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FINANCIAL ASPECTS OF THE RENEWABLE ENERGY IMPLEMENTATION IN UKRAINE AND INTERNATIONAL PRACTICE

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Relevance. *An analysis of the development of the world's energy sector was carried out, focusing on the rapid development of renewable energy. It is shown that the main source of financing for renewable energy in the world is borrowed funds and in much less extent private capital, which is invested in generation facilities with a capacity of up to 1 MW. In the process of quantitative analysis and comparison, the fact of significant development of renewable energy in Ukraine is reflected, which in terms of capacity deployment rates is not inferior to the world average. As in the whole world, in Ukraine the main role in the development of renewable energy is played by solar and wind energy. Ukraine is one of the few countries in the world that actively encourages the development of renewable energy through the mechanism of the feed-in tariff, with its gradual reduction as renewable energy develops. Special attention is drawn to the development of solar energy among households in Ukraine, which only in the last few years has exceeded the indicators of the installed nominal capacity of similar indicators of bioenergy and small hydropower of legal entities.*

Goal. Conduct a comparative analysis of the attracting investment funds in the development of renewable energy in Ukraine and the world. Determine the main factors that have the direct impact on the increase of installed capacities of renewable energy in Ukraine.

Methodology of problem analysis. The methodology which is used in this scientific work is the comparison of the levelized cost of energy production of solar and wind energy (levelised cost of energy - LCOE) and the real value of the feed-in tariff discounted by the inflation rate during the analyzed period of development of renewable energy in Ukraine.

A scientific innovation. A study of the impact of the feed-in tariff for solar power plants installed by households in Ukraine and the world average indicator of the levelised cost of energy production by solar power plants on the indicator of the total installed capacity of solar power plants among Ukrainian households was conducted.

Research results. The main factor that determines the rapid development of the solar energy among Ukrainian households was determined by the decrease in the present value of energy production, i.e. a decrease in the cost of generating plants. At the same time, the "feed-in tariff" established by the state is only an alternative to investing in

domestic state loan bonds and bank deposits. The "feed-in tariff" has no direct effect on the increase of installed capacities of renewable energy in Ukraine.

Practical significance. *According to the results of the research, it can be said that the optimal way to stimulate the development of renewable energy, in particular solar energy, on the part of the state can be the abolition of the duty on the import of production capacities of renewable energy and the reduction of the tax burden on enterprises engaged in the production and repair of specialized equipment of renewable energy facilities. These actions will make it possible to bring the level of prices for the installation of domestic solar power plants and other renewable energy capacities to the world average, which will accelerate the development of alternative energy in Ukraine. In addition, it is possible to adopt the global experience of lending to individuals and legal entities who have expressed a desire to install alternative energy production facilities.*

Key words: *Electricity supply, renewable energy, solar energy, households, feed-in tariff, financing of renewable energy, reduced cost of energy production, LCOE*

Introduction.

The evolutionary development of the Global economy is periodically going through complex, sometimes unpredictable challenges, and transformations. New advanced technologies in various sectors of the economy, which twenty or thirty years ago were available only to business corporations or large government programs, during this period have been seriously changed and adapted to the needs of the consumer. For example, only 15 years ago, electric cars were a major innovation in the automotive market, produced by single companies as more experimental models than production cars. Today, electric cars are increasingly being seen on the roads of ordinary cities around the world. At the same time, many manufactures in the United States, Europe, and Asia stop producing diesel engines and predict a gradual transition to electric motors.

In the case of a gradual transition to electric motors, a greater role plays the desire to reduce carbon emissions and avoid the effects of global warming. The most urgent factor requires a more rapid response to the economy. The global pandemic, caused by COVID-19, in just a few months transformed the usual lifestyle and economic mainstream. Because of the computer technology innovations and access to high-speed Internet, it has become possible to conduct distance learning and working.

All these phenomena and events has been reflected in the global energy market. The introduction of decarbonization policies in Europe and the United States has resulted in a gradual decline in coal use, which was offset by increased use of more environmentally friendly natural gas. The global pandemic has also affected the reduction of oil production and oil product consumption in 2020 and 2021. The experience of using nuclear energy is now reflected in its moderate use in recent decades and the absence of any trend towards increasing the capacity of nuclear power plants.

The desire to obtain some environmentally friendly, safe source of energy has motivated a lot of research centers and private companies for many decades to develop and implement new renewable energy technologies, the focus of which was a solar and a wind energy. Only for the last 11 years, namely from 2009 to 2020, the total increase in ca-

pacity of renewable energy facilities has resulted in 453% [13; 14; 15; 16]. Production and consumption of the solar or wind types of energy have an exponential growth trend.

In the context of making the production of new technologies cheaper and widely used, the main driver of the decarbonized global economy will be the performance of renewable energy, which, in the future, has good chance to completely transform the global energy market. The advantage of using renewable energy over fossil energy sources is a degree of its diversification. Renewable energy does not require significant investment at the level of the individual entity, and therefore does not involve the existence of only large energy companies. For example, today millions of people around the world can afford to have some small solar power plants at home, which allow them to fully meet their own energy needs: space heating, use of electrical appliances, and electricity generation to power their electric vehicles. Therefore, the question of the structure of financing renewable energy is urgent and strongly important.

In terms of the pace of development of renewable energy, Ukraine does not inferior to the Global indicators. And given that existing energy facilities, such as nuclear and thermal power plants, are almost completely depreciated, it is very likely that renewable energy will be tasked as the main force of upgrading the Ukrainian energy sector.

Literature review.

Numerous scientists have been actively involved in the renewable energy problem solving and expanding its economic potential since the 20th century. For example, in 1997, the Asia-Pacific Economic Society had high hopes for renewable energy as the key instrument for meeting the energy needs of people with limited access to power lines or frequent power outages, particularly in rural areas. At that time, there was believed that the main conditions, under which the renewable technologies could be able to provide electricity to rural areas, were the liberalization of energy markets and the mobilization of private capital [8].

In 2000, Norbert Wolgemuth and Giotti Painley [17] argued that renewable energy technologies are not deploying fast enough. At that time, there was a mismatch between their capacity to achieve sustainable development goals and the financial resources involved. Renewable energy sources during that time were more expensive than traditional fuel types. Low prices of fossil fuels only exacerbated the problem of switching to renewable energy. The researchers believed that the abolition of subsidies provided to the traditional energy sectors of the economy and the introduction of a policy of internationalization of social costs of carbon emissions should help solve this problem. According to the research, the transition to renewable energy sources should be the creation of the proper organizational, institutional, and financial conditions, under which the commercial market for these technologies can develop, especially, in the countries with poorly developed market economies [17].

In 2005, the German development bank Entwicklungsbank published the review of the process of the Global financing renewable energy [11; 12]. The researchers argued that renewable energy financing projects differ from other investment projects by significant capital investment at the beginning of

the project with subsequent low operating costs. Because renewable energy financing is capital-intensive, it automatically becomes the most sensitive to the structure and conditions of capital expenditure financing. At that time, the German researchers believed that the process of electrifying rural areas was not commercially viable and therefore depended entirely on the government subsidies [10].

