелених технологій у контексті глобальних викликів та потреби зменшення залежності від традиційних енергоносіїв. Досліджено також взаємозв'язок між свідомим розвитком споживачів та стимулюванням інновацій в енергетичному секторі в умовах кризи. Актуальність дослідження обумовлена глобальними тенденціями, змінами клімату та необхідністю реформ в енергетичному секторі. Гіпотеза допускає, що війна може стати каталізатором для впровадження стратегій зеленого розвитку та переходу до відновлюваних джерел енергії. Методологія містить аналіз етапів формування та стану енергетичного сектора під час військових дій та його готовності до впровадження екологічно чистих технологій. Результати дослідження підтверджують, що усвідомлений розвиток споживачів, спрямований на підтримку зелених ініціатив, може виявитися ключовим чинником у розвитку галузі відновлюваних джерел енергії в умовах геополітичної невизначеності.*

*Ключові слова:* енергетичний сектор, енергетична безпека, відновлювані джерела енергії, декарбонізація.

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## Introduction

Russia's full-scale invasion of Ukraine has proved that the energy sector of Ukraine is one of the strategically important branches of the national economy, which directly affects the stability of the country, its economic development and the social condition of the population. In view of the latest global trends, climate change, as well as reforms in the energy sector, the question of assessing the formation and development of the energy sector becomes significant for the long-term success of the country.

In addition, the problem of finding effective strategies for the modernization of national energy systems in the face of threats from global environmental and security challenges is in the epicenter of attention.

The relevance of the conducted research is determined by a number of factors. First, on the way to climate neutrality, achievement of climate ambitions and economic development, the world community recognizes the need for transformations in the energy sector, in particular with an in-depth focus on the transition to renewable energy sources (RES). Secondly, solving the issue of rapid and effective transformations in the energy sector directly and acutely concerns not only the issue of energy, but also national security and national sovereignty, and the transition to RES is considered a promising way to reduce systemic threats to national economies that are importers of energy resources.

Being part of the global world, striving to follow global trends and having a number of climate and environmental obligations, Ukraine has also chosen a course for decarbonization. However, the full-scale invasion of Russia on the territory of Ukraine, the terrorist attacks of the aggressor country on the facilities of the energy system of Ukraine make the situation extremely difficult and require attention to the problem of energy security, and also call into question the green development of the sector.

Therefore, the aim of this article is a comprehensive analysis of the energy sector of Ukraine, the stages of its formation, as well as confirmation or refutation of the hypothesis that Russia's war against Ukraine will not stand in the way of the decarbonization of the economy, as well as the green development of the energy sector.

The hypothesis that forms the basis of the article is the assumption that Russia's war against Ukraine will not only not slow down the process of decarbonization of the economy and the energy sector, but may also become an additional incentive for Ukrainian society and authorities to implement and accelerate green development strategies, in particular, the transition to a larger scale use of RES. The hypothesis also suggests that in the context of military aggression and post-war recovery, it is important to consider decarbonization as a component of a national recovery and development strategy, and not just as an environmental aspect.

The methodology of this research includes an analysis of the formation of the energy sector of Ukraine, an assessment of its state in different time periods and in accordance with national policies. The state

of the energy sector of Ukraine has been investigated since the beginning of the full-scale invasion, and an assessment of the situation and readiness for the development of the sector has been provided, in particular with regard to the expansion of RES capacities on the basis of available information using the methods of analysis and synthesis, abstraction and generalization, comparison and systematization, as well as approaches to evolutionary and institutional and comparative analysis. The obtained conclusions are based on the results of research by domestic and foreign scientists on the issues of energy transition, decarbonization and energy security research, supported by analytical data of the State Statistics Service of Ukraine, the National Commission that carries out state regulation in the fields of energy and communal services, PrJSC "National Energy Company "Ukrenergo", the State Agency for Energy Efficiency and Energy Saving of Ukraine, the analytical center DiXi Group, as well as the International Energy Agency IRENA.

The results of scientists, who considered the transformation of the energy sector in the context of the influence of various factors, in particular the energy transition, ecology and security factors, were analyzed. Thus, Metelenko N., Oglobina V. and Summa V., studied the post-war "green" recovery of Ukraine in the context of the energy transition and proved the economic feasibility of investing in renewable energy sources (Metelenko & Ogloblina, 2022). Through the prism of ecological and economic aspects, Vovk V. and Krasnoselska A. investigated the transformation of the energy sector, increasing the share of renewable energy sources in connection with increased attention to environmental issues and economic benefits (Vovk & Krasnoselska, 2023). Research on the theoretical foundations of energy market development, individual energy sector transformations, and sector development at the intersection of ecology and climate is highlighted in the studies of Dolinskyi A. and Doronina I., whose research focuses on the transformation of the energy sector and the mitigation of climate risks (Dolinsky, 2006; Doronina, 2019). The scientists' researches, which analyzed the impact of security factors on the further development of the sector, became particularly relevant. Thus, the article by Kudyrko L. proved that the war of the Russian Federation against Ukraine became a catalyst for the decarbonization of European economies (Kudyrko et al., 2022). In addition, O. Borodina researched that the management of the recovery of the national economy in ensuring energy decentralization and energy security is relevant, taking into account the need to restore and ensure the security of the energy infrastructure in the post-war period (Borodina, 2023).

