ХОЛОДИЛЬНА ТЕХНІКА ТА ЕНЕРГОТЕХНОЛОГІЇ

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Condition and prospective directions of development of renewable energy in Ukraine

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The problem of rational use of energy resources, increasing the level of energy efficiency and energy security is a necessary condition for the harmonious economic and social development of Ukraine. Renewable energy is a global trend and one of the most promising energy industries in the world. "Green" energy is able to provide the energy needs of all mankind and therefore requires significant attention. Its environmental friendliness and cost-effectiveness speak for themselves, as a result, today all developed countries are taking a cue from the popularization and development of renewable energy, and Ukraine is no exception. Ukraine has significant potential in the field of renewable energy, as evidenced by the main indicators of capacity, production and consumption. It is worth noting the investment attractiveness of this industry. In the paper has been investigated the role of renewable energy sources in the energy balance of Ukraine.The process of carrying out was accompanied by the use of the following general scientific and special research methods, in particular: analysis, synthesis, comparison during the study of the world experience in the development of renewable energy and the determination of promising directions of development. development of renewable energy sources in Ukraine; comparative and retrospective analysis and abstraction to determine the main trends and features of the development of the renewable energy sector of Ukraine, as well as to assess the investment opportunities of entrepreneurship; mathematical modeling to justify the energy and economic efficiency of bioenergy development in Ukraine; economic and statistical - to assess the state of renewable energy in Ukraine; tabular and graphic - for visual display of statistical material and schematic display of theoretical and practical provisions of the study. The segmentation of renewable energy and the analysis of capacities made it possible to determine the main prospects and directions of investment in the industry, based on the example of world experience, and the role of investments for the development of this industry was determined. The paper was carried out an assessment of the development potential of bioenergy in Ukraine based on agricultural crop waste.

Keywords: *Energy balance; Renewable energy; Renewable energy sources; "Green" investments; Bioenergy*

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1. Introduction

The problem of rational use of energy resources, increasing the level of energy efficiency and energy security is a necessary condition for the harmonious economic and social development of Ukraine. Today, the world is experiencing a rapid development of renewable energy, which is due to the strengthening of the negative impact of traditional energy on the environment and the constant increase in global energy

prices. Ukraine needs a new push in the field of energy because it's being dependent on energy imports. Renewable energy can help the state gain energy independence and economic stability.

Active research of these problems occurs both in the mass media and in the scientific works of foreign and domestic scientists, such as: L.P. Klymenko, S.M. Solovyov, G.L. Nord, O.M. Borodina, V.E. Baranovska, S.V. Berzina, O.D. Bohdan, O.I. Vozny, V.V. Lagodienko, M.I. Syrotyuk, A.I. Shevtsov, M.G. Zemlyanyi, T.V. Ryauzova and others.

The following general scientific and special research methods were used in the paper, in particular: analysis, synthesis, comparison during the study of the world experience in the development of renewable energy and the determination of promising directions for the development of renewable energy sources in Ukraine; comparative-retrospective analysis and abstraction to determine the main trends and features of the renewable energy industry of Ukraine, as well as to assess the investment opportunities of entrepreneurship; mathematical modeling to substantiate the energy and economic efficiency of the development of bioenergy in Ukraine; economic and statistical – to assess the state of renewable energy in Ukraine; tables and figures - for a visual representation of statistical material and a schematic representation of the theoretical and practical provisions of the study.

2. The essence and meaning of renewable energy

Renewable energy should be considered energy sources that tend to quickly restore their reserves. First, this is solar energy, as well as its derivatives: wind energy, plant biomass, water flows (Fig. 1).

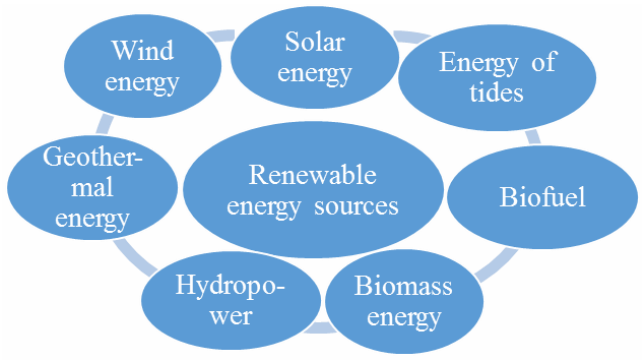

Figure 1 *–Classification of renewable energy sources*

Renewable energy sources also include geothermal and low-potential heat, as well as some energy sources that are related to human activity, including thermal "waste" from housing, organic waste from industrial and agricultural production [1].