The Global renewable energy sector has been transformed significantly and evolved over the last 20 years. Many hypotheses, proposed in the early 2000s, have been confirmed. Recent research by British scientists [11] has shown that the Global financing of renewable energy, including the countries with emerging market economies, is happening at a significant pace, primarily due to the global effects of climate change. Renewable energy goals have been achieved in at least 164 countries. The emerging market countries have strengthened investor confidence by creating an effective system of renewable energy development goals, which provides adequate analysis and reliable forecast of financial instruments for the future development of renewable energy. Therefore, the further development of renewable energy should be based on the introduction of special policies and certain rules of the legal framework by the state government [11].

The first phase of any energy project, including renewable energy, is usually financed directly by the owners and end-users. However, these funds are almost insufficient to complete the entire project, which threatens the optimal use of equity. In this regard, the practice of involving secondary sources of financing from commercial or state-owned banks and various capital markets is widely used. In addition, several companies with limited equity access to credit through financial intermediaries create several problems: banks have to deal with credit constraints, and the equity and debt markets remain underdeveloped [12].

The policy of decarbonizing the economy through the development of renewable energy tends to be actively supported by global corporations. For example, Apple, Microsoft, and Facebook have signed contracts for purchasing electricity from renewable energy sources [13].

Renewable energy investments come from a wide range of private and public entities, which usually have different roles and approaches in renewable energy financing. For example, the private sector, which provides the largest world share of renewable energy financing, is more focused on regions and technologies with a favorable investment environment. Public funding, by contrast, focuses on areas that still require more work for reducing the cost of capital [5,14].

Numerous Ukrainian researchers have worked on the renewable energy problems worldwide. Thus, the Ukrainian non-profit organization - Center for Environmental Initiatives "Ekodia" recently published a report on new mechanisms for renewable energy development. It considers reducing the payback period of commercial SES, the impact of green tariffs on renewable energy development, renewable energy auctions and contracts of direct sales of energy [6].

Herneho Yu. and Lyakhov O. argue that to strengthen the role of alternative energy in Ukraine, the state needs to focus on the growing demand for "environmental" energy generation tech-

nologies and the need for significant funding. It is also necessary to increase the share of debt financing for development and ensure the equity of financing [7].

From the scientific works reviewed above, it can be with confidence said that the development of renewable energy in the world remains relevant for the last 25 years. During this time, the technologies of renewable energy generation have devolved quite strong and now are able to meet the energy needs of those households and enterprises that have difficulties with the access to the traditional energy sources.

The borrowed funds, rather than own equity, are becoming the main investment resource in renewable energy. Although, the tendency to the investment into renewable energy by the largest international corporations is observed. That can be proved by their own example of the importance of switching to renewable energy sources.

Results.

The potential and development of the renewable energy cannot be considered separately from the current state of traditional energy. The tendency of the developed countries to fully provide their energy needs in the long term prospective with the clean and renewable energy sources is the main incentive to reduce the use of such energy resources as coal or nuclear energy.

A comparable analysis of renewable energy and other primary energy sources, which is shown in Fig.1 and Fig.2. The Fig.1 represents the dynamics of global consumption of the main energy resources from 2009 to 2020. The largest source of energy is traditionally fossil minerals, such as oil, natural gas, and coal, the total consumption equivalent of which in 2020 has been estimated to be more than 11 billion tons of oil equivalent.

Oil is used for both transport and chemical sectors of the economy, like natural gas is used in the chemical sectors, but just like coal, natural gas is mainly used for thermal energy (heating and generation of electricity).

In the analyzed time horizon, there is a gradual decrease in coal consumption since 2013 and an increase in the consumption of natural gas. This tendency can be explained by the implementation of decarbonization policies in many

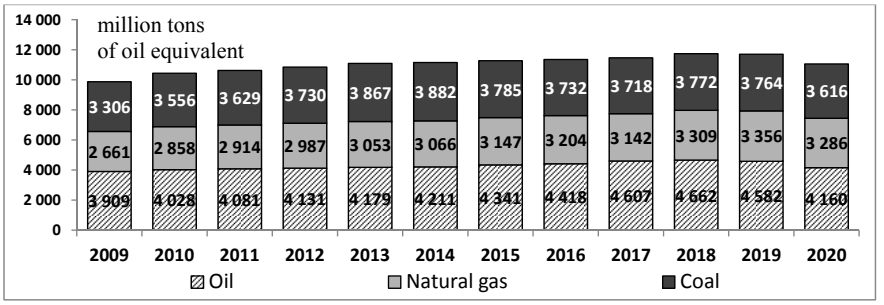

Fig. 1. Dynamics of the Global primary energy consumption of three main types of energy sources

Source: [20]

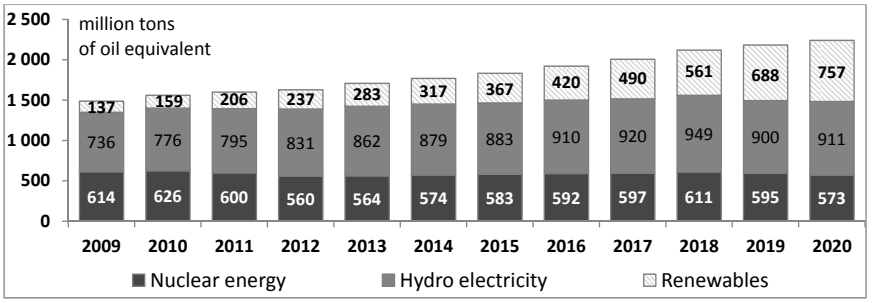

Fig.2. Dynamics of the Global primary energy consumption of other energy sources

Source: [20]

countries with emerging market economies. Other fossil fuels include a decline in oil consumption in 2020, caused by a global pandemic.

In addition to fossil fuels, the Global uses hydropower, nuclear energy, and renewable energy to generate electricity, which in 2020 together generated 2.2 billion tons of oil equivalents of energy (Fig. 2.). In the presented time horizon, the average consumption of nuclear electricity is 590 million tons of oil equivalent, with a slight variation in consumption. This is primarily because nuclear power plants have a fairly long period of construction and final commissioning (for the US about 10 years, for the EU 5-7 years), and the service life of 50 years and the extra 20 years in the case of modernization of reactors.

However, the policies of many countries are aimed to minimize the use of nuclear energy due to significant risks. Therefore, the pace of construction of new plants is significantly lower than in the 20th century, and today's nuclear power production is provided by existing facilities.

Hydropower energy consumption has a steady upward trend, so at the beginning of the second decade of the 21st century, the average consumption of this type of energy was 770 million tons of oil equivalent, while at the beginning of 2021 this figure was 920 million tons oil equivalent.

The most attention attracts the renewable energy sector. Thus, in 2009 it produced only 137 million tons of oil equivalent, which was the lowest value among all possible energy sources. However, over the last decade, it has shown almost an exponential growth rate of 15.4% per year. In 2020, the consumption of electricity from renewable energy amounted to 757 million tons of oil equivalent, which exceeded both the average and actual figures for nuclear energy. Now it is rapidly approaching hydropower.

