Effectiveness of Bioenergy Management and Investment Potential in Agriculture: The Case of Ukraine

Andrii Dankevych, Iryna Perevozova, Vitalii Nitsenko, Liubov Lozinska, and Yuliia Nemish

Abstract The resource and energy potential of crop biomass forms significant reserves for the economy. There are 42.3% oil, 37.4% meal, 18% husk and 0.7% sunflower oil sludge from 1 ton of sunflower. Currently, scientists are paying a lot of attention to biomass processing and improving ecology. Phosphatide concentrate and lycetin are obtained from sunflower oil sludge. Husk is a source of energy, and its energy value is 18 MJ/t. The purpose of this study is to assess the bioenergy and investment potential in agriculture. In particular, on the example of sunflower, the reserves for increasing the efficiency of electricity production. In particular, the energy cost equivalents of sunflower husk replacement of energy costs in production were estimated. The legal, organizational, and economic foundations of activities related to the prevention or reduction of waste generation have been studied. The substantiation of the necessity of including organic waste in the cycle of substances in the system "soil–plant–person" is confirmed. The need for funds for the modernization of the industry was estimated.

Keywords Agricultural management · Renewable energy · Bioenergy · Bioresource · Sunflower husk · Investment

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1 Introduction

The government of Ukraine has included bioenergy in the strategic direction of providing the country with an environmentally friendly type of renewable energy. This is explained by the country's high dependence on imported energy resources and the great potential of available bioenergy. Having a developed biofuel production industry, the country is still far from fully utilizing its resource potential compared to EU countries [1, 2].

At the same time, innovations in the field of waste processing and production of finished products contain significant reserves for increasing the efficiency of the economy.

Ultra-processed products and sunflower waste in the form of organic fertilizers can help reduce the anthropogenic impact on nature, including overcoming such negative phenomena as soil acidification caused by excessive doses of mineral fertilizers and reducing the accumulation of radionuclides in plants.

In this connection, plants are looking for an alternative to calcium and potassium, in the absence of which they absorb other available elements, namely strontium and cesium. It should be noted that the Chornobyl disaster caused the contamination of about 48 thousand square kilometers in Ukraine with radionuclides 137Cs and 90Sr [3].

Analysts note that during the next 50 years fossil fuel reserves may run out [4]. In these conditions, alternative energy sources are a perspective for the development of the economy. Ukraine has the greatest technical potential for the introduction of renewable energy sources (RES) in Europe. The total potential of electricity production from RES is more than 1 million GWh per year. The largest share (85%) is taken by wind energy. The capacity potential of renewable energy sources of Ukraine is estimated at 408.2 GW, including biomass—15.1 GW (4%) [5].

The Government of Ukraine adopted a number of draft laws aimed at stimulating the substitution of natural gas with alternative fuels, in particular:

- Granting preferential status to such projects.
- Simplification of the procedure for concession, lease and lifting of the ban on privatization of heat facilities of communal ownership.
- Development of technical conditions for acceptance of biomethane into the gas transmission system of Ukraine, a mechanism for stimulating its production and consumption.
- Amendments to the Laws of Ukraine regarding the transition to alternative fuels and to the stimulating regulation of relevant business entities [6].

The current agro-industrial production in Ukraine is based on the concept, which is grounded on the costly principle of its development [7]. Hence unrestricted, irrational, and unwise use of productive forces and land resources follows. In Ukraine, the cost of production per unit of gross agricultural output is, in particular, 3–6 times higher and the cost of fuel 2–5 times higher than in Europe [8, 9]. The driving factors for the development of renewable energy sources around the world are the cheapening of technologies. By 2035, the cost of installing solar power plants is predicted to decrease by 50–56% [10, 11].

A specific feature of Ukraine that allows launching projects on an industrial scale is the presence of agricultural holdings [12, 13]. Their accumulation of a wide range of resources, from financial to labor, allows investments in bioenergy. Increasing the efficiency of the interaction of different types of RES in electric networks can be achieved by automating the management of RES modes and optimizing their connection schemes, taking into account their basic features [14].

2 Methodology

Agro-production is characterized by reversibility, cyclicality and uncertainty, as well as by a significant influence of natural and climatic factors. The calculations of forecast indicators of production, yield and area of sunflower crops until 2035 are based on a combined forecast systematized on the basis of research by Ukrainian scientists and the Ministry of Economy of Ukraine [15], which were conducted on the basis of multivariate forecasting using geostatistical, abstract-statistical and system-statistical forecasting methods.

