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THE DEVELOPMENT OF GREEN ENERGY AS A WAY TO ENERGY INDEPENDENCE OF THE NATIONAL ECONOMY

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РОЗВИТОК ЗЕЛЕНОЇ ЕНЕРГЕТИКИ ЯК ШЛЯХ ДО ЕНЕРГЕТИЧНОЇ НЕЗАЛЕЖНОСТІ НАЦІОНАЛЬНОЇ ЕКОНОМІКИ

We state that in 2015 Ukraine does not purchase Russian gas for its own needs, which were fully met at the expense of other sources. Despite this, the current conditions created by Russia's military aggression against Ukraine and the large-scale attacks associated with it on its critical infrastructure, energy facilities, and hydro-engineering structures are increasingly violating access to all necessary energy resources, creating systemic risks for the equitable distribution of energy resources. Thus, the article is aimed at defining the peculiarities and directions of green energy development as a way to energy independence of the national economy of Ukraine. According to the results of the study, it is stated that it is important for Ukraine to abandon the development of centralized energy hubs, in favor of "energy cities. This is necessary to ensure that Russia's energy resources and Ukraine's national critical infrastructure are no longer an instrument of political or military influence on the state. According to the results of the study, it is stated that it is important for Ukraine to abandon the development of centralized energy hubs, in favor of "energy cities". This is necessary to ensure that Ukraine's energy resources and national critical infrastructure are no longer an instrument of political or military influence on Ukraine's national economy. Ukraine has been in constant strikes across its critical infrastructure. It's proved that the new situation complicates the production conditions and minimizes its effectiveness in terms of added value. Therefore, measures aimed not only at its renewal but also at increasing the availability of energy resources at local and regional levels are important. To restore energy independence to improve the availability of energy resources at regional and local levels, each city of our country should become an energy-independent or "energy city", which is possible based on the active development of cities with a significant concentration of wind power plant, solar power plant, bio- and biogas power plant. The perspectives of further research consist in the use of the results obtained for the adjustment of the Energy Strategy of Ukraine for the period up to 2035 "Safety, energy efficiency, competitiveness".

Сучасні умови, сформовані військовою агресією Росії проти України та пов'язаними з нею масштабними атаками по критичній інфраструктурі (національних енергетичних об'єктах та гідротехнічних спорудах) порушили доступ до необхідних енергетичних ресурсів, створили системні ризики для їх справедливого розподілу у сфері господарської діяльності громадян, у якій створюються, розподіляються і споживаються життєві блага. Відтак стаття спрямована на визначення особливостей та напрямків розвитку зеленої енергетики, як шляху до енергетичної незалежності національної економіки України. За результатами дослідження констатовано, що для України важливо

відмовитися від розвитку централізованих енергетичних хабів, на користь «енергетичних міст». Це потрібне для того, щоб енергетичні ресурси РФ та національна критична інфраструктура України перестали бути інструментом політичного чи військового впливу на державу. Доведено, що нове становище ускладнює умови виробництва та мінімізує його результативність з точки зору доданої вартості. За результатами дослідження констатовано, що для України важливо відмовитися від розвитку централізованих енергетичних хабів, на користь «енергонезалежних міст». Важливими є заходи, спрямовані не тільки на відновлення критичної інфраструктури, але й на розширення доступності енергетичних ресурсів в нових умовах. Для того, щоб відновити енергетичну незалежність національної економіки доцільно розширити доступність енергетичних ресурсів на регіональних і локальних рівнях, зокрема кожне місто нашої країни має стати енергонезалежним, що можливо на основі активного розвитку міст зі значною концентрацією об'єктів зеленої енергетики, до складу яких входять: промислові сонячні електростанції; домашні сонячні електростанції; вітроелектростанції; електростанції на біомасі; біогазові електростанції. Такі енергетичні об'єкти швидко будуються, мають різні формати функціонування та відрізняються швидкістю трансформації. Перспективи подальших досліджень полягають у використанні отриманих результатів для коригування «Енергетичної стратегії України на період до 2035 року «Безпека, енергоефективність, конкурентоспроможність».

Ключові слова: критична інфраструктура; енергетичні хаби; вітрова генерація; сонячна генерація, електростанції на біомасі; біогазова енергетика.