Among foreign scientists, certain aspects of the development of renewable energy, decarbonization of the economy, and the "green" transition in the context of energy security were considered by Antenucci A., Granado P., Georgiev B., and Sansavini J., who concluded that the impact of long-term decarbonization policy on security energy supply is critical

to ensuring a reliable and sustainable energy transition (Antenucci et al., 2019). Other scholars (Tian et al., 2022) have confirmed that transitioning to low-carbon energy sources and reducing dependence on fossil fuels are crucial steps in achieving energy security and economic stability. In line with recent geopolitical developments affecting the energy sector, scholars have also explored ways to improve energy strategies. Thus, Rabbi M., Popp J., Mate D., Kovacs S. investigated that the energy industry can be decarbonized and achieve energy security with the help of three main strategies, such as supply diversification, energy conservation and faster adoption of RES (Rabbi et al., 2022).

At the same time, the possibility of continuing the implementation of decarbonization policies, in particular the energy transition using renewable energy sources, in the context of Russia's military aggression against Ukraine and post-war reconstruction, requires an in-depth analysis and disclosure.

The article is divided into two sections, which logically lead the reader from the general analysis of the formation of the energy sector, which is confirmed by a statistical assessment to the sector development during the war and the possibilities of post-war recovery.

## 1. Evolution of the energy sector formation of Ukraine

During the years of independence, the energy sector of Ukraine underwent a significant transformation, which was caused by a change in national priorities, geopolitical dynamics and global energy trends. Taking into account the external and internal factors of influence, it is possible to single out the stages of formation of the system of regulation of the energy sector in Ukraine.

The first stage is early independence and energy security (1991–2000). In the first years of independence, the primary energy goal of Ukraine was to ensure stable energy supply. After the collapse of the Soviet Union, Ukraine was heavily dependent on Russian energy imports, in particular natural gas, so the main focus was on ensuring a stable supply of energy resources to meet domestic needs. This period is characterized by a change in the ownership structure in the fuel and energy complex of Ukraine such as the process of privatization of coal mines (1996), electricity distribution companies (1998) and oil refineries (1999) began (Ukraine. Overview of energy policy, 2006).

II stage is reforms and diversification of the energy sector (2000–2010). In the early 2000s, energy sector reforms aimed at creating a more market-oriented and transparent energy system began in Ukraine (Institutional Reform of the Energy Sector of Ukraine, 2016). Diversification of energy sources became particularly important during this period, as Ukraine sought to reduce its dependence on Russian gas by seeking alternative suppliers and increasing domestic energy production, particularly coal and renewables.

III stage is energy efficiency and sustainable development (2010–2014). In the early 2010s, energy efficiency became a central goal. High energy consumption and inefficiency in industry and buildings have been recognized as major economic and environmental problems. Ukraine launched energy saving programs and improved energy efficiency standards. The pursuit of sustainable development has also gained momentum with increased attention to the development of renewable energy and reducing emissions.

IV stage is modernization of the energy sector and European integration (2014-present). After the events of 2014 and Ukraine's commitment to bring its policies closer to those of the European Union (EU), the energy goals have changed significantly. The focus was on bringing Ukraine's energy sector to EU standards and norms (Overview of the energy sector of Ukraine, 2019). The key tasks were liberalization of the energy market, integration with the European electricity and gas markets, compliance with EU energy directives. Ukraine's energy strategies emphasized transparency, competition, and regulatory compliance (Institutional Reform of the Energy Sector of Ukraine, 2016). The increase in RES capacity is becoming noticeable, and the policies are appropriate – with the aim of reducing carbon emissions and increasing energy security. Energy security remained a priority with an emphasis on diversifying energy sources, improving infrastructure and reducing dependence on Russian gas.

V stage is following the global energy transition and green European politicians (present time). In recent years, the energy policy of Ukraine has seen the constant importance of adapting to global energy transition trends, which includes an increased emphasis on decarbonization, reduction of greenhouse gas emissions, and coordination with international climate agreements and European politicians. Thus, Ukraine became one of the first countries to support the European Green Deal in order to influence the processes of minimizing potential threats with the help of joint projects on decarbonization and climate protection. In addition, despite active hostilities on the territory of Ukraine and heavy losses of the energy sector, in April 2023 Ukraine approved the Energy Strategy until 2050 to bring the energy sector as close as possible to climate neutrality. The document is based on international commitments undertaken by Ukraine, in particular within the framework of the Agreement on the Association of Ukraine with the EU and the Paris Climate Agreement.

### *1.1. Analysis of national energy key goals strategies*

The system of regulation of the energy sector and energy policies developed in response to the change in the national and global context, which is also reflected in the key policies and goals of the Energy Strategies of Ukraine (*Table 1*).