Since there are quite a lot of definitions of the category "renewable energy sources", I suggest paying attention to the definition according to L.P. Klymenkom and G.L. Nordum, which is extremely simple but apt: "Renewable energy sources include solar, wind, geothermal, tidal, etc." Today, the energy potential of most renewable energy sources is many times higher than the current level of energy consumption, that is why they can be considered as an efficient source of energy production [1].

The need for the development of the energy complex of Ukraine based on the use of renewable energy is determined by the following factors:

- imbalance in the development of the fuel and energy complex, its focus on the production of nuclear electricity in the absence of appropriate infrastructure and raw materials;
- the presence of significant energy potential of the most important types of renewable energy sources;
- favourable natural and climatic conditions for development;
- a modern and powerful scientific and technical base that can ensure the efficient and stable operation of renewable energy.

Renewable energy sources are characterized by several advantages that give it a significant advantage over traditional energy:

- they are inexhaustible, unlike fossil fuel and energy resources;
- renewable energy resources can be used without significant changes in global geochemical cycles;
- renewable energy sources are capable of meeting the energy needs of all mankind and its future generations [2].

Since energy prices in the world are constantly increasing, reserves of traditional fuels are gradually being depleted, and ecology is constantly suffering, the search for alternative energy sources is becoming urgent. The development of this direction, although it requires significant investments, is extremely valuable and promising for the economies of all countries of the world.

3. Regulation and development of renewable energy in Ukraine

According to Ukrainian legislation, the concept of "renewable or non-traditional energy sources" was

interpreted for the first time in the Law of Ukraine "On Energy Saving" at July 1, 1994. RES were defined as sources of clean energy that have a stable nature of existence and function in the natural environment in the form of wind energy, Earth's heat, the sun, seas, oceans, rivers, and biomass [3]. Prospects for the development of "green energy" created a need for clear regulation of the economic, legal, and organizational aspects of their use. That is why the Law of Ukraine "On Alternative Energy Sources" was adopted in 2003 [4]. Since 2008, the main form of support for the development of the industry has been the "green" tariff [5].

Important role in the development of renewable energy was played by the Paris Agreement, the main task of which was to increase the potential of countries to combat the consequences of climate change. This was because in November 2017, the Government of Ukraine approved the "National Emissions Reduction Plan", the purpose of which is to reduce emissions of harmful substances into the atmosphere [6].

In Ukrainian practice, the main normative and legislative documents of the strategic development of green energy are concepts, strategies, state programs, national action plans and action plans. [7]. Among them, there are seven main documents (Fig. 2) [8-14].

1. National security strategy of Ukraine
2. Sustainable Development Strategy "Ukraine-2020"
3. State target program of energy efficiency and RES development for 2010-2020
4. Energy strategy of Ukraine for the period until 2035
5. National renewable energy action plan until 2020
6. The concept of state policy in the field of climate for the period up to 2030
7. Action plan for the implementation of the Concept of state policy in the field of climate for the period up to 2030

Figure 2 *– The main legislative documents of Ukraine regarding the development of renewable energy sources [8–14]*

4. World trends in the development of renewable energy

The most important indicators characterizing the development of alternative energy sources are the dynamics of renewable energy production in the world and in individual countries, the structure of renewable energy production by generation sources, so we will now consider them [15].

As for the dynamics of world production, the leaders in the development of renewable energy sources are the EU countries, in which the share of renewable energy in the total energy consumption is 14% (Fig. 3).

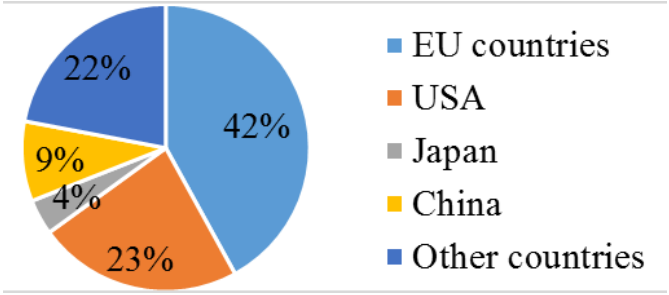

Figure 3 *– Distribution of global consumption of renewable energy by country, 2018*

Despite this, most countries continue to use traditional fuels and energy resources, even though the strategic direction of the UN by 2030 is to double the share of renewable energy in the world energy balance [16].

Next, we will move on to sources of renewable energy generation, but first we note that the installed capacities of alternative energy around the world in 2018 exceeded 2 thousand GW and reached 2,011 GW (for comparison, in 2008 there were less than 1 thousand – 992 GW). Of this amount, 56% or 1,122 GW is accounted for by hydropower (Fig. 4) [18].