The basic Box-Jenkins time series model [16] was used to forecast production volumes. This model is widely used in economics to predict the results of future periods using data sets from past periods to the present. The advantage of the model is that it implements an autoregressive approach using the so-called "moving average", which allows us to describe both stationary and non-stationary sets (linear vectors) of statistics. In the scientific literature, such a model is also called ARMA (p, q) model.

As you know, the data implementation algorithm consists of two blocks. These blocks are called AR-block and MA-block according to the mathematical apparatus they use. The AR part is responsible for the stationary component of the time series, and the MA part is responsible for random harmonics. In analytical form, the model can be presented as:

$$y_t = \sum_{i=1}^{p} a_i y_{t-i} + \sum_{i=1}^{q} b_q \varepsilon_{q-i} \tag{1}$$

where y_t is the predicted parameter for the period t (years), which corresponds to the indexation of a natural number with the index $i = 1, 2, 3 \ldots p$; ε_{q-i} is a component that depends on $\boldsymbol{q}$ harmonics of influences; a_i, b_q are coefficients of AR and MA-parts.

For the needs of the presented scientific research the task of development of the strategic forecast for a term long enough has arisen. Therefore, to form a relevant forecast, the traditional model needed to be modified. The purpose of the modification was to level the influence of high-amplitude harmonics of random oscillations in these time series of past periods. Random fluctuations of high-amplitude harmonics for long-term forecasts form a certain initial deviation from the relevant forecast, the effect of which increases with each subsequent period, which leads to significant deviations for remote values (large values of indices i).

Therefore, the algorithm is as follows. Using the autoregressive approach and the moving average, a polynomial equation is formed for each of the sets (vectors) of data. Next, there is the analysis of the amplitudes of random harmonics. In the set of amplitudes, irregular high-amplitude components whose values are higher than a certain, expertly established, threshold value are distinguished by the method of comparison. The next step of the algorithm is to re-apply the traditional algorithm to the specified, but already modified data sets (vectors). Algorithm, namely: predict the area of the raw material base (sunflower crops), million ha (Eq. 2), the gross production of products (seeds) of sunflower, million tons (Eq. 3) and the yield of sunflower, t/ha (Eq. 4).

Accordingly [16]:

$$y = -0.117x^3 + 0.812x^2 + 0.626x + 14.03 \tag{2}$$

$$y = 0.153x^3 - 1.26x^2 + 3.62x + 3.5 \tag{3}$$

$$y = -0.052x^3 + 0.42x^2 - 0.851x + 3.1 \tag{4}$$

where y is the value of the named forecast factor, x is the corresponding time period according to its index i = 1, 2, 3… [16]. Equations (2–4), obtained at the first stage of using the algorithm, were modified into linear equations at the next stage, respectively:

1. To determine indicators of the area under sunflower, million hectares:

$$y = 2.191x + 13.16 \tag{5}$$

2. To determine indicators of gross sunflower production, million tons:

$$y = 0.48x + 5.8 \tag{6}$$

3. To determine the yield rate of sunflower, t/ha:

$$y = 0.12x + 2.47 \tag{7}$$

The equations obtained in the process of research were used by us in further analytical calculations of the balance of sunflower production on the territory of Ukraine. The main parameters used were sown area, gross harvest and yield, economic indicators are the price of grain and profitability. During the growing season there are changes in the size of sown areas, which are primarily associated with crop losses due to changes in weather and climatic conditions.

3 Results

Agricultural land of Ukraine is 32.5 million hectares, it is the 8th bank of agricultural land on the planet. Arable land accounts for 54% of the total area of Ukraine, of which more than 80% have no serious restrictions. This ensures a more efficient farming operation, as it requires less capital and operating costs [17]. Sector specialists suggest that average field size in Ukraine is between 150 ha, while average field size in the EU is below 100 ha. Larger fields allow using large-scale agricultural machinery and equipment, which reduces fuel and labor costs per ha adding to efficient farming [18, 19]. Ukraine is the only country in the world with 2/3 of its total area in mollisols while the remaining 1/3 is in alfisols. Mollisols (chernozem, black soil) are among some of the most fertile and productive agricultural soils in the world. South of Russia, Argentina, North of Kazakhstan, part of Canada and the USA are also covered with mollisols. Due to its geographical location and fertile soils, Ukraine is well positioned to benefit from the advantage in the global commodities market (Fig. 1).