The reason for the renewable energy consumption growth is the rapid development of this industry, which has been provided by the significant investment. Fig. 3 shows the dynamics of the Global investment in renewable energy by main types. The largest investments are made through borrowed funds, which the investor receives from commercial and state-owned banks as collateral for the entire investment object. In general, this type of investment at the beginning of the 21st century had significant risks, including the risk of the newest technol-

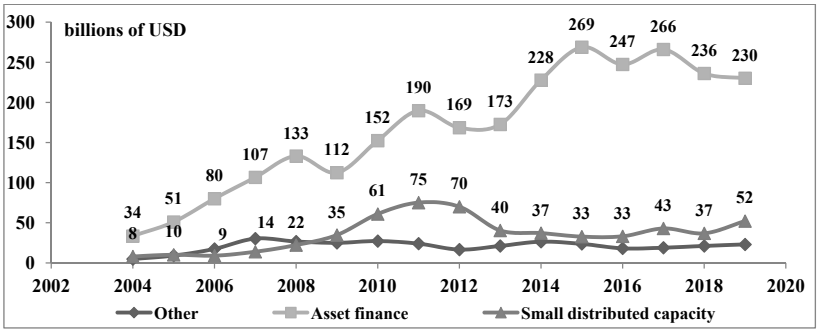

Fig. 3. The global dynamics of different types of investments in the renewable energy

Source: [15]

ogies, the effectiveness of which has not been proven over time, given the significant risk of losing the credit rating or even default. Thus, the companies that financed these facilities could not only make a profit, but also could jeopardize the current operating activities. However, from 2004 to 2008, the volume of this type of investment increased from 34 to 133 billion dollars. The global economic crisis of 2008 slightly reduced the investment rate, which can be seen in the 2009, but since 2010 there has been a steady growth of this type of investment and in 2019 it amounted to 230 billion dollars.

Investment in generation facilities is up to 1 MW. This type of investment is typical for both individuals and entities that invest their own funds in relatively small renewable energy generation facilities. In contrast to the investment of borrowed funds, the investment of own funds had not had such a significant increase over the past decade. With an investment level of 8 billion dollars in 2004, at the

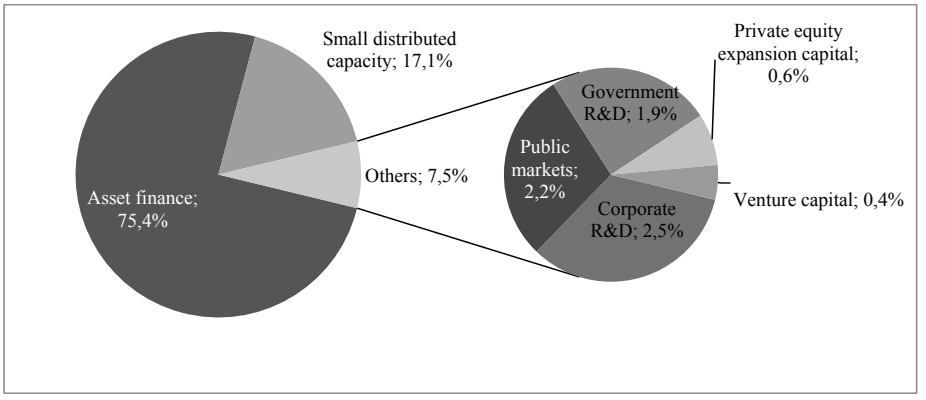

Fig. 4. The global structure of different types of investments in the renewable energy in 2019

Source: [15]

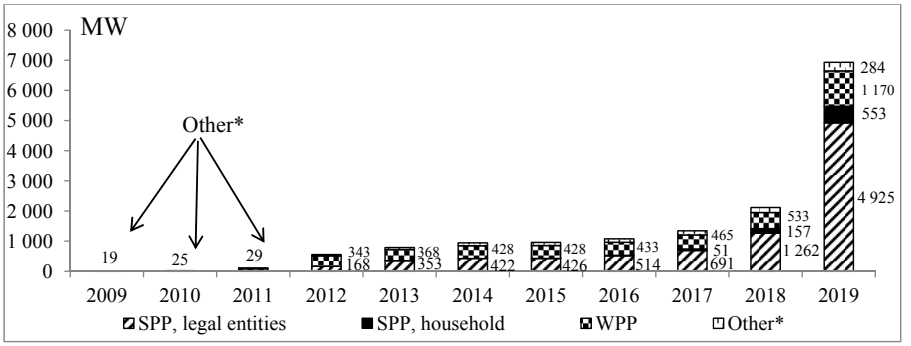

Fig. 5. Dynamics of installed capacity in the renewable energy sector of Ukraine

Source: [1,18]

* The category of "other" includes bioenergy and small hydropower

beginning of 2020, they amounted to only 52 billion dollars, the peak of their growth was 2011, when the investment rate reached 75 billion dollars.

Let's consider the structure of types of global investment in renewable energy in 2019. Fig. 3 shows that 75% of the investments are placed in obtaining loans from commercial and non-commercial banks. Equity investments in facilities up to 1 MW are around 17%.

All other investment sources together make up only 7.6%. At the same time, it should highlight such type of investments as: private sector investments in research and development (2.5% of global), public research and development (1.9% of global). Despite the small share of these types of investment, they are the main reason, that allows technologies to increase their own efficiency and reduce costs of production each year. Also, some investors are interested in buying shares of existing companies that show profitable activities, but the share of such investments does not exceed 2.8% of global.

Taking into consideration the growing consumption of the renewable energy and the volume of attracted investments, whose annual volumes have increased by 6 times (from 50 billion dollars in 2004 to 300 billion dollars in 2019), the renewable energy is the most promising sector of the Global energy market.

No less impressive indicators of the development of renewable energy are observed in Ukraine (Fig. 5). In contrast to the economically developed countries, where the development of green energy began at the early 21st century, in Ukraine until 2012 the total capacity of renewable energy did not exceed 29 MW, and it consisted mainly of bioenergy.

However, since 2012, Ukraine has begun to stimulate the development of renewable energy through government programs, namely the introduction of a feed-in tariff. The main objects of investment from 2012 to 2015 were the wind power plants, but since 2016, the solar energy has been in the lead. It might be interesting that in just two years from 2017 to 2019, the total capacity of solar power plants in Ukraine increased almost by 10 times, from 742 MW to 5478

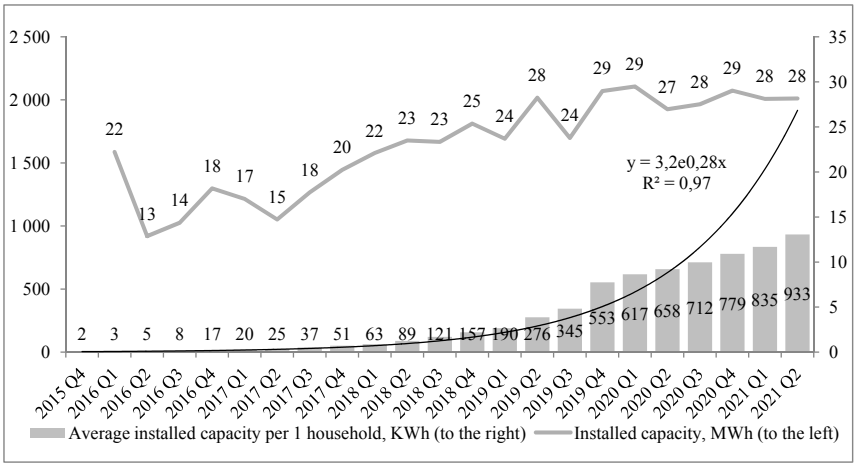

Fig. 6. Dynamics of solar energy development among Ukrainian households
Source: [1]

MW, while in 2019 the capacity of wind energy was only 1170 MW.