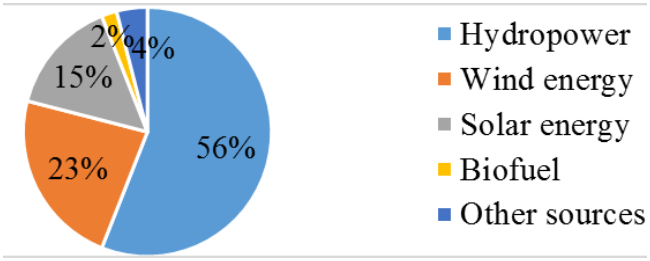

Figure 4 *– Distribution of global consumption of renewable energy by type, 2018*

Most of the remaining capacity is occupied by wind and solar energy – 467 and 296 GW, respectively, and bioenergy – 110 GW. Other sources include 13 GW of geothermal energy and 500 megawatts of marine energy [17].

As we can see, global trends in RES development generally have positive trends, although highly developed countries are leading in this field. Many countries of the world have already taken a course to expand the generation of "green" energy, the EU countries, as well as the USA, China and Japan, are leading in this category. Renewable energy requires signifi-

cant scientific support and large capital investments. The top three positions by segmentation in the world are occupied by hydropower, wind power and solar energy, which have the greatest production and economic prospects.

5. Analysis of the use of renewable energy in Ukraine

In the energy balance of the country for 2020 the volume of the total supply of primary energy was 86,4 million tons of oil equivalent, which is 3.3% less compared to 2019. Although renewable energy occupies a small share of 6.6% in the overall balance, it continues to increase its position (Fig. 5) [18].

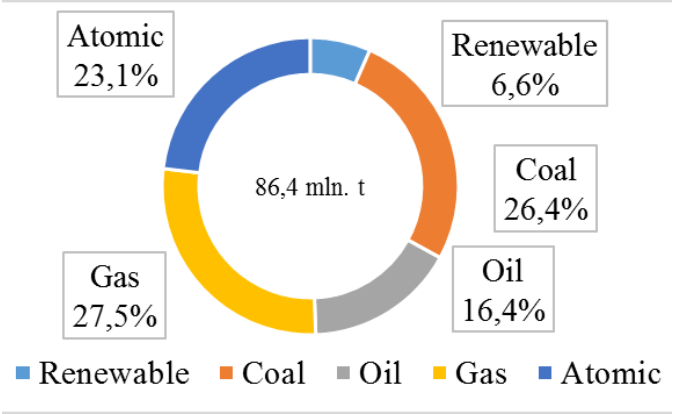

Figure 5 *– Distribution of energy sources in the total primary energy supply of Ukraine for 2020*

As for the structure of electricity production, hydropower still has the largest specific weight among RES. However, in 2020 the share of hydropower decreased by 16,3% and for the first time occupied less than half of the volume of electricity production from renewable energy sources, at the same time the shares of solar energy increased by 11,8%, wind energy by 3,3% and biofuel by 1,2% (Fig. 6) [18].

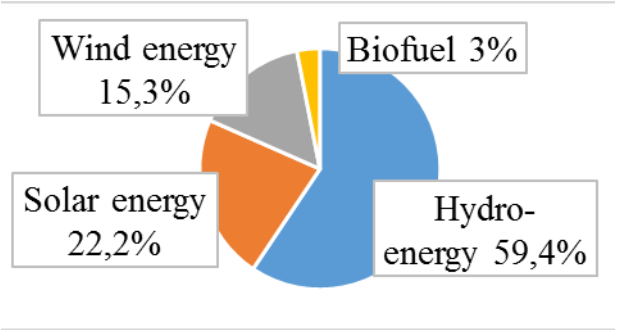

Figure 6 *– Structure of electricity production from renewable energy sources in Ukraine for 2020*

Next, we will consider the dynamics of energy consumption of renewable energy using the example of the most popular sources: hydropower, wind and solar energy, biofuels, and waste. Despite the greatest potential and power of renewable energy sources such as: sun, water, and wind, we observe the greatest trends in the development of energy consumption in the field of biofuels. This is due to its technical parameters and features of heat transfer in heating processes. Since 2013, there has been a steady increase in the amount of energy consumption from biofuels and waste, in 2020 they amounted to 4,241 (thousand tons of oil equivalent) (Fig.7).