More than 30% of the world's production and export of sunflower oil is concentrated in Ukraine (Fig. 2). Ukraine's climate is changing and becoming warmer. The agro-climatic zones of Ukraine (Steppe, Forest-Steppe and Polissya) have shifted 200 km to the north over the last two decades. 19% of the arable land, which is 6.3 million hectares, became suitable for sunflower cultivation, as a result of which, as of 2000, the area of sunflower cultivation increased by 4.7 million hectares, or four times compared to 1990. Warming increases the yield of oilseeds. According to preliminary estimates, by 2050 the yield will increase by 32.4% [7]. In 2021, the sown sunflower area may reach a record 6.9 million hectares, and the sunflower harvest—17.8 million tons [22]. Under favorable conditions, production may reach 22 million tons by 2050.

Sunflower processing produces a significant amount of by-products. From 1 ton of sunflower, it is possible to obtain 420 kg of oil, 370 kg of meal, 180 kg of husk, as well as a small amount of phosphatide concentrate (Fig. 3).

If one interprets the data of Fig. 3 the calorific value of 2.5 million tons of sunflower husk emits as much heat as 1.0 billion m^3 of natural gas [26, 27]. Taking into account the costs of maintaining cogeneration plants—2.5 million tons of husks will give 3.8 billion kWh in 2020, with further growth to 6.0 in 2050. For comparison, this amount covers 40.2% of the annual electricity needs of the capital of Ukraine.

Given the depletion of basic resources, this is a real step towards the import substitution of natural gas, which took about 41% in the structure of primary energy consumption in Ukraine in recent years, while it is only 21% in the world. As a result, oil extraction plants, which produce sunflower husks and oil sludge as industrial residue, have begun to look for the most profitable ways to use and dispose of them. Payback of such projects is up to 3 years [23, 28, 29]. According to the results obtained [24], the energy consumption for the production of 1 ton of sunflower oil can be equated to 215 kg of sunflower husks (Fig. 4). It should be noted that at the moment about half of the received sunflower husk waste is transformed into electricity and heat.