This development of solar energy in Ukraine can be explained primarily by the higher level of feed-in tariffs compared to wind energy, as well as the simplicity of installing the solar panels with additional equipment and connecting them to the central power grid. To accept this hypothesis, we can observe the dynamics of the installed capacity of solar energy by households, which from 2017 to 2019 increased by 10 times from 51 MW to 553 MW.

For a better analysis of the dynamics of solar energy development among households, the quarterly data from 2015 to 2021 (Fig. 6) have to be considered. In six and a half years, the installed capacity of domestic SES has increased from 2 to 933 MW and is approximated by an exponential growth trend with a coefficient of determination of 97%. According to this trend, the quarterly increase in installed capacity is 28%, which is significantly higher than the Global average.

In addition to the indicator of installed capacity, it also should be noted the growth of the average value of the installed capacity per 1 household. The first households, that installed solar power stations during the first quarter of 2016 preferred significant capacity (22 kW), but when new players began to join the market, the average capacity fell to 13 kW, indicating the reluctance of individuals at the time to take significant risks. With each subsequent quarter, households gradually increased their risk of appetite and installed more powerful SES, and by the beginning of the 3rd quarter of 2019 the average power of domestic SES was 28 kW, which was only 2 kW less than the maximum allowable value under the law on feed-in tariffs in Ukraine. During 2019 and 2021, the average power of new SES installed ranged from 27 to 29 kW with a median value of 28 kW.

Let's dwell on the analysis of the feed-in tariff in Ukraine. Table 1 represents the indicator of the green tariff for domestic SES, private SES, and the

1. Dynamics of the feed-in tariff indicator for households and entities in Ukraine

Period	The average euro exchange rate for the period	House-holds UAH kops. / kWh (nominal values)	House-holds, euro cents / kWh	SES: compa-nies with a capacity of up to 1 MW, euro cents / kWh	SES: compa-nies with a capacity of more than 1 MW, euro cents / kWh	wind power plant
2013-2014	13	1131	86,3	15,7	14,4	9,4
the first half of the year 2015	24	1018	42,7	15,7	14,4	9,4
the second half 2015	25	632	25,7	15,7	14,4	9,4
2016	28	600	21,2	14,8	13,6	9,4
2017-2019	30	571	18,8	13,9	12,8	9,4
January-October 2020	30	513	17,0	11,0	11,0	8,8
November December 2020	34	513	15,1	11,0	11,0	8,8
2021	32	513	15,9	10,6	4,4	8,8
2022	32	513	15,9	10,2	4,2	8,8

Source: [4, 9]

*SES stands for solar electric stations

wind farms. These indicators were chosen on the grounds that these types of renewable energy account for the lion's share of all renewable energy in Ukraine during recent years.

Since 2013, the feed-in tariff has been revised several times, so for domestic SES the number of re-views was 5 times, and the value of the indicator decreased from 11.31 UAH in 2013 to 5.13 UAH nowadays. For private companies, the government divided the feed-in tariff for SES into several main types: for SES with a capacity of up to 1 MW and SES with a capacity of more than 1 MW, with SES with a capacity of up to 1 MW in most analyzed periods more feed-in tariff. As for domestic SES, the feed-in tariff for private SES was revised quite often: 4 times during the analyzed period.

The feed-in tariff for the wind energy had the lowest number of re-views, only once. In terms of the value, the feed-in tariff for domestic SES with the highest value is the largest for all analyzed periods and slightly lower for private SES with a capacity of up to 1 MW, which indicates that the state encourages small producers. Such a policy can be explained by the state's efforts to diversify production capacity in the renewable energy market and prevent its monopolization by large companies and corporations.

Another important aspect that needs to be emphasized is the gradual reduction of the feed-in tariff in proportion to

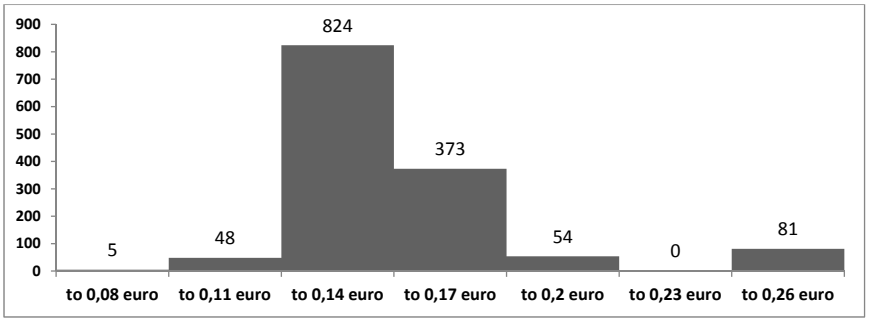

Fig. 7. Histogram of the distribution of solar power plants in Ukraine in relation to the feed-in tariff

Source: [3]

the growth of installed capacity in the country. Thus, with the rapid growth of installed capacity of SES among households, the feed-in tariff for this group of producers had been revised the biggest number of times, and in equivalent of the UAH it decreased by 2 times, while in real terms, expressed in eurocents, it decreased from 86 to 16 eurocents or 5.4 times.

The same situation is observed for large producers, for which the feed-in tariff has decreased in real terms by more than 3 times. Also, the hypothesis of reducing the feed-in tariff in proportion to the growth of installed capacity is confirmed by the feed-in tariff, which has been revised only once for the wind energy, which has a significantly lower rate of development compared to solar energy.

The revision of the feed-in tariff does not apply to those entities that have entered a contract for the supply of renewable energy before the revision of the tariff. From fig. 6 as of the beginning of 2022 in Ukraine there are 1385 SES, owned by entities. Moreover, more than 500 SES supply electricity at a feed-in tariff of more than 14 eurocents, which indicates the beginning of the SES data until 2013, when the state only introduced incentives for the development of renewable energy with a significant feed-in tariff. Currently, most of all private SES (63%) operate on a feed-in tariff, which does not exceed 14 cents. It should also be emphasized that each entity receives its unique size of the feed-in tariff within the maximum allowed, which indicates the presence of factors that affect the determination of this tariff for each individual entity.

Feed-in tariff, as a tool to stimulate the development of renewable energy, is not very popular for well-developed countries. Thus, the United States and the United Kingdom have set a feed-in tariff for solar energy as close as possible to zero. Many European countries have abolished the feed-in tariff altogether. The countries with the highest values of the established feed-in tariff for solar energy at this moment are Estonia, the Netherlands, Switzerland, and Turkey (Fig. 8). It should be emphasized that at the beginning of 2020 the value of the feed-in tariff for solar power plants in these countries was very similar to feed-in tariff in Ukraine.