Key words: critical infrastructure; energy hubble; wind generation; solar generation, bioenergy; biogas energy.

Problem setting (description of the problem being analyzed in general and its connection with important academic or practical tasks). We note that after the Russian invasion, Ukraine has begun to operate an economic model, the negative features of which have become a full balance of interests of all participants of the market exchange concerning access to all necessary energy resources in the amount required for the economic system. In fact, since 2015 our country does not buy Russian gas and energy for its own needs but completely satisfies them at the expense of other sources. Despite the current conditions created by Russia's military aggression against

Ukraine and the large-scale attacks associated with it on its critical infrastructure, energy facilities and hydro-engineering structures are increasingly violating access to all necessary energy resources, creating systemic risks for the equitable distribution of energy resources in society as a current one. Russia will probably continue to strike critical infrastructure, energy facilities, and hydro-technical facilities of Ukraine in the autumn-winter period, further violating access to the necessary energy resources.

The analysis of the last research and publications in which the solution to this problem is begun. The group of domestic and foreign scientists who considered the issues of concrete ways to energy independence in their works belong: Goncharuk I. [4], Stuchynska N. [7], Barannik V. [1], Peshko A., Nazarenko A. [6]. This issue was touched also foreign researchers, among which Shafiy C. and Salima R. At the same time, most scientific works either deal with the evolution of theoretical principles of positioning energy independence of Ukraine as a social and economic phenomenon, or present a forecast of development of production of alternative energy sources in all spheres of the economic life of Ukraine. At the same time, the new realities have changed the focus of this issue slightly, taking into account new challenges for Ukraine's energy independence. Thus, as of November 18, 2022, another rocket attack by the Russian troops ended with the fact that without electricity there were more than 10 million citizens of Ukraine. Currently, planned, stabilizing and emergency light-off became a common phenomenon throughout the country. To correct the situation and restore energy independence Ukraine will be able to further develop the regional green energy systems, calculating the equal placement of its facilities within the country.

The wording of the purposes of the article (problem). The purpose of the article is to define the peculiarities and directions of green energy development as a way to energy independence of the national economy of Ukraine

The paper's main body with full reasoning of academic results. The authors emphasize the importance for Ukraine to abandon the development of centralized energy hubs, in favor of "energy cities". This is necessary to ensure that the energy resources of the Russian Federation and related national critical infrastructure of Ukraine are no longer an instrument of political or military influence on the national

economy of Ukraine. It should be noted that even though Ukraine does not purchase Russian gas, it has kept a certain energy dependence on Russia. In addition, Ukraine has been in constant strikes across its critical infrastructure. Of course, we speak about industrial power, in particular power plants, power systems, and their networks or parts, the disruption or destruction of which will have the most serious consequences for the national economy. The new situation complicates production conditions and minimizes its effectiveness from the perspective of added value. Therefore, measures aimed not only at its renewal but also at increasing the availability of energy resources at regional levels by changing the format of the national energy infrastructure are important [1; 4; 6; 7].

To restore energy independence in new conditions, each city of our country should become energy-independent or be transformed into "energy-independent local cities", which is possible based on the active development of cities with a significant concentration of wind power plant, solar power plant, bio- and biogas power plant. In particular, such objects do have not only the capacity development, enough to live independently both industrial objects and their households. Energy cities should become energy-efficient, which have a surplus that can be used to accumulate electricity to cover the temporary energy consumption (in winter periods, in periods temporarily unfavorable for generation).

Therefore, it is obvious that the development of green energy in Ukraine, which consists of:

- industrial solar power plant;
- domestic solar power plant (home solar farms);
- wind power plant;
- bio power plant;
- biogas power plant;
- mini hydro power plants (or hydropower plants with a capacity from 100 to 1000 kW).

Such energy objects are quickly built, with different formats and speeds of conversion.

It should be noted that by the beginning of Russia's military aggression against Ukraine and its military invasion, the rate of development of green energy has increased. In particular, only in the first half of 2018 more "green" capacities were put into operation than in the whole of 2017. In 2018, the installed capacity of the renewable energy sector was 2280,7 MW, whereas in 2019 it was 6826,1 MW (or 1.99 times more than in the previous period), and in 2020 it was 8486,7 MW (2,72 times more than in 2018). At the beginning of 2022, the total capacity of green energy facilities in Ukraine reached 9 656,95 MW. (or 3.23 times more than in 2018). The general dynamics of the growth of installed capacity of objects of green energy, for 2018-2021 is given in fig.1.