*Table 1*

Comparative characteristics of the national energy key goals strategies of Ukraine

| Indicator | Energy strategy of Ukraine for the period: | | |
|---|---|---|---|
| | until 2030 | until 2035 "Safety, energy efficiency, competitiveness" | until 2050 |
| RES | 12.6% by 2030 | 25% by 2035 | 100% carbon-free energy mix in 2050 |
| Energy efficiency | Reducing the specific consumption of energy resources in the economy by 30–35% by 2030. | Reducing the energy intensity of the country's GDP by half by 2035 (0.13 toe) | n/a* |
| Reduction of emissions | – | <50% limitation of $CO_2$ emissions to the level of 1990; >20% reduction in emissions in $CO_2$ equiv. on final fuel consumption | |
| The need for investment | UAH 1821 billion (UAH 130 billion for RES) | – | |

* n/a (not available).

*Source:* developed by the author based on the data of the Energy Strategies of Ukraine (Order of the Cabinet of Ministers of Ukraine No. 1071-r, 2013; Order of the Cabinet of Ministers of Ukraine No. 605-r, 2017; Order of the Cabinet of Ministers of Ukraine No. 373-r, 2023).

In the Energy Strategy of Ukraine until 2030, which was approved in July 2013, it was noted that in order to maintain the reliability of the energy sector of Ukraine and stimulate the growth of the economy, the priority tasks of the electricity sector under any scenario of demand growth were planned (Decree of the Cabinet of Ministers of Ukraine No. 1071-r, 2013):

• modernization of existing generating capacities, such as thermal and gas power plants, with the installation of modern dust and gas cleaning equipment on new units, nuclear and hydroelectric power plants, with the solution of problems of sorbent supply and disposal of waste from its use;

• modernization and development of main and distribution power networks;

• implementation of construction projects of hydro- and geothermal power plants with a total capacity of 5 GW;

• extension of the operational life of existing power units of nuclear power plants to 20 years with appropriate safety inspections;

• construction of the third and fourth power units at the Khmelnitsky NPP with a minimum capacity of 2 GW;

• development of renewable energy sources;

• construction of 4 GW of coal-fired power plants to replace outdated capacities;

• launch of pre-project works in 2017 and start of construction of new nuclear units in 2022 to replace old units that will be decommissioned after 2030;

• construction of nuclear units in new territories with a minimum capacity of 3 GW under the base scenario and 5 GW under the optimistic scenario of forecasted demand;

• additional construction of coal-fired power plants with a capacity of 9 GW under the base scenario and 11 GW under the optimistic scenario.

Thus, the Energy Strategy of 2013 provided for the development of renewable sources, namely, a forecast of the appropriate aggregate capacity of renewable energy sources in 2030 at the level of 12.6% of the total installed capacity or 8 GW (14 GW, including large hydroelectric power plants), and the production volume – 14 TWh (28 TWh, including large HPPs). In addition, the overall technological potential of increasing energy efficiency on average across the economy in the base development scenario of 30–35% has been established. The document also notes the importance of reducing pollutant emissions and reducing greenhouse gas emissions, but the overall goal for the energy sector has not been established (Order of the Cabinet of Ministers of Ukraine No. 1071-r, 2013).

However, in addition to the goals for the development of clean energy and energy efficiency, reducing emissions, the strategy also provided for increasing the capacity of nuclear units and the construction of coal-fired power plants. The total need for investments in the energy sector by 2030 was predicted at the level of UAH 1 821 billion, of which only UAH 130 billion (7.14%) was needed for the development of RES (Decree of the Cabinet of Ministers of Ukraine No. 1071-r, 2013).

The energy strategy of Ukraine for the period until 2035 "Security, energy efficiency, competitiveness" was approved in 2017 to replace the previous version (Decree of the Cabinet of Ministers of Ukraine No. 605-r, 2017). The prerequisites for creating a new strategy were changes in the energy policy of the European Union – the establishment of the Energy Union in Europe, the agreement on the full integration of energy markets between Ukraine and the EU, participation in the Paris Agreement on climate change, and Russia's aggression against Ukraine, including the occupation of part of its territory (Uatom, 2019).

The main differences between the Energy Strategy until 2035 and the previous one are the transition from an energy model dominated by the use of fossil fuels, inefficient networks and insufficient transparency of gas and coal markets to a new model that provides equal opportunities for the development of all types of energy production. Special emphasis is placed on the importance of increasing energy efficiency and the use of energy from RES (Uatom, 2019).

The strategy until 2035 identifies among the tasks the reduction of the energy intensity of GDP from the current 0.28 toe/USD 0.13. The percentage of losses in electricity networks, which is currently more than 12%, must be reduced to less than 7.5% by 2035. In general, the limitation of $CO_2$ emissions compared to the level of 1990 should reach 60% by 2020, 2025 and 2030; and – 50% by 2035 (Order of the Cabinet of Ministers of Ukraine No. 605-r, 2017).

Reductions in $CO_2$ emissions from final fuel consumption must exceed 5% by 2020 and increase by at least 5% every 5 years, reaching a reduction of more than 20% by 2035.

The forecast of the strategy regarding the share of renewable energy sources (RES) in total energy consumption correlates with the forecast of the International Energy Agency IRENA, which foresees the possibility of Ukraine achieving a share of RES at the level of 22% by 2030 (IRENA, 2015).

The strategy does not specify the need for investments, however, the State Agency for Energy Efficiency and Energy Saving of Ukraine estimates the need for investments to achieve these goals at the level of (EUR 12 billion) (Karmelyuk, 2017).