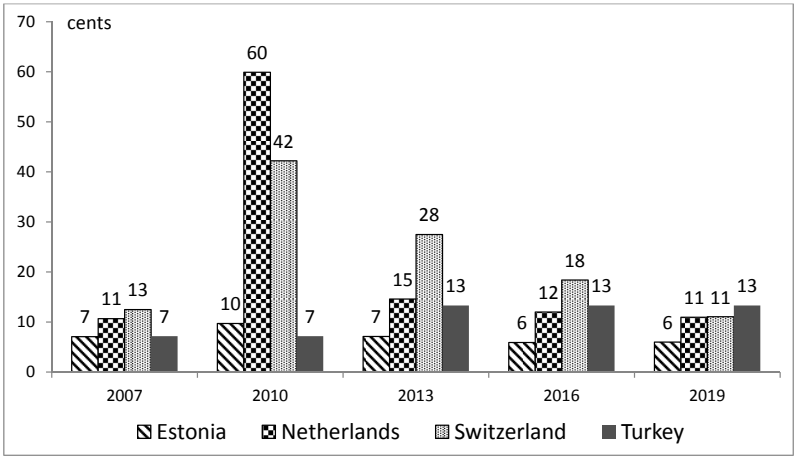

Fig. 8. Dynamics of the feed-in tariff for solar power plants for Estonia, Netherland, Switzerland and Turkey (USD cents)

Source: [19]

Thus, we can say that Ukraine is one of the countries that actively stimulate the development of renewable energy.

Most European countries that stimulated the development of renewable energy through the feed-in tariff had the highest values of the feed-in tariff in early 2010-2013. The active development of renewable energy in the countries with the developed economy can be explained by the efforts of the private sector to obtain energy sources that are independent of external and internal energy markets and can further guarantee energy independence, which will have a direct positive effect on economic efficiency and profitability.

Returning to discussion of the rapid development of renewable energy in Ukraine, in particular households, the question arises about the factors which have the biggest impact on this growth. Of course, one of the main factors in this development is the feed-in tariff, which the government guarantees to pay during entire term of the final agreement with it, and non-fulfillment of its obligations can only be related to the default of the economy.

In today's realities of the Ukrainian economy, there are not so many tools that allow you to make a profit at the lowest level of risk. For example, the purchase of securities imitated by Ukrainian entities can be highly profitable, but the credit risk is enormous, and the purchase of securities by non-residents of Ukraine is often limited by the NBU. When investing in deposits of private banks in Ukraine for a time horizon of more than 1 year, you can get a return of more than 10% per annum, but the investor again assumes the credit risk of the bank in which he invests, and he will have to pay income taxes. Also, in the Ukrainian economy there is an opportunity to invest in foreign or domestic government bonds, the yield on which is usually greater than the yield on commercial banks, and there is no need to pay income tax, while the investor assumes only credit risk of the whole state commercial institution.

Of the considered investment in-

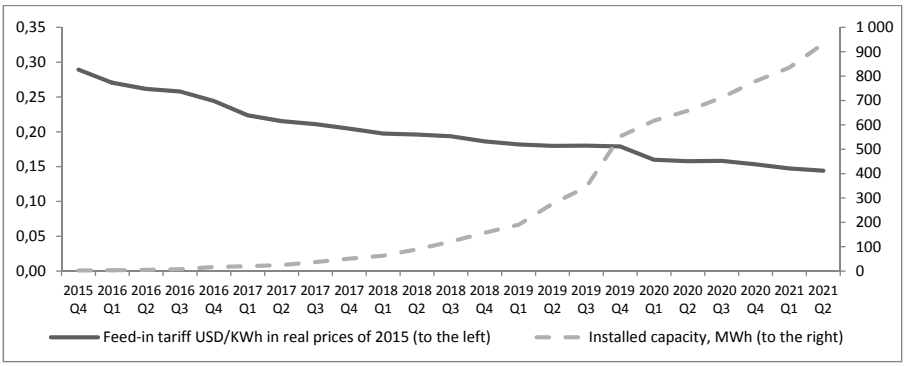

Fig. 9. Dynamics of increasing the installed capacity of domestic SES and reducing the real size of the feed-in tariff in Ukraine

Source: [1; 2; 4; authors' estimations]

struments, only the feed-in tariff allows to obtain a return on borrowed funds. Unlike deposits or government bonds, where the yield depends on the amount of capital invested, in the case of a feed-in tariff, the investor can get a loan from a commercial or state bank under favorable terms, in the case of appropriate coverage, and invest obtained loan in renewable energy with the subsequent connection to feed-in tariff.

However, the existence of a green tariff for renewable energy in Ukraine does not fully explain its rapid development. This can be best demonstrated by simultaneously considering the dynamics of increasing the installed capacity of SES households and the dynamics of reducing the feed-in tariff in real prices in 2015 (Fig. 9). The figure shows that since 2015, the installed capacity has had a steady upward trend towards growth, while the real feed-in tariff has tended to decrease across the horizon, due to both its revision by the Ukrainian government and inflation in the Ukrainian economy.

Hence, it can be hypothesized that the feed-in tariff exists only as a nominal alternative to investing in other sectors of the economy, but there is no marginal impact on economic growth, because the hypothesis that reducing the amount of profit (feed-in tariff) positively affects the level of investment contradicts the laws of economics and common sense.

The answer to what is the second main factor in the rapid development of renewable energy in Ukraine is the reduction of the Levelised cost of energy (LCOE). In other words, the cost and, accordingly, the market price of renewable energy equipment is rapidly declining year by year.

From Fig. 10, since 2010 to 2018 the reduced cost of energy generation for solar power plants decreased by 77%, while the same number for offshore wind energy decreased by only 35%. Given that the Ukrainian economy is dependent on imports for new technologies, these facts perfectly describe all aspects of renewable energy development in Ukraine, namely the predominant development of solar energy over wind and other types of renewable energy generation. It is interesting to note

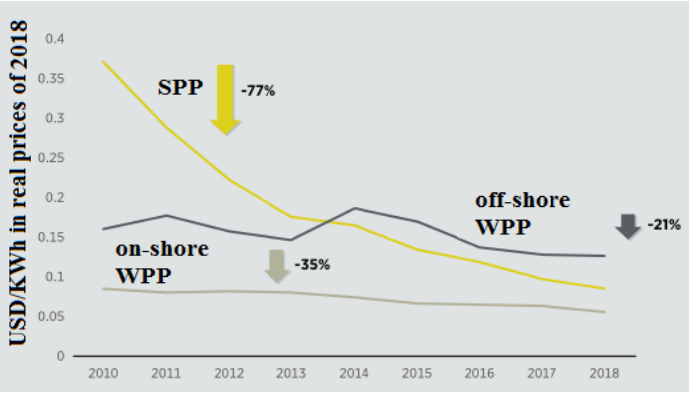

Fig. 10. Dynamics of the global average value of the reduced cost of electricity production for solar and wind power plants

Source: [16]

that in Ukraine the total capacity of all wind farms from 2012 to 2018 increased from 343 MW to 533 MW or 55%, which was as close as possible to the percentage of LCOE for ground-based wind farms (-35%).

In order to confirm the hypothesis of direct impact of reducing the cost of renewable energy equipment on its development indicators, let's consider the regression dependence of the installed capacity of SES among households in Ukraine on the average value of the reduced cost of electricity for SES in the Global (Table 2). The coefficient of determination of this model is 57%, which indicates the presence of other factors in the Ukrainian economy, which additionally explain the 43% variance of the dependent variable and are not included in this model.