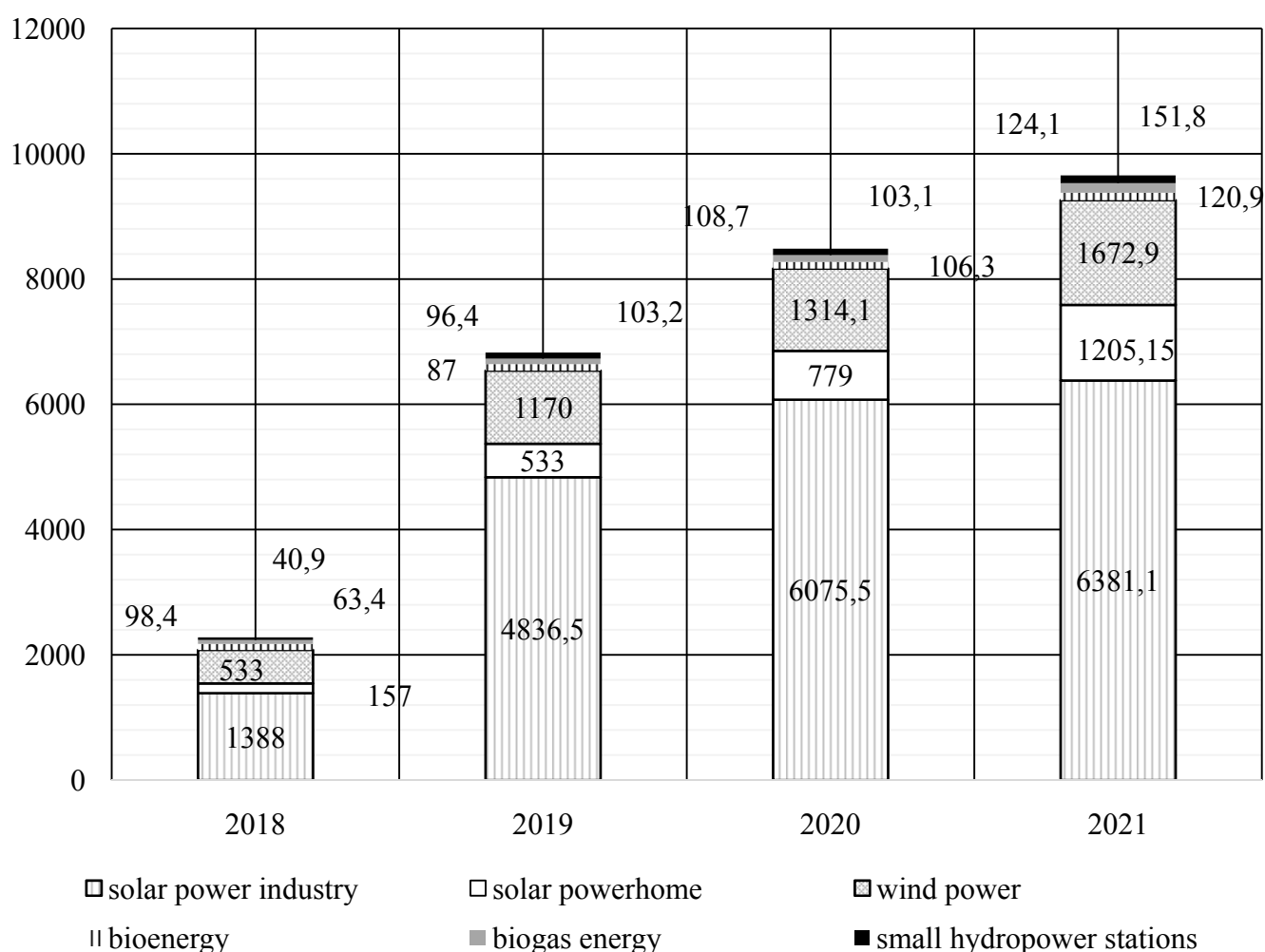
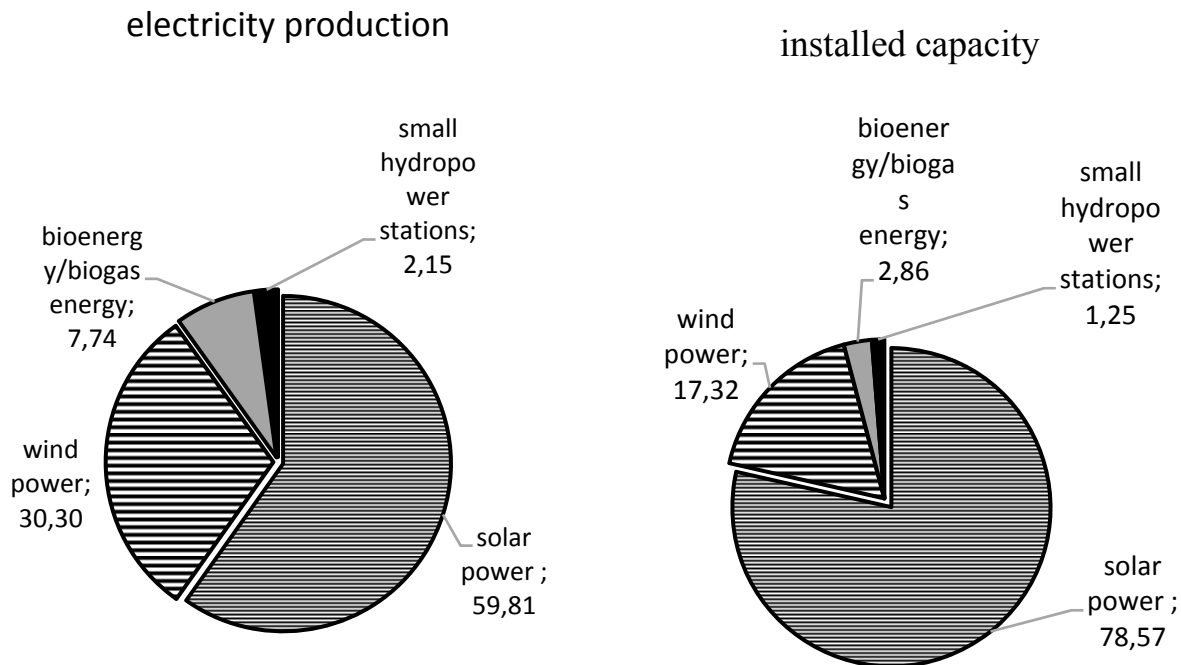