In May 2023, the Energy Strategy of Ukraine until 2050 was adopted. The document has the status "For official use" and is distributed for perusal among ministries and specialized state companies only in paper form (Davidenko & Chaika, 2023).

It is only noted that the Energy Strategy of Ukraine until 2050 takes into account:

- the consequences of a full-scale war, increasing the importance of energy security and strengthening the stability of the energy system;
- the results of joining the Unified Energy System Operator of Ukraine to the European Network of Electricity Transmission System Operators (ENTSO-E) and deepening the integration of the energy system of Ukraine into the pan-European context;
- application of advanced technologies (production and use of hydrogen, small modular nuclear reactors, energy storage systems), technical transformations in the energy sector, world trends and innovative solutions, compliance with the environmental standards of the European Union and Ukraine’s environmental safety commitments;
- fulfillment of Ukraine’s international obligations regarding energy efficiency and use of renewable energy sources, reduction of greenhouse gas emissions, etc.;
- development of decentralized electricity generation throughout the country (UKRINFORM, 2023).

The key goal of the Strategy is to transform Ukraine into the energy hub of Europe, contributing to the global goal of phasing out Russian fossil fuels. The strategy sets the goal of achieving climate neutrality in the energy sector by 2050 (Denisyuk, 2023).

The document itself is not publicly available for security reasons during the war, which creates uncertainty in the vectors of development of the sector until 2050 for various groups of stakeholders.

Consequently, Ukraine's energy strategies were updated in accordance with internal and external events that could affect the transformation of the energy sector and the market in general. As a result, Ukraine's energy goals reflect the desire for a safe, efficient and environmentally responsible energy future, from early efforts to ensure energy supply to the current commitment to sustainable development and alignment with EU standards. A constant challenge is the effective implementation of national strategies to achieve goals and overcome difficult conditions, particularly geopolitical ones, in order to achieve energy security.

## 2. Assessment of the energy sector development: statistics

If we follow the stages of development of the regulation system of the energy sector in Ukraine in a statistical dimension, we will get the following results (*Figure 1*).

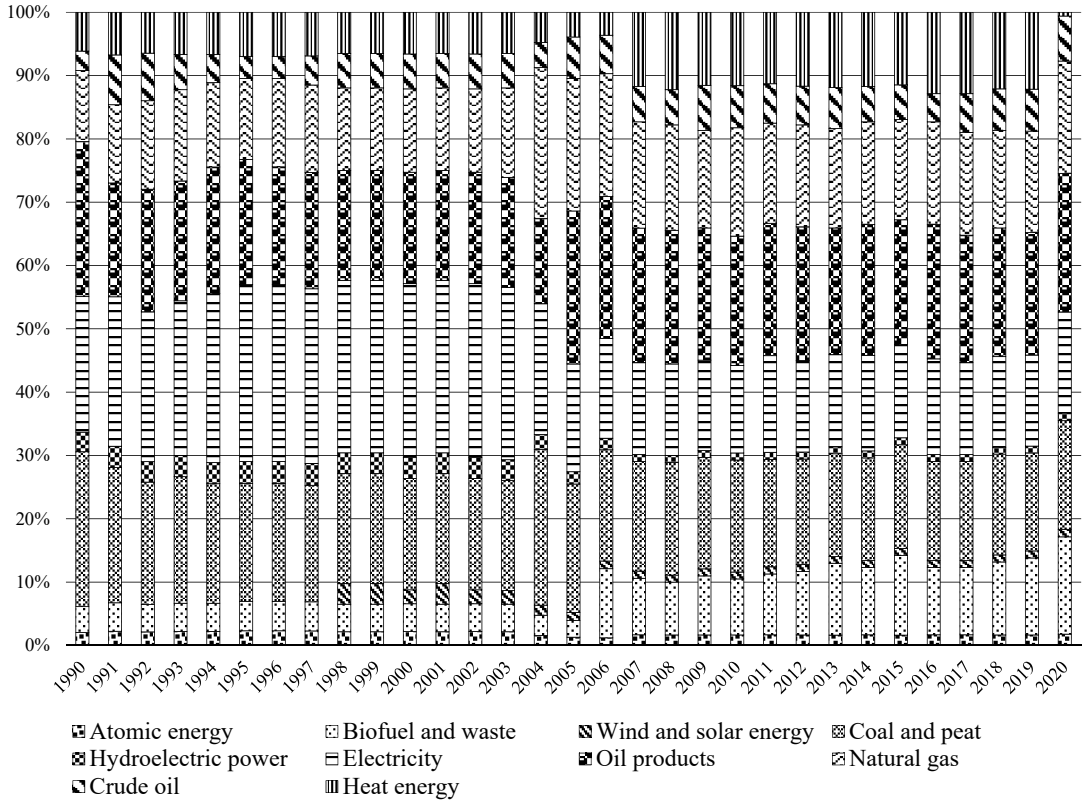



Figure 1. Total energy balance of Ukraine for 1990–2020, %

*Source:* (Energy Map, 2021).

It can be seen from *Figure 1* that in the energy balance of Ukraine in production in 1990, coal and peat significantly prevailed (about 65%). And in 2020, the share of coal in energy production has almost tripled. In

turn, the growth of nuclear generation, natural gas, energy from biofuels and waste, as well as, albeit not significant, growth of renewable energy sources is being monitored. According to the data on the amount of electricity produced, the share of RES in production increased 5 times from 2017 to 2021, and this growth shows positive dynamics every year (*Figure 2*).