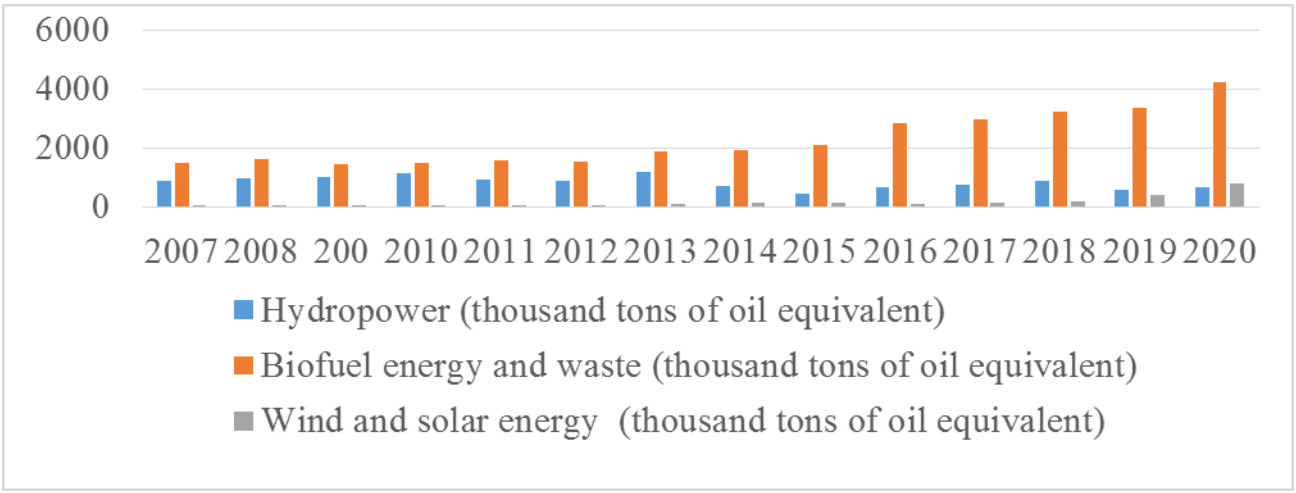

Figure 7 *– Dynamics of energy consumption from the main renewable sources in Ukraine for 2007-2020*

Renewable energy sources occupy their niche in the energy balance of Ukraine and are gradually developing their potential. Solar energy, wind and hydropower, as well as biomass energy have strong prospects for development. It is biomass that has significant potential for the future. Energy

consumption maintains its position and grows every year. The most promising RES sectors are electricity, transport, heating and cooling.

6. Assessment of capacities of renewable energy facilities in Ukraine

Ukraine has significant potential in the development of renewable energy and perfectly solves the problems of developing its capacities. In 2020, the largest level of renewable electricity capacity was provided by Hydroelectric power station (HPS) and Pumped-storage hydroelectricity (PSH) – 6,317.4 MW [19], Solar power plant (SPPs) – 5,576 MW and 618 MW (household SPPs), and Wind power plants (WPP) – 1,207 MW (Table 1).

According to the Ukrainian Renewable Energy Association, since 2010, 12,3 billion dollars have been invested in the renewable electricity production industry in Ukraine. USA [20].

Table 1 *– The capacity of renewable energy sources in Ukraine in 2014–2020 (MW) [20]*

Sources	2014	2015	2016	2017	2018	2019	2020
SPPs	411	432	531	742	1388	4925	5576
SPPs household	0.1	2	17	51	157	553	618
WPP	426	426	438	465	533	1170	1207
Small HPS	80	87	90	95	99	114	116
Biomass	35	35	39	39	51	84	91
Biogas	15	17	20	34	46	86	86

Also, one of the most promising directions in Ukrainian renewable energy is the production of solid biofuel, the capacity of which in 2020 was 91 MW. The most powerful thermal power plant in Ukraine, which operates on solid biofuel and provides electric and thermal energy to one of the districts of the Kyiv region, belongs to Biogazenergo LLC. The second place is occupied by Smilyansk Thermal power plant, which operates on wood chips. In third place is Mykolaiv thermal power station "Yevgroil", which uses sunflower waste as fuel [21].

In 3 months of 2020, renewable energy facilities that were issued a "green" tariff produced 2,240 million kWh of electricity. The data can be viewed in more detail in Fig. 8, which clearly shows RES segments, their shares and capacities.