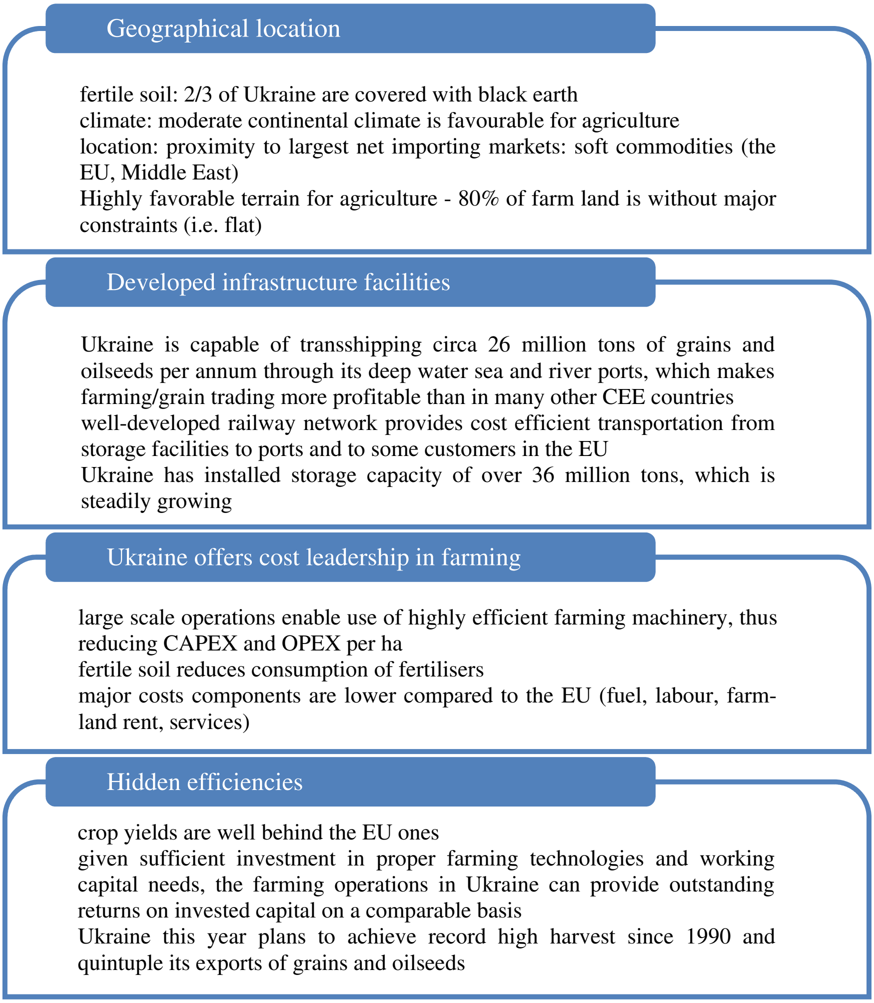


Fig. 1 Ukraine’s farming sector: investment case [20, 21]

Compliance with environmental emission standards during combustion implies the presence of powerful electro-filtration. Manufacturers are not interested in complying with environmental emission standards and investing in the environment as these investments are usually unaffordable for them.

The cost of filtration, as a rule, exceeds the cost of the boilers themselves. Payback of such projects is not less than 5 years, and profitability is 12–15%. As a result, the husk, which is pelleted and burned, is sold to third parties. It can be seen that the consumption of heating pellets will only grow, taking into account the increase in the cost of natural gas [30, 31].

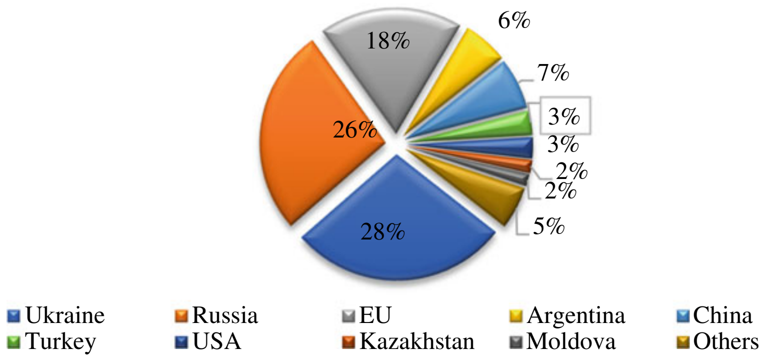


Fig. 2 The place of Ukraine in the world cultivation of sunflowers, 2020 [23, 24]

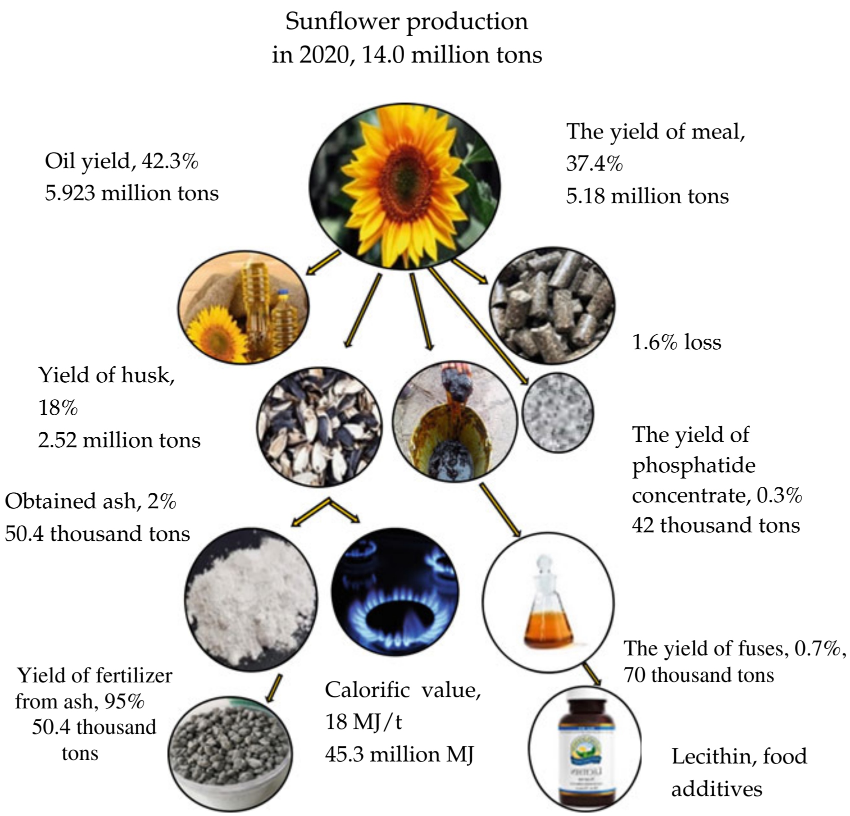
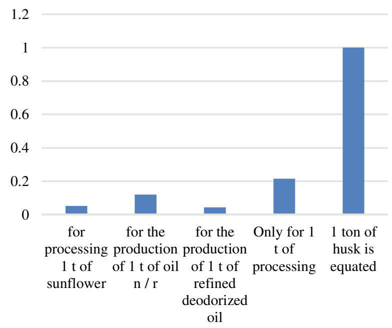
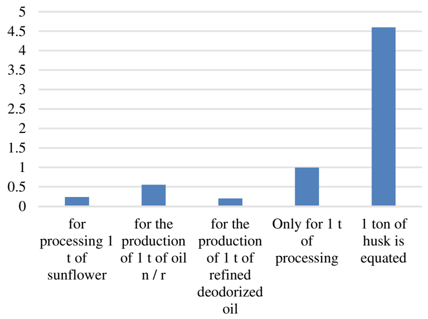