The coefficient of marginal impact of LCOE reduction on the development of domestic SES capacities in Ukraine is 12,861 MW, thus, in average, when the cost of electricity generation for SES is reduced by 1 USD for 1 kWh the total capacity of the installed solar power

2. Regression dependence of the installed capacity of SES among households of Ukraine on the average value of the reduced cost of the Global electricity production for SES

Variables	N	Regression model	R^2	S	T_0	T_1	p_0	p_1
y – installed capacity of SES among households in Ukraine x_1 – reversed indicator of LCOE	23	y = 1233 + 12861x1	0,57	215	6,6	5,3	1,4E-06	3E-05

Source: [authors' estimations]

plants will increase by 12.861 MW. This coefficient of marginal impact is adequate according to the student's t-test and exists at a significance level less than 0.001. If we convert the calculated marginal impact ratio from US dollars to US cents, we obtain a forecast of an increase in the total capacity of domestic SES in Ukraine of 128.6 MW with a decrease in LCOE by 1 cent. For comparison, the total capacity of domestic SES in Ukraine at the beginning of the third quarter of 2021 was 933 MW.

With the beginning of the full-scale military invasion of the Russian Federation in Ukraine, the issue of the development of the energy sector of Ukraine changed to an urgent need to optimize its structure to preserve energy security in the conditions of war. It can be said unequivocally that both the structure of consumption and the structure of energy production changes with each passing day of hostilities. In terms of energy consumption, we can unequivocally talk about a colossal decrease due to the forced migration of a significant part of the population abroad (as of August 2022, more than 7 million people are in forced emigration), the shutdown of state and private enterprises, as well as the direct temporary occupation of part of the territories. Energy supply through own production or through imports will be significantly reduced due to the following factors:

- Destruction of generation facilities during hostilities;
- The occupation of the big generation facilities on the occupied territories (in particular, the Zaporizhzhia nuclear power plant);
- Possible destruction of generation facilities by ballistic or cruise missiles in future periods, etc.;

In addition to the decommissioning or complete destruction of energy generation facilities, there are already major problems with the production and import of fuel. Thus, the production of own coal in Ukraine will be maximally complicated by hostilities, its import will also be maximally complicated by the Russian blockade of the Black Sea.

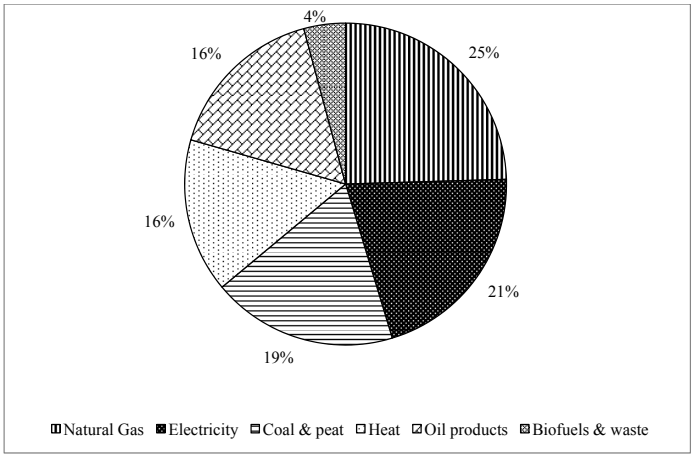

Fig. 11. Structure of final energy consumption in Ukraine for 2021
Source: [21]

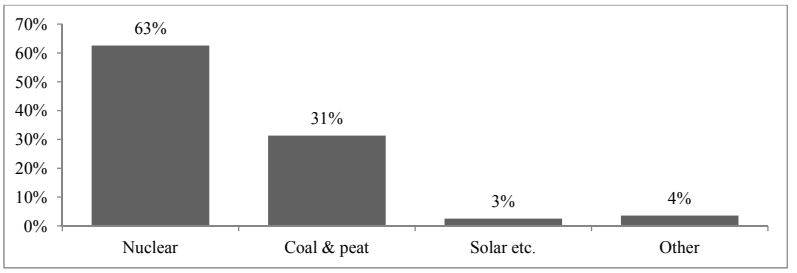

Fig. 12. Structure of electricity production in Ukraine for 2021

Source: [21]

Given Russia's ability to blackmail energy, it is quite likely that the export of natural gas to European countries will be stopped during the winter period, because of which Ukraine will be forced to use only its own production and reserves of natural gas.

To quantify the impact of the war on Ukraine's energy sector, let's first consider the structure of energy consumption in Ukraine as of 2021. As can be seen from fig. 11 the largest shares were natural gas (25%) and electricity (21%). In addition, coal was consumed at a significant level (19%); thermal energy (16%) and oil products (16%).

Electricity production (Fig. 12) in Ukraine consisted by 63% of nuclear power plants and by 31% of coal-fired power plants. Renewable energy sources accounted for 3% of all energy production, and all others energy sources accounted for 4% (hydropower, biofuels, etc.). According to forecasts, nuclear power plants are expected to operate without interruption due to current nuclear fuel stocks and a possible increase in nuclear fuel supplies from the United States. However, with the production of electricity by coal-fired power plants, significant obstacles are possible due to active hostilities directly near the places of coal mining, as well as the blockade of the Black Sea, it remains possible to import it only through European countries by road or rail transport. Taking into account the fact that most European countries will increase their coal consumption in the coming years, there is a high probability of a physical shortage of coal in Ukraine.

In the structure of heat production,

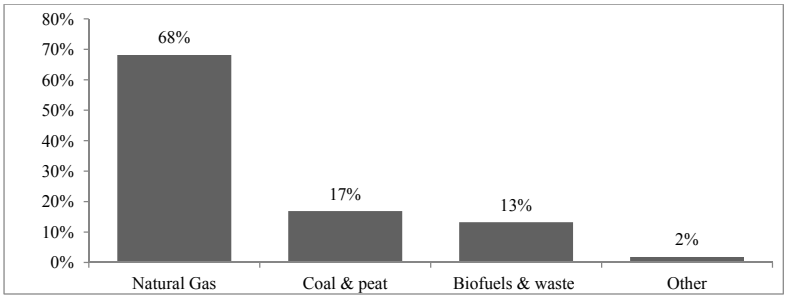

Fig. 13. Structure of heat energy production in Ukraine for 2021

Source: [21]

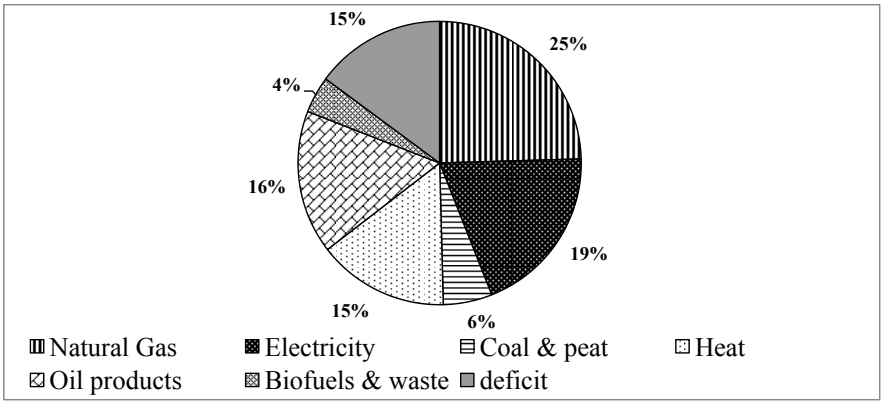

Fig. 14. Modeled structure of final energy consumption in Ukraine in the event of an 80% reduction of coal supply

Source: [21; authors' estimations]

natural gas accounts for the largest share (68%), considering the largest gas storages of natural gas in Europe (more than 30 billion cubic meters), it can be assumed that in the winter period, even in the event of stopping the export by the Russian Federation, Ukraine will be able to meet its energy needs with this type of fuel. Coal accounts for 17%.