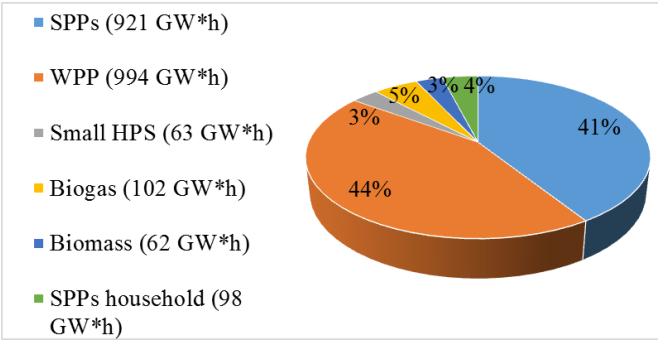

Figure 8 *– The structure of electricity production by renewable energy facilities for 3 months of 2020*

As we can see, RES have a positive increase in capacities and are developing every year, as evidenced by the dynamics of RES capacities for 2014-2020. The leaders of capacities are hydropower, solar power and wind power, which also make up a large part of the RES structure of Ukraine and have great potential for development. It is also worth saying about biomass, although its capacities are not as large as those of the leaders, but it has a significant consumer potential, the positive trends of which are growing many times every year.

7. Analysis of the global experience of investing in renewable energy, prospects for Ukraine

Renewable energy is a trend of modernity, economic stability, and environmental friendliness. Its capacities and capabilities are growing every year, which is why it needs not only control, but also significant support in the form of capital investments. One of the most popular methods of such support is investments that help develop renewable energy around the world. Already today, the share of renewable energy in the world has reached 25%. And although Ukraine is actively trying to join the global trend, the share of RES in its energy remains at the level of 5-6% [18].

The total volume of investments in the development of RES in Ukraine in 2020 already amounted to 6,41 billion dollars. USA [20]. The share of our state in global investment flows in alternative energy reaches only 1.2%, and in 2019, in total, 282.2 billion dollars were invested in RES in the world. USA (Fig. 9).

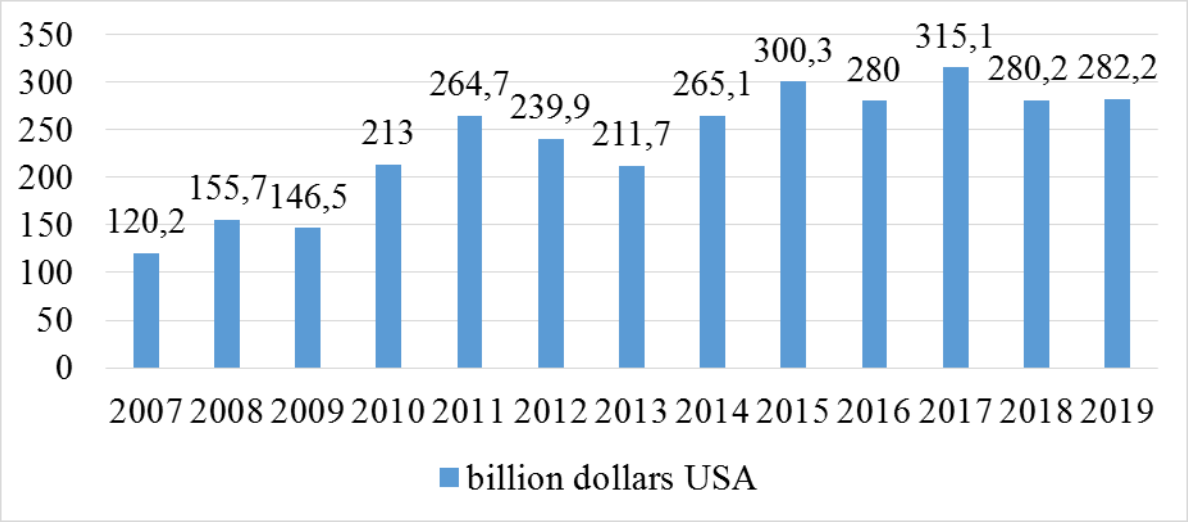

Figure 9 *– World investments in RES development in 2007-2019 [22]*

As for the structural distribution of global investments in RES, in 2018 their largest share falls on wind energy – 60%, solar energy – 30%, and 10% on other sources, which include: generation of energy from biomass and waste, biofuel, geothermal energy, thermal hydropower, etc.

"Green" projects related to renewable energy sources (wind, solar, biomass, small hydroelectric power plants) have the greatest investment appeal in Ukraine. In the period from 2015 to 2020, 6.41 billion dollars were attracted to the sphere of foreign trade of Ukraine. USA. In the world, this indicator during the last five years exceeds 300 billion US dollars and in 2018 was equal to 332.1 billion US dollars, which is 8% less than in 2017, which indicates a certain decrease in green energy investment in the world [23].

The need to increase green investment is due to its benefits for the economy and the environment. Therefore, it is obvious that "green" investments in the coming years may become priority directions for the economy of Ukraine, which will determine the further growth of renewable energy capacities in Ukraine [24].