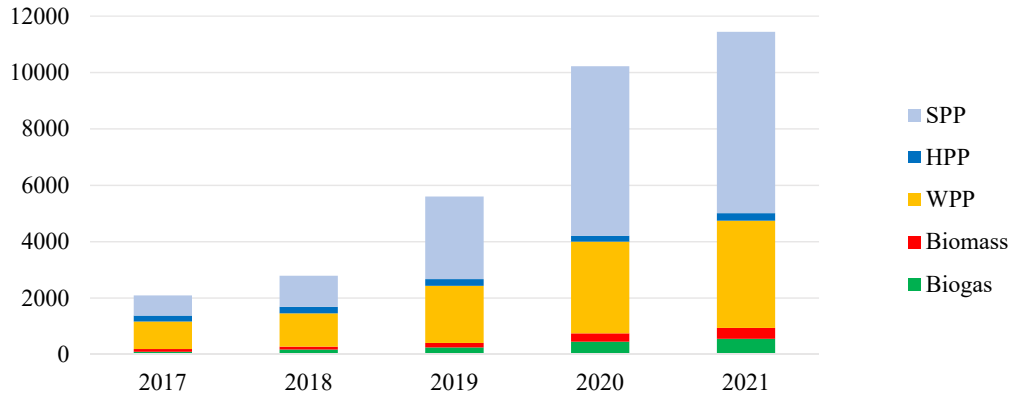



Figure 2. The amount of electricity generated from RES from 2017–2021, million kWh

*Source:* (Energy Map, 2022a).

If you follow the dynamics of the installed electric capacity of power plants of the energy system of Ukraine, detailed by type of power plants (nuclear power plants, thermal power plants, hydroelectric power plants, RES), you can see that 2018–2021 were the peak years in terms of installed capacities. In addition, the dynamic growth of solar and wind capacities is monitored (*Figure 3*).

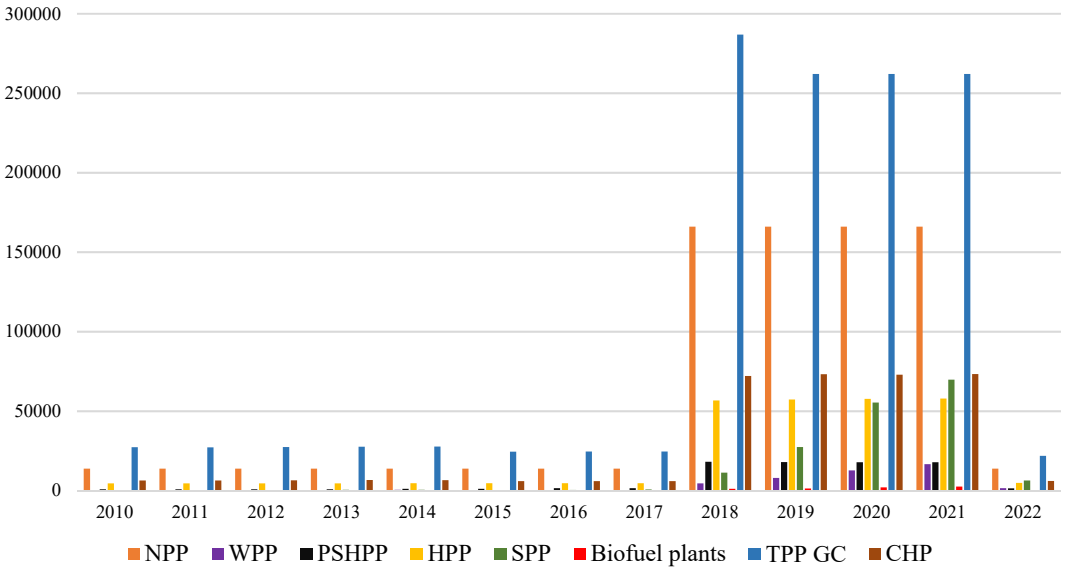
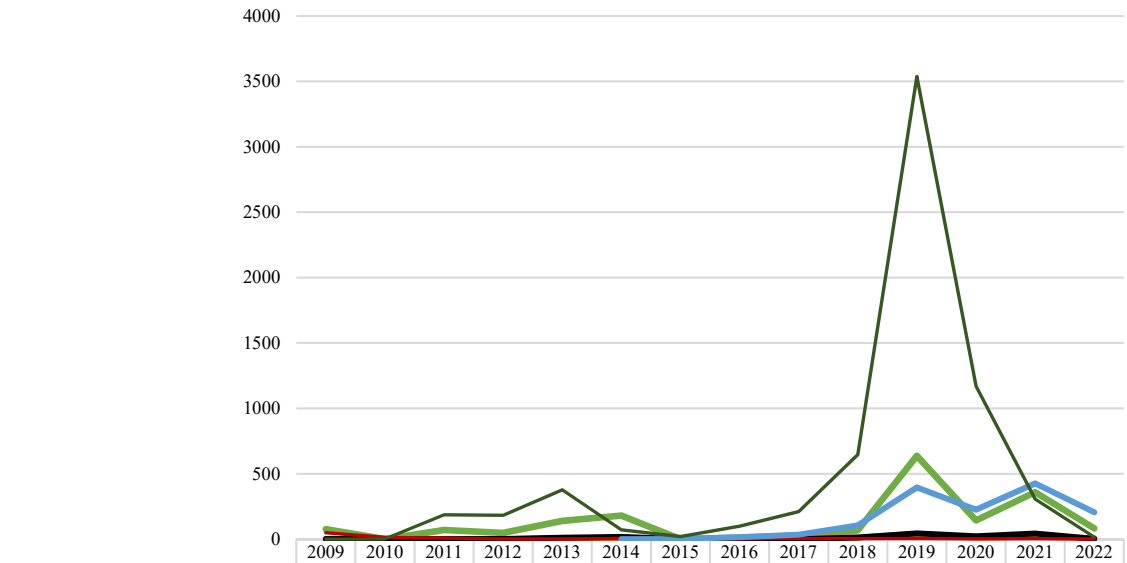