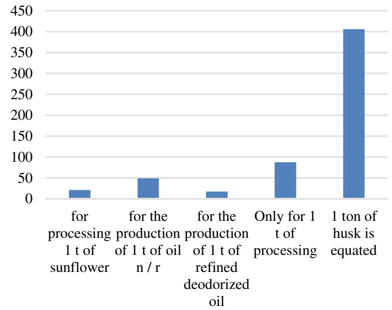
Fig. 3 Bioresource potential of sunflowers in 2020 [24, 25]



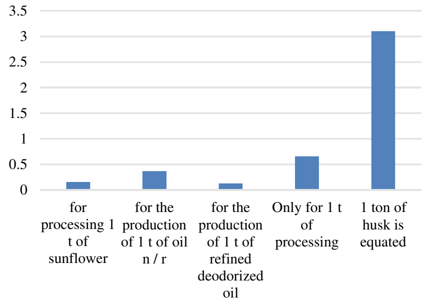
a) The cost of husks for processing products, t.



b) Volumes of steam is equivalent to sunflower husk, t.



c) Volumes of gas is equivalent to sunflower husk, m^3.



d) Volumes of thermal energy is equivalent to sunflower husk, Gcal.

Fig. 4 The cost of husks for processing products and energy consumption for the production, 2020 [24, 25]

Ensuring the growth of production of renewable energy sources, including electricity, is supported in Ukraine by the “green” tariff mechanism. In particular, since 2009 in Ukraine, its size has been set at the level of the retail tariff for consumers of the second voltage class. With a gradual decrease of 30% until 2028 (Fig. 5) [32, 33].

Among the most important projects in this area, the activities of the company “Kernel” should be noted. Almost all oil extracting plants will be equipped with combined heat and power plants that will generate electricity from burning sunflower husks. Annually, the company’s enterprises will produce more than 338 thousand MWh of electricity by burning 228 thousand tons of sunflower husk [33].

Kernel Agroholding already gets more than 50% of energy from renewable sources in the 2021, and its contribution to EBITDA is $10 million in the first half of 2021 [33]. According to the company’s semi-annual financial report, the total investment in the program reached $169 million since its inception in 2018, three cogeneration facilities have already been built and their commissioning is being completed, and

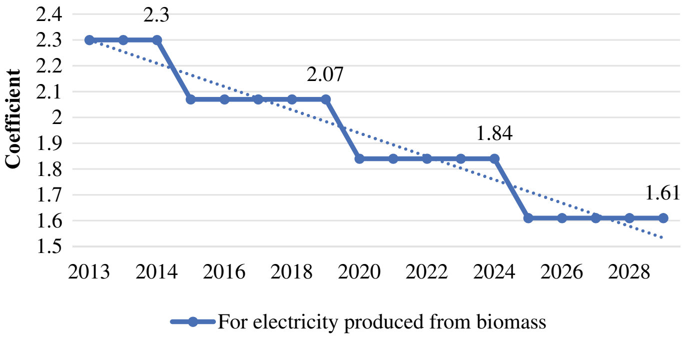


Fig. 5 Coefficient of "green" tariff for facilities put into operation [33]

three more facilities will be commissioned in 2022 [34]. In total, eight projects related to the transition to alternative fuels have been implemented in the country (Table 1).