Thus, RES have significant investment potential both in the world and in Ukraine. Their investment issues are of a global nature. As we can see, the basis of the structure of global investments in foreign trade is wind power, solar power, hydropower and biomass. Investing in these sources is also promising for Ukraine, even without considering the certain reduction in global investment rates in RES, because it is these sources that already attract a significant amount of investment to our country and have decisive capacities and opportunities for further expansion in the energy balance of Ukraine.

8. Evaluation of the raw material base of bioenergy in Ukraine

Bioenergy has significant development prospects in Ukraine. Bioenergy is energy created using biofuels, which are produced from biomass through its appropriate processing. In the agricultural sector, the main source of biomass is waste and by-products of plant and animal husbandry, as well as some energy crops. The use of biomass will help solve a number of economic and environmental problems.

Potential biomass energy resources can be divided into two groups:

• plantations of plants grown for energy purposes (corn, rapeseed, energy willow, potatoes, Jerusalem artichoke, miscanthus);

• organic residues and waste - remains of cultivated plants, waste from the cultivation and processing of plant products, animal husbandry waste, other organic waste [25].

Leaders in the structure of the energy potential of bioenergy in Ukraine are agricultural waste, which is the largest part of the potential of biomass. Its structure is represented by corn production waste (24%), sunflower waste (20%) and grain straw (12%). While energy crops (16%) and silage corn (8%) reflect the possible volume of biofuels that can be obtained from growing these crops on vacant land [26].

Ukraine has great potential for expanding the use of biomass for energy purposes. However, the potential of bioenergy in Ukraine is used too little and lags far behind the production of electricity from biomass and biogas in European countries. The first half of the energy supply potential is accounted for by

the production of energy from agricultural waste and wood biomass, and the second by energy obtained from energy crops and biogas.

The lag in the development of bioenergy in Ukraine is associated with such main factors as: the lack of state support and a clear strategy for the development of bioenergy potential, an outdated technological base, a lack of professional personnel, and the absence of a biomass market [27].

The main priorities in the field of development of energy crops should be defined as: development of the biomass market in Ukraine, expanded selection of energy plants, development, and patenting of new varieties of energy crops, creation of a strategy for the development of bioenergy, state support for biomass processing enterprises, stimulation of the development of biofuels both regionally and at the national level [27].

Therefore, the main sources of biomass in Ukraine are wood, agricultural waste and residues (straw, stalks and stalks of corn, stalks and husks of sunflower), as well as energy crops (willow, poplar, miscanthus), which are grown for energy needs. The main types of biofuels produced in Ukraine are: biogas, bioethanol, biodiesel and solid biofuels. Ukraine has significant raw material potential for the development of biomass, as one of the most promising types of RES.

9. Justification of energy and economic efficiency of biofuel

Today, in terms of production volumes, plant biomass as a fuel occupies one of the leadingpositions in the world among RES. For the effective development of biofuels in Ukraine, we need to comprehensively study our potential in the field of plant resources, as one of the main sources of cheap and ecological energy. Special attention in solving this issue should be paid to the agricultural sector, as it has prospects to become the main source of bioenergy for our country [28].

Today, biofuel production is extremely popular and promising in Ukraine, especially for farms. That is why it is important to consider such indicators of biofuel as: the potential of plant residues, energy and economic potential of biomass. These indicators will help you form a clear opinion about the energy efficiency and cost-effectiveness of using biofuel in your household.

We will consider these indicators on the example of farming. We chose the following crops for research: wheat, corn, sunflower, soy, rapeseed. We will analyze the energy and economic efficiency of each crop per 1 hectare of land as of 2020-2021.

Let's start with the potential of plant residues of agricultural crops, which will be determined by:

$$P_{pr} = GC_{mr} \cdot C_{pr} \cdot (1 - C_l) \cdot C_{bu}, \quad (1)$$

where GC_{mr} –the gross collection of the main products, t/ha; C_{pr} – coefficient of plant remains; C_l – coefficient of loss of plant residues; C_{bu} – coefficient of use of plant residues;

The first thing we will need is the gross collection of studied crops tons per hectares (table 2).

Table 2 *–Yield of main crops t/ha in 2020 - 2021 [18]*

Culture	2020 year	2021 year	Average over the years
Wheat	3,88	4,64	4,26
Corn	5,69	8,01	6,85
Sunflower	2,06	2,52	2,29
Soy	2,09	2,68	2,4
Turnip	2,34	2,95	2,6

As we can see, from table 2, for all studied crops, there is an increase in yield (in 2021 compared to 2020), wheat (+0,76 t/ha) and corn (+2,32 t/ha), sunflower (+0,46 t/ha), soybean (+0,59 t/ha), rapeseed (+0,61 t/ha).