Figure 3. Installed electric power by generation, MW

*Source:* (Energy Map, 2022b).

At the beginning of 2022, according to the latest available analysis, the capacity of the renewable energy sector in Ukraine was 10475.1 MW, taking into account the generation of domestic solar power plants. However, this growth was particularly intense due to the active installation of SPP (*Figure 4*).



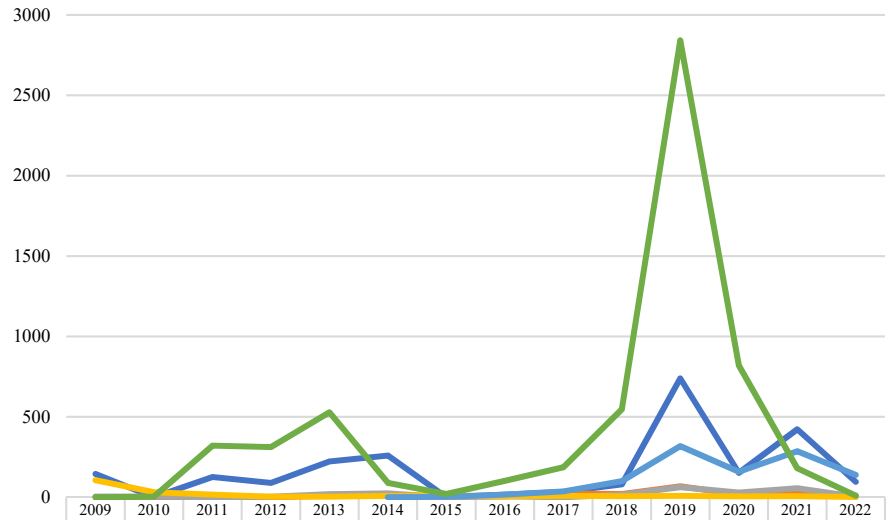

| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind Power Plan | 76 | 0 | 70 | 48 | 140 | 180 | 0 | 12 | 27 | 68 | 637 | 144 | 359 | 82 |
| Biogas Power Plant | 0 | 0 | 0 | 0 | 6 | 8 | 3 | 3 | 14 | 13 | 40 | 10 | 20 | 6 |
| Biomass Power Plant | 2 | 2 | 0 | 2 | 11 | 18 | 0 | 4 | 0 | 12 | 44 | 22 | 43 | 3 |
| Small Hydropower Plant | 49 | 14 | 8 | 2 | 2 | 5 | 7 | 3 | 5 | 4 | 5 | 3 | 4 | 1 |
| Household Solar Power Plant | | | | | | 0,1 | 2 | 15 | 34 | 106 | 396 | 226 | 426 | 206 |
| Industrial Solar Power Plant | 0 | 2 | 186 | 183 | 377 | 71 | 20 | 99 | 211 | 646 | 3537 | 1169 | 306 | 16 |

Figure 4. Dynamics of the installed capacity of RES facilities in Ukraine in 2009–2022, MW

*Source:* compiled according to data (Energy Map, 2022).

In the renewable energy sector nationally, wind power installations remain second only to solar power in terms of total installed capacity. According to the Ukrainian Wind Energy Association (UWEA), before the full-scale war, there were 34 wind power plants or 699 wind turbines in Ukraine, and the average capacity of each of them was 3.5 MW (UWEA, 2022). Thus, the total capacity of wind generation reached almost 1.7 GW, not taking into account the capacity of wind power plants in the occupied territories of Donetsk and Luhansk regions, as well as the annexed Crimea. However, within a year of the start of the full-scale invasion, Ukraine lost more than 90% of its wind generation, three-quarters of its thermal generation, almost half of its nuclear generation (due to Russian control over the Zaporizhzhia NPP), a third of its solar generation and block thermal power plants.