In the current conditions, it is not possible to simulate all possible scenarios of changes in the structure of the energy balance of Ukraine. It is rather difficult to assess possible problems with the supply of primary energy to Ukraine, taking into account the stochastic component of the future situation on the global energy market and the course of war. However, at the moment, the most realistic scenario is precisely the problems with the production and import of coal.

Consider a scenario in which the total amount of coal produced and imported into Ukraine will decrease by 80%. In this case, not only the direct consumption of coal by various sectors of the economy will decrease, but also the volume of produced electricity and heat energy will decrease. At constant energy consumption, an 80% reduction in coal supply would cause a deficit in energy

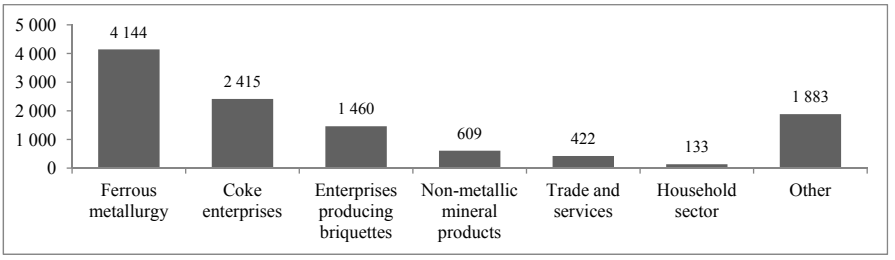

Fig. 15. Structure of coal consumption by economic sectors of Ukraine for 2021.

Source: [21]

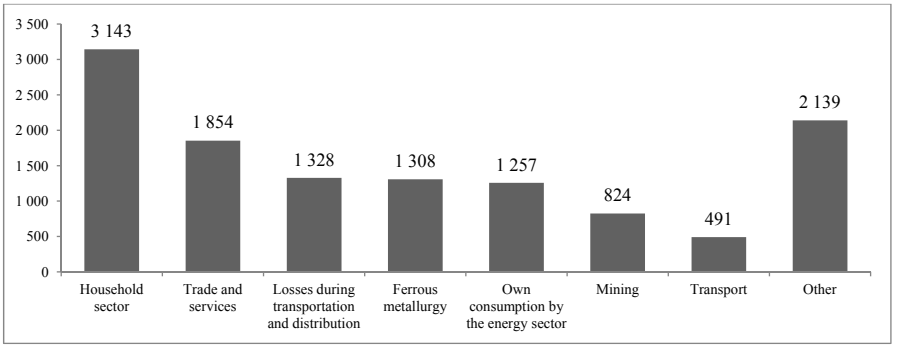

Fig. 16. Structure of electricity consumption by economic sectors of Ukraine for 2021.

Source: [21]

consumption of 15%. At the same time, electricity consumption would decrease from 21% to 19%, and heat energy from 16% to 15%. Direct consumption of coal would decrease from 19% to 6%.

However, a deficit of 15% is formed only in the event when consumption remains at the "pre-war" level. In order to assess the potential level of energy consumption reduction in Ukraine, we will consider the structure of coal consumption by economic sector. From fig. 15. it can be seen that the largest consumers of coal in Ukraine are ferrous metallurgy, coke enterprises and enterprises producing briquettes. Taking into account the temporary occupation of territories where some of the largest metallurgical complexes are located or their maximum proximity to the place of active hostilities, it is possible to hypothesize that these sectors of the economy will reduce coal consumption by at least 50% due to stopping or suspending production.

In the structure of electricity consumption, the largest share fell to the household sector, trade and service provision, ferrous metallurgy, and the mining sector. Of course, the consumption of electricity by the household sector will not decrease, even in the conditions

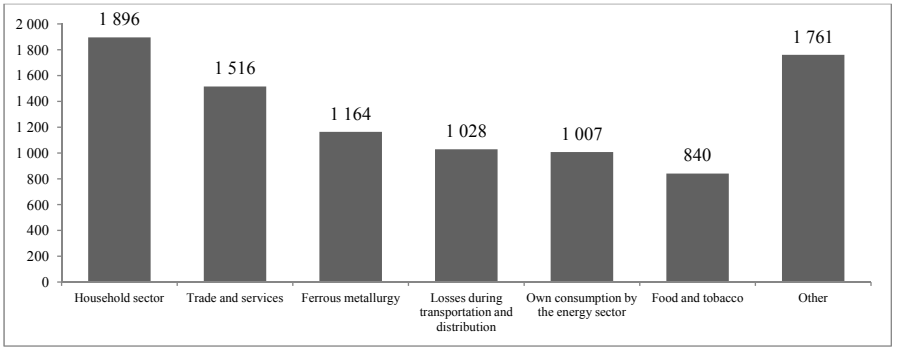

Fig. 17. The structure of heat energy consumption by economic sector of Ukraine for 2021.

Source: [21]

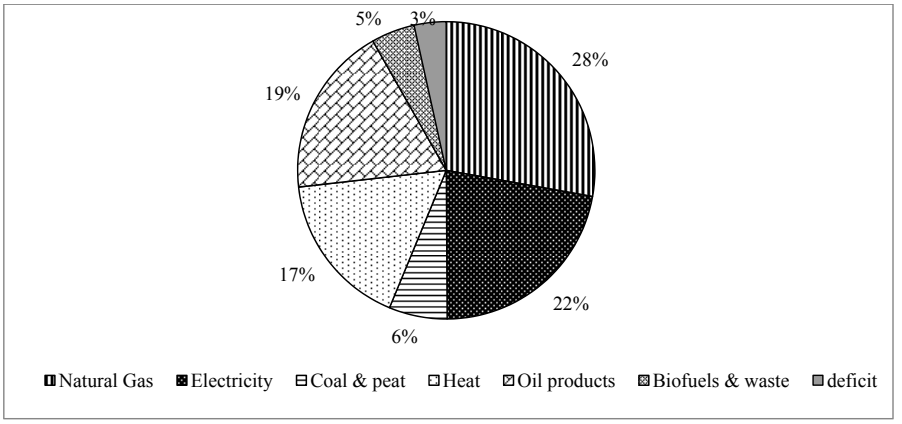

Fig. 18. Modeled structure of final energy consumption in Ukraine in the event of an 80% reduction in coal supply and economic recession as a result of the war.