Biomass plays a significant role in the energy balances of industrialized countries. The use of electricity produced from biofuels at an average annual rate of over 8% was noted in China, Japan, Germany and the United Kingdom. Ukraine has the most energy-intensive economy. The energy intensity of Ukraine's national income is 4–6 times higher than that of the United States, Japan and Western Europe. Consumption of conventional fuel per capita in our country is about 6.5 tons unlike only 4.2–5.5 tons in these countries. The main types of energy resources in Ukraine are coal, oil, gas, nuclear and hydropower (Fig. 6).

The largest energy consumers are the People's Republic of China (30%), the USA (25%), the Russian Federation (about 10%), Japan (5.5%) and Germany (7.3%). The energy consumption of Ukraine (about 3%) was comparable to the energy consumption of Great Britain, France, Canada or India [38]. As of the end of 2020, renewable energy capacities have been installed, which produce about 7.3% of the total electricity supplied. The largest share of RES in Ukraine is occupied by wind and solar power plants, which in 2016 produced 925 GWh and 492 GWh of electricity, respectively (Table 2).

Biomass is the most progressively growing segment of renewable energy sources in Ukraine (Table 3). The development of the use of biomass energy is important not only in terms of electricity production, but also even more valuable from the standpoint of ecology, as it solves the problem of waste disposal of industrial and agricultural enterprises.

If in 1995 the share of biomass in the total consumption of primary energy in the European Union was 3%, in the US it was 3.2%, in Denmark it was 8%, in Finland it was 21%, in Austria it was 11%, and in Sweden it was 19% [40], then the IEA forecasts an increase in demand for primary energy from biomass to 12% of the total global demand for primary energy by 2030. The energy potential of biomass in Ukraine is estimated at 11–18 million tons of conventional fuel per year, which is equivalent to about 14.3–24% of total primary energy consumption. In fact, in 2020, this share will be 0.05% in Ukraine. Until recently, its use was limited to

Table 1 Chronology of implementation of projects on transition to alternative fuel of oil enterprises of Ukraine

Name of the enterprise	Year	Project implementation stage
OJSC "Melitopol MEZ"	1997	Development of design documentation for reconstruction, installation of steam boiler KE 10-14 MT
CJSC "Pologi SEZ"	1998	Design and commissioning works on gas generator automation. Reconstruction of E 35-3,9-440 GM for husk burning
OJSC "Vinnytsia MZhK"	2000	Commissioning and thermochemical tests of the modernized steam boiler KE-10-1,4-285 on husk and natural gas
OJSC "Kirovogradolia"	2000	Development of technical documentation for the reconstruction of the steam boiler DKVR 20-13-250 Art. №3 when transferring to the burning of sunflower husk
CJSC "Poltava MEZ - Kernel Group"	2000	Development of design documentation for reconstruction and installation of steam boiler E-16-2,1-350 HMDV for burning sunflower husk with auxiliary equipment
CJSC with II "Dnipropetrovsk SEZ"	2000	Commissioning works, ecological and thermal tests, adjustment of a water mode on a steam boiler of production of LARDET-BABCOCK firm with fuel "sunflower husk" with a productivity of 30 t/h
CJSC "Zaporizhzhya MZhK"	2001	Commissioning and research work of the steam boiler OL-20, which burns sunflower husk (manufactured by RAFAKO)
OJSC "Chernivtsi MZhK"	2002	Reconstruction of a boiler room with installation of a reconstructed boiler with a steam capacity of 12 t/h for burning sunflower husk

Source Formed by the authors using [35]

direct combustion over an open fire or in furnaces and stokers with relatively low efficiency and did not comply with environmental requirements for emissions of harmful substances [39].