In turn, before the war, the volume of investments in the industry exceeded USD 12 billion. Most of the projects were started by 2020, and the peak of investments fell on 2019 (*Figure 5*).




| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind Power Plan | 144,9 | 0 | 125,9 | 89,3 | 222,7 | 259,1 | 0 | 16,8 | 33,5 | 80,7 | 739,4 | 151,6 | 422,4 | 96,5 |
| Biogas Power Plant | 0 | 0 | 0 | 0 | 9,5 | 12,1 | 5,1 | 5,1 | 23,5 | 20,9 | 67,9 | 16,23 | 31,09 | 9,33 |
| Biomass Power Plant | 4,3 | 4,5 | 0 | 4 | 19,2 | 24,5 | 0 | 5,8 | 0 | 16,3 | 62,86 | 29,91 | 56 | 3,9 |
| Small Hydropower Plant | 105,8 | 31,8 | 16,1 | 4 | 3,8 | 8,3 | 12,6 | 5,4 | 8,8 | 6,78 | 8,93 | 5,26 | 6,72 | 1,68 |
| Household Solar Power Plant | | | | | | 0,1 | 2,5 | 16,3 | 36,4 | 100,61 | 318,21 | 158,60 | 286,39 | 138,49 |
| Industrial Solar Power Plant | 0 | 3,9 | 321,2 | 312,2 | 528,4 | 88,8 | 20,7 | 102,6 | 186,7 | 547,46 | 2842,23 | 820,35 | 180 | 9,41 |

Figure 5. Dynamics of investments in the capacity of RES facilities in Ukraine in 2009–2022, mln EUR

*Source:* compiled according to Energy Map data based on data from the State Agency for Energy Efficiency and Energy Saving of Ukraine (Investments in "green" generation capacity, 2022).

In 2019, Ukraine was among the TOP-10 in terms of renewable energy development rates, and in 2020 – in the TOP-5 European countries in terms of solar energy development rates. In the same 2019, Ukraine took 8th place in the Climatescope rating by Bloomberg New Energy Finance (Bloomberg NEF) among 104 countries in the world in terms of the attractiveness of investments in the development of low-carbon energy sources and the construction of a "green" economy, rising from 63rd place. In 2021, Ukraine ranked 48th in terms of overall investment potential among 136 countries in the world according to the BloombergNEF rating (Konechenkov, 2022).

### *2.1. Sector development during a full scale invasion*

Since the beginning of the full-scale invasion, due to security risks, a large amount of information has been restricted from being published in the public domain, particularly in the energy sector, which has become one of the targets of terrorist attacks by the Russians.

The war had a significant impact on the transparency of the sector and the availability of data. DiXi Group's research on access to data showed that restricting access to information has a negative impact on the sector and stakeholders, so it needs to be reviewed to make part of the data open, taking into account security risks and avoiding manipulation (DiXi Group, 2023a).

On December 11, 2023, for the first time in almost 2 years, NEURC published information (NEURC, 2023), which allows for a generalized analysis of the sector development. By the end of autumn 2023, the Register has 3,600 active licenses in the field of energy, including the markets of electricity, natural gas, oil and petroleum products, as well as the field of heat supply (*Figure 6*).

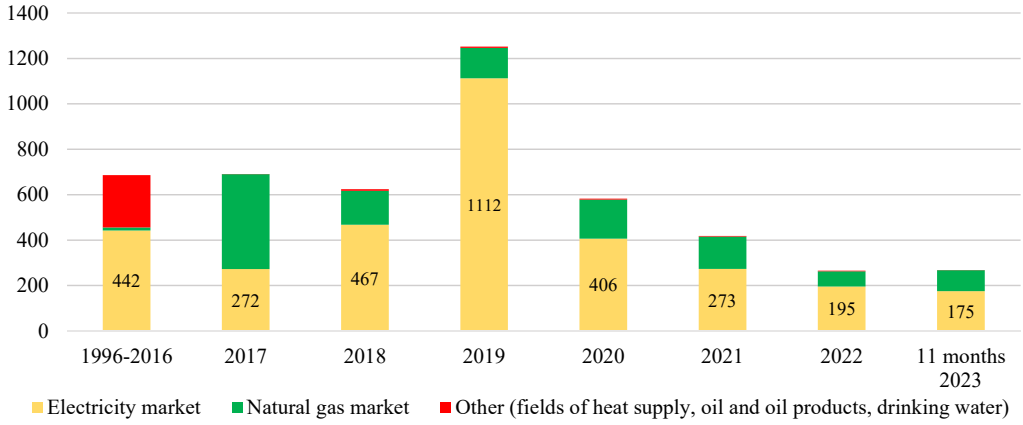



Figure 6. Dynamics of the number of issued licenses for economic activity in the energy sector in 1996–2023

*Source:* (NEURC, 2023).

The number of licenses issued in 2022 is the lowest in the last 6 years. During this period, 265 licenses were issued, of which 15% were issued by February 24. Compared to 2021, the number of licenses decreased by 37%. During the first 11 months of 2023, 268 licenses have already been issued. During the war, the majority of licenses were obtained for activities related to the supply of electricity (243 or 49%) and natural gas (147 or 30%). 66 licenses were granted for electricity production, 30 for resale, and 1 more for storage. Four licenses were obtained for heat production and one for natural gas distribution (DiXi Group, 2023b).

As for the sector of renewable energy sources, according to the information of the Chairman of the Committee of the Verkhovna Rada of Ukraine on energy and housing and communal services, in 2023 the following were put into operation:

- 182.3 MW of wind power plants;
- about 500 MW of solar power plants;
- about 100 MW of gas power plants.