Next, let's move on to the main calculation coefficients of eq. (1), it is worth noting that all of them are conditional (average), since in general the obtained result will largely depend on weather conditions, fertilizer application, soil quality indicators (table 3).

Table 3 *– Coefficients of the potential of crop production waste [29]*

Culture	Coefficients		
	C_{pr}	$1 - C_l$	C_{bu}
Wheat	1,0	0,5	0,33
Corn (stalks)	1,3	0,7	0,7
Sunflower (stems)	1,9	0,67	1
Soy	0,9	0,7	1
Turnip	2,0	0,7	1

Using these coefficients, as well as the gross collection of crops per 1 ha, we will calculate the potential of their residues, table 4.

Among the studied crops, corn stalks have the greatest potential for plant residues in 2020-2021

(4.36 t/ha), followed by rapeseed straw (3.7 t/ha), followed by sunflower stalks (2.92 t/ha), soybean straw (1.5 t/ha) and wheat (0.7 t/ha).

Table 4 *– The potential of plant residues of agricultural crops for use as biofuel, t/ha*

Remains of culture	Year		Together in 2 years	Average for 2 years
	2020	2021		
Wheat (straw)	0,64	0,77	1,41	0,70
Corn (stalks)	3,62	5,10	8,73	4,36
Sunflower (stems)	2,62	3,21	5,83	2,92
Soya (straw)	1,32	1,69	3,01	1,50
Rape (straw)	3,28	4,13	7,41	3,70

Next, we will move on to the energy potential, which will be determined by:

$$EP_{pr} = P_{pr} \cdot Q / 7000, \text{ t/ha}, \qquad (2)$$

where P_{pr} – potential of plant residues, t/ha; Q – lower heat of combustion of plant residues, kcal/kg; 7000 – calorific value of conventional fuel, kcal.

Before proceeding to the direct calculation, let's determine the lower heat of combustion of plant residues for each culture, this indicator is conditional and depends significantly on weather conditions. Detailed information on each culture is given in table 5.

Table 5 *– Lower heat of combustion of the studied cultures [29]*

Culture	*Q* - Lower heat combustion, kcal/kg
Wheat	3285
Corn (stalks)	3270
Sunflower (stems)	3270
Soy	3800
Turnip	3660

Now let's move on to the direct calculation of the energy potential indicator, which will allow us to single out cultures for the further perspective of their development, Table 6.

Analyzing table 6, we can see that the largest increase in energy potential over the last year was observed in the remains of corn (+ 0,69 ton of oil equivalent (toe) and rapeseed (+ 0,45 toe). Here, the first place is occupied by corn waste (2,38 toe), the second position is occupied by rapeseed waste (2,16 toe), followed by sunflower waste (1,5 toe), soybeans (0,92 t of dry weight) and straw (0,66 t of dry weight). This indicates that farms should pay attention to these crops, and especially to the most energetically profitable ones, which are corn, rapeseed and sunflower, but in my opinion, they are all worth attention and development.

Table 6 *– Energy potential of plant residues of agricultural crops, tons/ha in 2020-2021*

Remains of culture	Year		Together in 2 years	Average for 2 years
	2020	2021		
Wheat (straw)	0,30	0,36	0,66	0,33
Corn (stalks)	1,69	2,38	4,08	2,04
Sunflower (stems)	1,23	1,50	2,72	1,36
Soya (straw)	0,71	0,92	1,63	0,82
Rape (straw)	1,71	2,16	3,87	1,94

The final indicator will be the indicator of economic potential, which will allow us to determine the most economically profitable crops for farms for the purpose of developing bioenergy. We will find this indicator using:

$$EC_p = En_p \cdot C \cdot P \cdot D_{eu}, \qquad (3)$$

Where EC_p – economic expression of biomass potential, UAH; En_p – energy potential, ton of conventional fuel (per 1 hectare); C – coefficient for the conversion of a ton of conventional fuel into a barrel of oil equivalent, equal to 4.79; P – price for 1 barrel of oil, USD USA (we took the average value for 2021, which was $75 (Brent)); D_{eu} – dollar exchange rate (we took the average value for 2021, which is $27.5).

In this way, we will evaluate the economic potential of the biomass of the studied crops for 2021 (table 7).

Table 7 *– Economic potential of biomass as of 2021 (UAH/ha)*

Remains of culture	Economic potential (UAH/ha)
Wheat (straw)	3557
Corn (stalks)	23513
Sunflower (stems)	14819
Soya (straw)	9080
Rape (straw)	21340

As you can see, the biomass of corn (23513 UAH/ha), rapeseed (21340 UAH/ha) and sunflowers (14819 UAH/ha) has the greatest economic potential; it is the biomass from these crops that will bring the farm the highest profit from the price per 1 ha of land. Soy (9080 UAH/ha) and wheat (3557 UAH/ha) are in the last positions.