Fig.1. Total dynamics of growth of installed capacity of objects of green energy, in 2018-2021, MW.

Source: UWEA, NEURC, 2021

According to the general dynamics of the growth of the installed capacity of the green energy facilities, the structural capacity of the sector and the resulting generation of electricity by types (as of the end of 2021) was concentrated in several basic segments: solar generation and wind generation (Fig. 2).



Sectors green energy	electricity production		installed capacity	
	million kWh	Structure, %	MW	Structure, %
solar power plant	7670	59,81	7586,35	78,57
wind power plant	3886	30,30	1672,9	17,32
bio- and biogas power plant	992	7,74	275,9	2,86
small hydropower stations	276	2,15	120,9	1,25

Fig. 2. The structure of electricity generation and the installed capacity of the green energy sector, 2021, %.

Source: Ukrenergo NEC, State Energy efficiency Agency, 2021

Thus, according to the structure of power of green energy sectors in the structure of electricity generation formed by it in 2021, the largest share - 59,81% (or 7670 million kWh) was on solar generation and 30,3% (or 3866 million kWh) on wind generation. In addition, 7,74% (or 992 million kWh) was formed at the expense of generation at the expense of biomass and biogas and only 2,15% (276 million kWh) at the expense of a generation of mini hydropower stations. It is obvious that the share of power of small hydropower is critical, and in 2021, it grew only 1,24% or 14,6 MW, due to the high risk of environmental disaster for Ukrainian rivers and the entire natural

system surrounding them. In addition, according to official data of PJSC "Ukrhydroenergo", hydro potential in Ukraine was used by 80% [5].