Source:[21; authors' estimations]

of the forced migration of millions of citizens abroad since possible problems with the supply of heat energy will be compensated by increasing the use of electric heating.

At the same time, in accordance with the above-mentioned factors, it is possible to reduce electricity consumption by the metallurgical sector and the mining sector (at least by 50%).

In the structure of heat energy consumption, a significant place is occupied by the private sector, trade and services and, again, ferrous metallurgy. In order to optimize the use of natural gas, the government of Ukraine predicts a decrease in the minimum permissible temperature in multi-apartment buildings, which will directly reduce the consumption of heat energy by the private sector, also in the current conditions of war and recession of the economy, there will be a decrease in the use of heat energy by the trade and ferrous metallurgy sector. In the listed sectors of the economy, the use of heat energy will be reduced by at least 30%.

Thus, the deficit in energy supply will be "reduced" to 3% as a result of the suspension or complete stoppage of some of the largest sectors of the economy and the forced migration of millions of citizens outside of Ukraine (Fig. 18).

The scenario discussed above shows that the lack of coal can already cause quite crisis phenomena in the economy of Ukraine and its energy security. In real life, a combined scenario (such as problems with the provision of various types of energy resources: natural gas, oil products, etc.) is more possible. Thus, in war conditions, the government needs to increase the production and import of all possible types of energy resources in the country, since they will be able to compensate each other in some extent.

Along with this, it's necessary to emphasize the need to increase the capacity of renewable energy at the level of individual households. Because in addition to the problem of providing heating energy in the winter period, each household has energy needs in the

field of telecommunications, ensuring uninterrupted operation of household electrical appliances. Generating installations of renewable energy with minimal capacities are already able to meet such needs. In addition, it should be taken into account that their value decreases every year, and the probability of problems with electricity supply in modern realities only increases.

Since the beginning of the full-scale war in Ukraine, the number of electric vehicles has increased significantly. The reason for this is the significant rise of prices of petroleum products in Ukraine and problems with their supply. In conditions of uninterrupted operation of nuclear energy, electric transport is an optimal alternative to transport which works on internal combustion engine. But in the event of problems in the supply of electricity, home installed SES can become a reliable source of energy for owners of electric vehicles.

Conclusions.

Over the past 15 years, the Global's renewable energy industry has shown an exponential rate of development, whose production has increased by more than 450%. The bulk of the production of renewable energy is solar and wind energy.

In the global structure of investment in renewable energy in the first place is the borrowed funds secured by generation facilities (75%). The second is the investing of equity in renewable energy facilities with a capacity of up to 1 MW (17%). All other sources of investment are not more than 8% of the share.

Ukrainian economy does not inferior to the Global average in terms of the pace of development of renewable energy. Thus, since 2009, the total number of installed capacities of renewable energy has increased by 368 times, namely increased from 19 MW to almost 7,000 MW. Like the Global trends in Ukraine, the main drivers of the renewable energy development are solar and wind energy.

Since 2015 Ukrainian households have increased the total installed capacity of solar energy from 2 MW to 933 MW. In recent years, the average installed capacity per household was 28 kW, which was almost equal to the maximum allowable installed capacity for households of 30 kW. However, government incentives for the development of renewable energy in Ukraine (as the feed-in tariff) have no marginal impact on the development of renewable energy in the country.

As a result of regression analysis of the impact of reducing LCOE on increasing the total installed capacity of solar power plants among Ukrainian households, the hypothesis was confirmed. Therefore, reducing the cost of renewable energy generation equipment has a direct positive impact on renewable energy development in Ukraine.

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ФІНАНСОВІ АСПЕКТИ ВПРОВАДЖЕННЯ ВІДНОВЛЮВАЛЬНОЇ ЕНЕРГЕТИКИ В УКРАЇНІ ТА СВІТІ
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Анотація. *Актуальність. Проведено аналіз розвитку енергетичного сектору світу, акцентувавши увагу на стрімкому розвитку відновлюваної енергетики. Показано, що основним джерелом фінансування відновлюваної енергетики у світі виступають залучені кредитні кошти та в значно меншій мірі власний капітал, який інвестується в об'єкти генерації потужністю до 1 Мвт. В процесі кількісного аналізу та порівняння відображено факт значного розвитку відновлюваної енергетики в Україні, яка за темпами розгортання потужностей не поступається середньо світовим показникам. Як і у всьому світі, в Україні основна роль у розвитку відновлюваної енергетики покладається на сонячну та вітрову енергетику. Україна, одна з небагатьох країн світу, яка активно стимулює розвиток відновлюваної енергетики через механізм зеленого тарифу, з його поступовим зменшенням по мірі розвитку відновлюваної енергетики. Особливу увагу привертає розвиток сонячної енергетики серед домогосподарств України, яка тільки за останні декілька років перевищила показники встановленої номінальної потужності аналогічних показників біоенергетики та малої гідроенергетики юридичних осіб.*

Мета. Провести порівняльний аналіз стану залучення інвестиційних коштів у розвиток відновлюваної енергетики в Україні та світі. Визначити основні фактори, що мають безпосередній вплив на збільшення встановлених потужностей відновлюваної енергетики в Україні.

Методика аналізу проблеми. Використовується методологія порівняння приведеної вартості виробництва електроенергії сонячної та вітрової енергетики (levelised cost of energy – LCOE) та дисконтованої на показник інфляції величини реального значення зеленого тарифу протягом аналізованого періоду розвитку відновлюваної енергетики в Україні.

Наукова новизна. Проведено дослідження впливу зеленого тарифу для сонячних електростанцій, що встановлені домогосподарствами в Україні та середньо світового показника приведеної вартості виробництва електроенергії сонячними електростанціями на показник загальної встановленої потужності сонячних електростанцій серед домогосподарств України.

Результати дослідження. Основним фактором, який визначає стрімкий розвиток сонячної енергетики серед домогосподарств України було визначено зменшення приведеної вартості виробництва електроенергії, тобто здешевлення собівартості генеруючих установок. В той самий час встановлений державою «зелений тариф» являє собою лише альтернативу інвестування в облігації внутрішньої державної позики, банківських депозитів. Безпосереднього впливу на збільшення встановлених потужностей відновлюваної енергетики в Україні «зелений тариф» немає.

Практична значущість. Відповідно до отриманих результатів дослідження можна говорити, що оптимальним шляхом стимулювання розвитку відновлюваної енергетики, зокрема сонячної, з боку держави може виступати скасування мита на імпорт виробничих потужностей відновлюваної енергетики та зменшення податкового навантаження на підприємства що займаються виробництво та ремонтом спеціалізованого обладнання об'єктів відновлюваної енергетики. Вказані дії дадуть зможу привести

рівень цін на встановлення домашніх сонячних електростанцій та інших потужностей відновлюваної енергетики до середньо світових, що прискорить розвиток альтернативної енергетики в Україні. Крім цього можливий варіант переймання світового досвіду кредитування фізичних та юридичних осіб, які виявили бажання встановити виробничі потужності альтернативної енергетики.

Ключові слова: *Електропостачання, відновлювана енергетика, сонячна енергетика, домогосподарства, зелений тариф, фінансування відновлюваної енергетики, приведена вартість виробництва енергії*