So, from the conducted research we can draw conclusions that it is expedient for farms to use biomass energy in the processes of creating ecologically clean, safe and cheap, compared to traditional types of energy. A special factor here is their significant resource potential, which allows to quickly and effectively expand the creation of bioenergy on the basis of individual farms and enterprises.

It is worth noting that by using biomass, farms will be able to save a significant part of their financial resources, which is proven by the conducted research. It is promising to develop and use the crops listed in the study (in particular, corn, sunflower, rapeseed, soy, wheat), with the parallel introduction of modern technologies for the creation of bioenergy. The use and development of bioenergy for farms is the key to their energy stability and security.

10. Conclusions

Ukraine is developing renewable energy and needs the introduction of new tools to regulate the development and use of renewable energy sources. Their effective development will be impossible without the introduction of the necessary tools of state support. Therefore, it is necessary to outline real targets for the development of RES sectors, which will ensure their optimal development and balance along with traditional energy.

In the process of research, the following achievements and scientific results were obtained:

1. Renewable energy occupies its niche in the energy balance of Ukraine and is gradually developing its potential. Solar energy, wind and hydropower, as well as biomass energy have strong prospects for development. It is biomass that has significant potential in the future.

2. Renewable energy has a positive increase in capacity that develops every year. The leaders of capacities are hydropower, solar power and wind power, which also make up a large part of the RES structure of Ukraine and have great potential for development. Although the power production capacity from biomass is not as large as that of the leaders, it has a significant consumer potential.

3. Investing in renewable sources is promising for Ukraine, because these sources already attract a significant amount of investment in Ukraine and have decisive capacities and opportunities for further expansion in Ukraine's energy balance.

4. Calculations of the energy and economic potential of agricultural crops were carried out. It has been proven that the most promising in bioenergy is the development and use of such crops as: corn, sunflower, rapeseed, soy, wheat, with the parallel introduction of modern technologies for the creation of bioenergy.

Особистий внесок авторів CRediT

Воронін А.В.: перевірка, формальний аналіз, написання – огляд та редагування, адміністрування. **Панасюк П.І.:** концептуалізація, методологія, дослідження, написання – оригінальний проект.

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Стан та перспективні напрями розвитку відновлюваної енергетики в Україні

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Проблема раціонального використання енергетичних ресурсів, підвищення рівня енергетичної ефективності та енергетичної безпеки є необхідною умовою гармонійного економічного, соціального розвитку України. Відновлювальна енергетика є глобальним трендом і однією з найперспективніших галузей енергетики у світі. «Зелена» енергетика здатна забезпечити енергетичні потреби всього людства і тому потребує значної уваги. Її екологічність і економічність говорять самі за себе, в результаті чого сьогодні всі розвинені країни беруть приклад з популяризації та розвитку відновлювальної енергетики, і Україна не є винятком. Україна має значний потенціал у сфері відновлювальної енергетики, про що свідчать основні показники потужностей, виробництва та споживання. Варто відзначити інвестиційну привабливість цієї галузі. У статті досліджено роль відновлювальних джерел енергії в енергетичному балансі України. Процес написання супроводжувався використанням наступних загальнонаукових та спеціальних методів дослідження, зокрема: аналізу, синтезу, порівняння при дослідженні світового досвіду розвитку відновлювальної енергетики та визначення перспективних напрямів розвитку відновлювальних джерел енергії в Україні; порівняльно-ретроспективного аналізу та абстрагування для визначення основних тенденцій та особливостей відновлювальної енергетики України, а також оцінки інвестиційних можливостей підприємництва; математичного моделювання для обґрунтування енергетичної та економічної ефективності розвитку біоенергетики в Україні; економіко-статистичний – для оцінки стану відновлювальної енергетики в Україні; табличний та графічний – для наочного зображення статистичного матеріалу і схематичного подання теоретичних та практичних положень дослідження. Сегментація відновлювальної енергетики та аналіз потужностей дозволили на прикладі світового досвіду визначити основні перспективи та напрями інвестування галузі та визначити роль інвестицій для розвитку цієї галузі. Проведено оцінку потенціалу розвитку біоенергетики в Україні на основі відходів сільськогосподарських культур.

Ключові слова: *Енергетичний баланс; Відновлювальна енергетика; Відновлювані джерела енергії; «Зелені» інвестиції; Біоенергетика.*

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