Specific to this process was that during the period considered, the most active rate of development of capacities was observed in the segment of solar power, which formed home solar power plants and industrial solar power. Thus, the capacity of the domestic solar power plant in 2021 increased by 426,1 MW, which is 36,4% of the new green power plants put into operation last year. It is worth noting that the total installed capacity of all domestic solar power plant at the end of 2021 reached 1205,1 MW (that is, in 2021, increased by 426,1 MW, which is 36,4% of new green energy capacities). In 2021, the power of industrial solar generation increased by only 305,5 MW (26,1% of the new green power plants introduced in 2021), which is 818,1 MW or 3,6 times less than the 2020 figure of 1 123,6 MW. Before the war in Ukraine approximately 10 thousand private and more than 2 thousand industrial solar power stations were functioning (fig. 3).

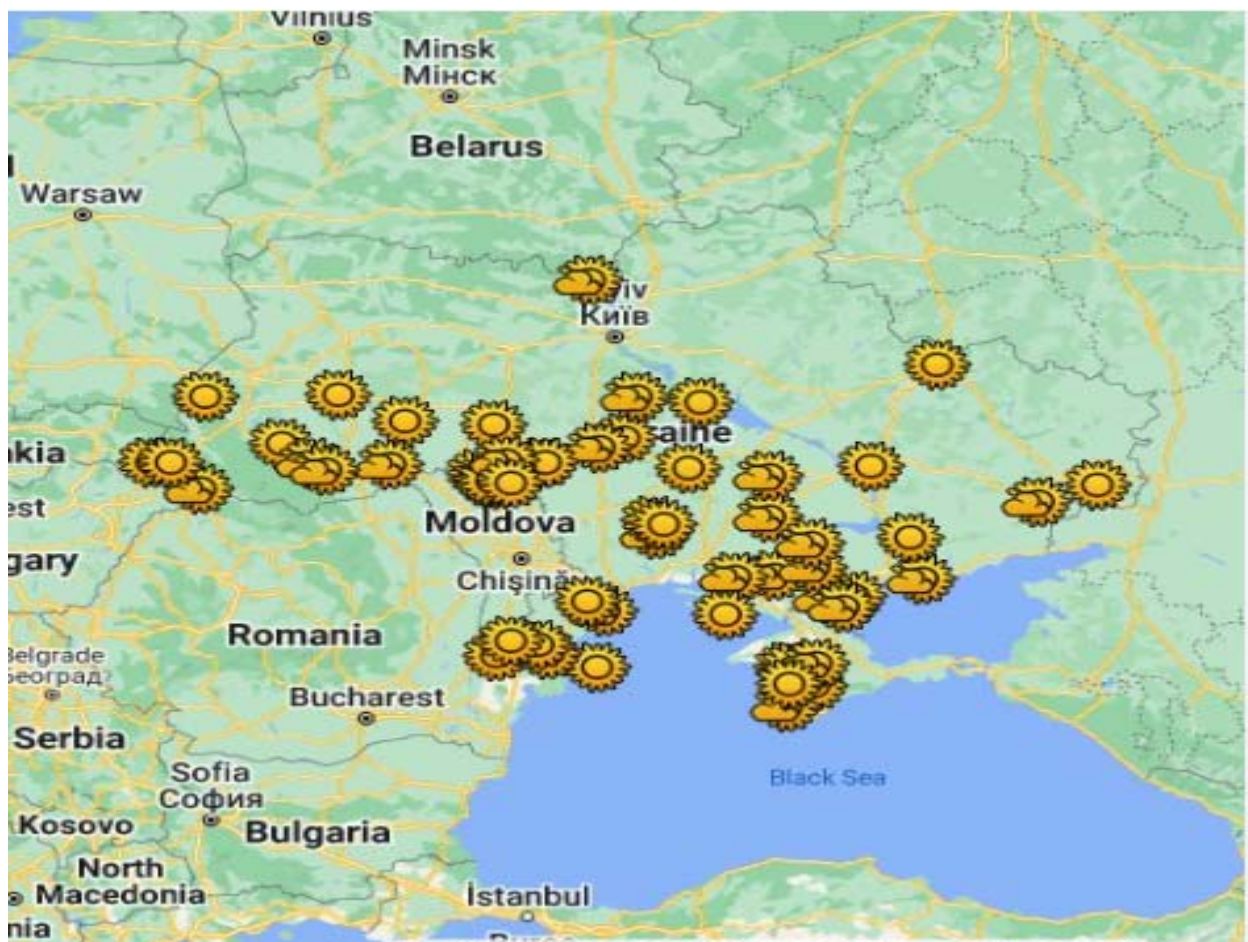


Fig. 3. Map of the location of solar power plants in Ukraine, 2021

Source:: UWEA, NEURC, 2021

At the same time, the largest solar power plants in Ukraine are concentrated in the following areas: Dnipropetrovsk with a capacity of 290 MW; Odesa with a total capacity of 240 MW; Vinnytsia with a total capacity of 228 MW; Kherson with a total capacity of about 100 MW.