According to him, the largest number of generating facilities was introduced with a capacity of 1 MW or less, accounting for more than 90% of the number of all power plants built in 2023, which duplicates last year's situation (Gerus, 2023, December 30).

With the beginning of the full-scale invasion, especially during the difficult winter period, Ukrainians began to actively install domestic SPPs in

order to provide themselves with energy and be energy independent. In 2022, the share of investments in domestic SPPs was more than 50% of the total investment in green generation capacity (*Figure 7*).

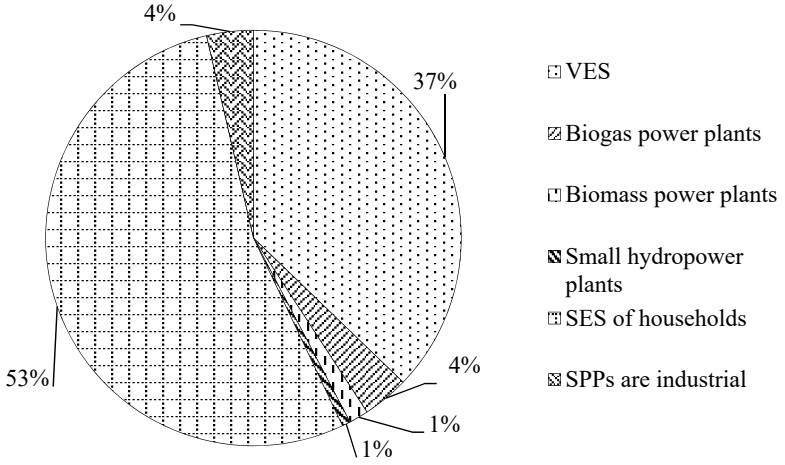



Figure 7. Investments in "green" generation capacity in Ukraine in 2022, %

*Source:* compiled according to data (Energy Map, 2022 c).

The results of the analysis of Figure 7 show a high level of adaptability and responsibility of consumers in difficult socio-economic conditions. The development of the sector does not stop, but rather adapts to global challenges, which shows the potential for further improvement and growth. A significant factor is the efforts of citizens in achieving energy independence, which emphasize the importance of the development of RES and supporting the decarbonization of the sector despite the war.

The study of the energy sector formation of Ukraine and the prospects of green development in the conditions of a full-scale invasion of Russia determined the key role of this industry in the national economy, the stability of the country and ensuring energy security.

## Conclusions

During the years of independence, the energy sector of Ukraine has undergone several stages of transformation, including ensuring energy security, reforms and diversification, increasing energy efficiency, modernization and European integration, as well as adaptation to global energy trends and green European policies. Ukraine is actively working on decarbonization and reducing greenhouse gas emissions, and is also implementing measures to achieve climate neutrality by 2050.

The results of the analysis of the key goals of the national energy strategies of Ukraine show that, despite the war, the country strives for a safe, efficient and environmentally responsible energy future, in particular by increasing energy efficiency, reducing emissions of pollutants and developing renewable energy sources. Strategies are updated in accordance

with internal and external geopolitical events affecting the energy sector and the market in general.

Emphasis on the transition to RES in the context of global climate ambitions and economic development is defining for the study. Despite the challenges associated with Russia's military aggression and terrorist attacks on energy system facilities, the study indicates that Ukrainian society and the authorities remain interested in the development of the green energy sector.

The hypothesis that the war will not only not lead to delays in decarbonization, but can also become an incentive for the accelerated development of green strategies, is confirmed. The conditions of the war proved to be a catalyst for consideration of decarbonization as a key component of the national recovery and development strategy, not only at the level of the state, but also at the level of citizens in their own provision of energy resources and gaining energy independence.

The research expands the understanding of adaptability and responsibility of consumers in conditions of social and economic instability. In particular, the significant contribution of citizens to achieve energy independence and support decarbonization is highlighted.

Thus, the research makes an important contribution to understand the relationship between military conflict and a country's energy strategy, emphasizing that decarbonization can be not only a national, but also a social and environmental response to the geopolitical challenges of the time.

The results of the research will serve as a basis for further improvement of the energy strategy of Ukraine with the determination of prospects for the implementation of decarbonization policies in the conditions of military aggression and post-war recovery. Among the priority areas of future research in the context of the development of the presented topic, the following can be considered:

- econometric testing of decarbonization factors, which will consist in conducting a more detailed econometric analysis to determine the factors that affect the speed and quality of the transition to renewable energy sources (RES);
- financial aspects of decarbonization, which will include a detailed study of financial mechanisms and investments necessary for the implementation of decarbonization strategies and will consist of an assessment of the efficiency of investments in the RES sector and the development of recommendations on the need for financial support;
- modeling of risks and adaptation strategies will consist of studying the risks associated with military conflict, national and energy security. The development of models of adaptation strategies to ensure the sustainability and efficiency of the energy sector in conditions of environmental instability will be important for further research on the issue.

These lines of research can help expand understanding of the importance of implementing effective strategies for the sustainable development of Ukraine's energy sector during military, social, economic and security challenges, as well as post-war recovery.

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