Also, compared to 2015-2017, the wind power segment, which was the second, after solar power, grew quite actively from 2018 to 2021. In particular, in the green power sector, it reached 1672,9 MW in 2021 at a total installed capacity of 409,5 MW. in 2021 (fig. 4).

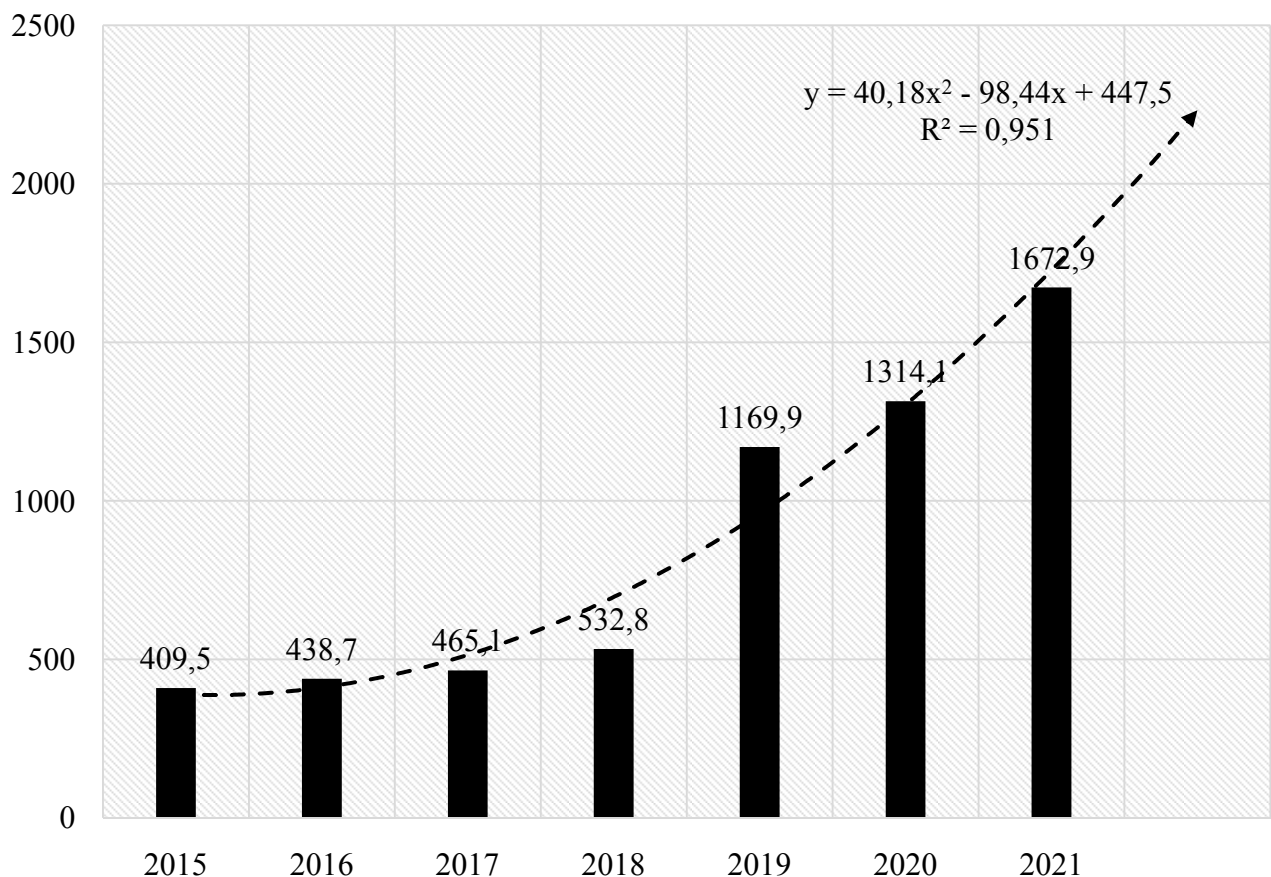
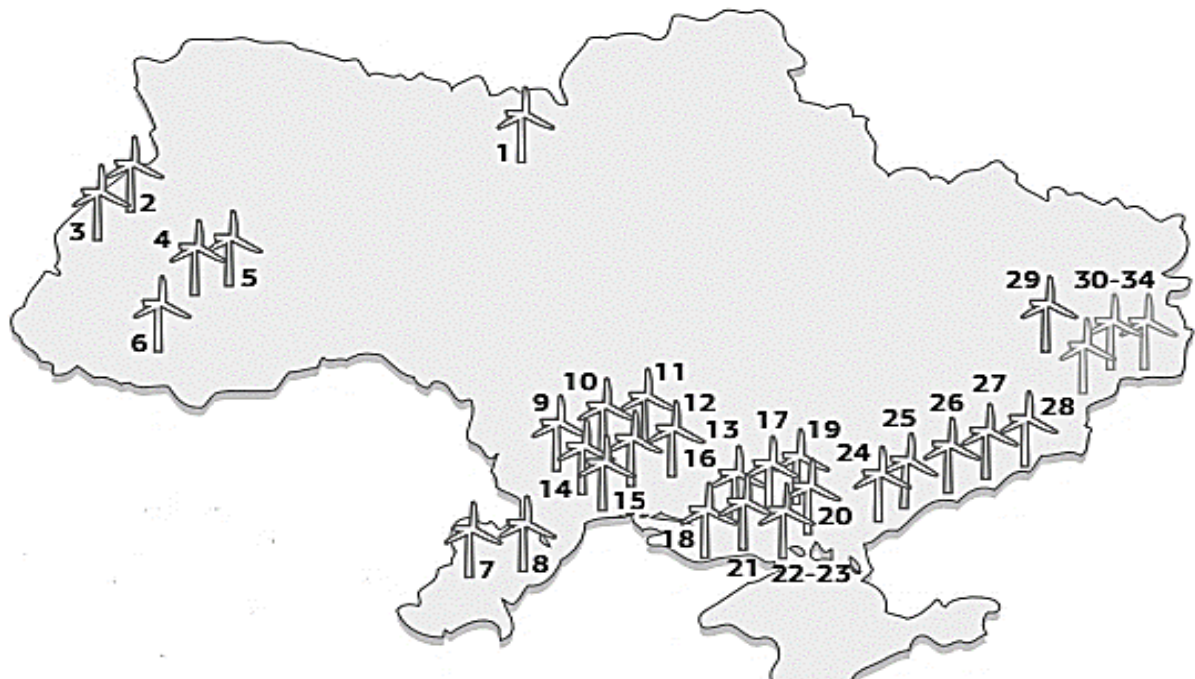


Fig. 4. Total dynamics of the installed capacity of wind power plants in 2015-2021, MW

Source: [4]

It is worth noting that this sector has added the largest number of new facilities to the Green Energy sector in 2021. The share of wind power plants that were put into operation in 2021 was 30,6% or 358,8 MW (this is 2,5 times more than the volume of new wind power plants introduced in 2020). By the beginning of the large-scale war, 34

wind power plants in Ukraine were already operating on the territory of which 699 wind turbines with an average single capacity of 3,5 MW were built. (fig. 5).



Wind farm: (1) Bonus, Kyiv region.; (2) Staryi Sambir 1, Lvov region; (3) Staryi Sambir 2, Lvov region; (4). Zborivska, Ternopol region; (5) bioenergoproduct, Ternopol region; (6) Shevchenko-1 (first turn), Ivano-Frankivsk region; (7) OOT Vind, Odesa Oblast; (8). Dniester, Odesa region; (9). Yuzhnoye Energia, Odesa region; (10) Ochakivsky Vytnyi Park, Mykolaiv region; (11) Blagatny Vytnyi Park, Mykolaiv region; (12) Vytnyi Park, Prychornomorsky Park, Mykolaiv region; (13) Vytnyi Park, Mykolaiv region; (14 17) Vytnyi Park, Mykolaiv region; (15) 16; (18) Bets, Kherson region; (19) Beregova, Kherson region; (20) Novotroitskaya, Kherson region; (21) Overyanivska, Kherson region; (22) Mirnenskaya, Kherson region; (23) Sivanskaya, Kherson region; (24) Sivska, Kherson region; (25) Botievska WT, Zaporozhe region; (26) Primorska 1, Zaporozhye region; (27) Primorska 2, Zaporozhe region; (28) Orlovska, Zaporozhe region; (29) Zaporizhzhya, Zaporozhe region; (30) Kramatorsk, Donetsk region; (31) Vitroenergoprom, Donetsk region; (32) Vitriyanyy park Novoazovsky, Donetsk region; (33) Vitriyanyy park Krasnodonskiy, Lugansk region; (34) Vitriy park Lutuginsky, Lugansk region

Fig. 5. Map of the location of the wind stations of Ukraine, as of the end of 2021

Source: [4]

At the same time, it is problematic that about 60% of solar and wind power facilities were in the zone of the most active fighting activities and suffered the greatest losses from Russian invaders. The reason for this is a large area of object placement [2]. Thus, according to various estimates (specified by the location of generating facilities in the area of active combat operations), 30-40% of power stations in the regions affected by the Russian invasion (this is 1120-1500 MW of installed capacity) suffered. In particular, it is known about the destruction of 100% of generating capacities of solar

power stations in the Kharkiv region [2], 80% of the industrial solar power plants that are located in the Mykolaiv energy unit can be quickly compared because up to 80% of the construction is assembled. Thus, these facilities can be the basis for balancing access to the industrial and household facilities located there with the necessary energy resources.

Currently, stored green energy facilities do not operate at full capacity, because, almost daily for the whole daylight day, they receive dispatch commands to limit generation to ensure the reliability of the power system and to switch on to generation. However, the outlined objects can be quickly included in the energy system of cities. This is extremely important because, in the conditions of impacts on the entire critical infrastructure, it becomes extremely important to develop in a harmonious and even way all sectors of green energy in every region of Ukraine.

Apart from solar and wind power, there are significant prospects for strengthening the energy independence of the national economy in the bioenergy sector. It is important against the background of the gas market turbulence and the critically high prices for natural gas. Bioenergy and biogas energy produces renewable heat, electricity, biogas, and biomethane, liquid biofuel. Thus, this sector has considerable potential for further development by burning biomass and biogas. It can close part of the natural gas deficit in the issue of heat and electric energy production at the level of a separate city. In total, in 2021, 21 MW (or 1,79%) of bio power plant were put into operation (this is 50% more than in 2020, and 43,1 MW (or 3,68%) of biogas power plant (which is twice the growth of 2020 bio-energy capacities).

Summary research summary and prospects for further tasks in this area.

According to the results of the study, it is stated that it is important for Ukraine to abandon the development of centralized energy hubs, in favor of "energy cities". This is necessary to ensure that Russia's energy resources and Ukraine's national critical infrastructure are no longer an instrument of political or military influence on Ukraine's national economy. The following conclusions were made:

1. Ukraine has been in constant strikes across its entire critical infrastructure (primarily industrial power, in particular, power plants, power systems, and its networks

or parts, the disruption or destruction of which will have the most serious consequences for the national economy). The new situation complicates production conditions and minimizes its effectiveness in terms of added value. Therefore, measures aimed not only at its renewal but also at increasing the availability of energy resources at local and regional levels are important.

2. To restore energy independence to improve the availability of energy resources at regional and local levels, each city of our country should become an energy-independent or "energy city", which is possible through the active development of cities with significant concentrations of wind generation, solar generation, bio-, and biogas generation.

3. The development of green energy in Ukraine, which consists of: industrial solar power plant; domestic solar power plant; wind power plant; bio power plant; biogas power plant should play a significant role in restoring Ukraine's energy independence. Such energy objects are quickly built, with different formats and speeds of conversion.

The perspectives of further research consist in the use of the results obtained for the adjustment of the Energy Strategy of Ukraine for the period up to 2035 "Safety, energy efficiency, competitiveness" taking into account the need for transformation of critical infrastructure of Ukraine.

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