According to the Biomass Research Center, of the 109 million tons of agricultural waste (straw, corn stalks, sunflower waste, cattle and pig manure, poultry manure, food waste, etc.), 59 million is used as fertilizer or for livestock needs and only 1 million tons is used for the production of heat and electricity. The analytical report of the International Finance Corporation estimates that using only 20 million tons of waste for energy production, Ukraine will cover 25% of annual electricity needs, which will replace more than 8.02 billion m^3 of natural gas. That is, the use of only agricultural residues makes it possible to refuse from the import of natural gas by 75–80%. The analysis of experts showed that it is agricultural pellets from sunflower

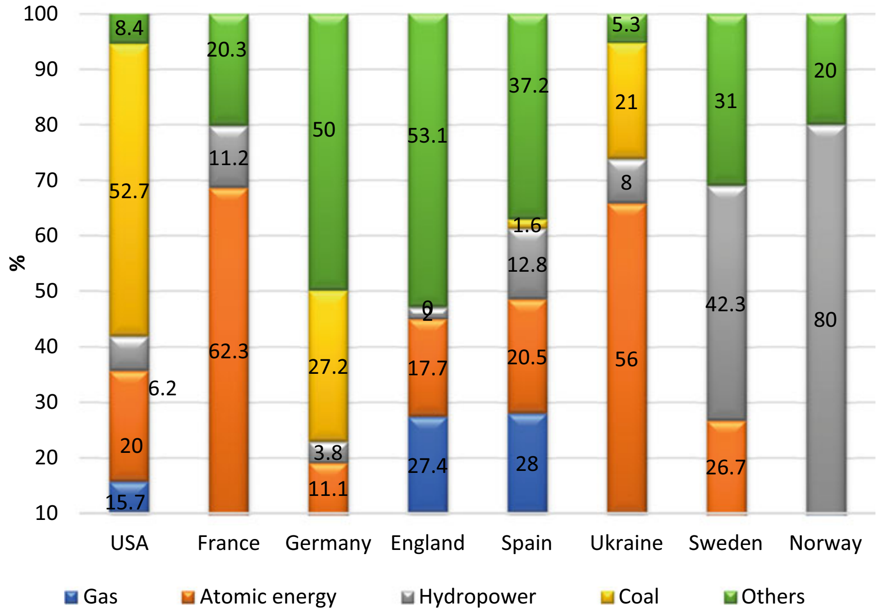


Fig. 6 Structure of electricity production in the world, 2019 (in %) [35–37]

Table 2 Electricity generation by type of power plant

Type	2010 (%)	2012 (%)	2014 (%)	2019 (%)	2020 (%)
NPP	47.4 ▼	45.5 ▼	48.5 ▲	53.9 ▲	51.2 ▼
TPP	41.5 ▲	44.7 ▲	41.3 ▼	36.2 ▼	35.2 ▼
HPP/PSP	6.9 ▲	5.5 ▼	5.0 ▼	5.1 ▼	5.1 ▲
Block stations	4.2 ▲	4.0 ▼	4.3 ▼	1.09 ▲	1.21 ▲
SPP/WPP/biomass	–	0.3 ▲	1.0 ▲	3.62 ▲	7.3 ▲
Incl. biomass			0.055 ▲	0.019 ▲	0.023 ▲

Source Calculated by the authors using [37, 39]

husks that have a greater impact on the growth of production volumes in the Ukrainian biofuel sector. Expert estimates show that the energy potential of biomass in Ukraine may increase to about 45 million tons of o.e./year (Fig. 7) by 2050. It is expected that the total installed capacity of bioenergy equipment will increase to 49.6 GW and 5.2 GW by 2050. The total consumption of biofuels will be more than 20 million tons of o.e./year.

The implementation of these measures will require investments of 21… 33 billion euros and will lead to the replacement of about 20.1 billion m^3 of natural gas a year and the creation of more than 160.2 thousand jobs by 2050 [38].

Table 3 Renewable energy capacity, MW

Type	2010	2012	2014	2019	2020
Wind	87	194	426	1170	1314
Solar	3	326	411	4925	6094
SPP of households	–	–	0.1	553	779
Small hydropower	68	73	80	114	109
Biomass	–	6	35	55.9	91
Biogas	–	–	14	70.3	103
Large HPPs/PSPs	5400.2	5400.2	5724.2	6048.2	
Total	5558.2	5999.2	5853.3	12,936.4	8490

Source Calculated by the authors using [37, 39]

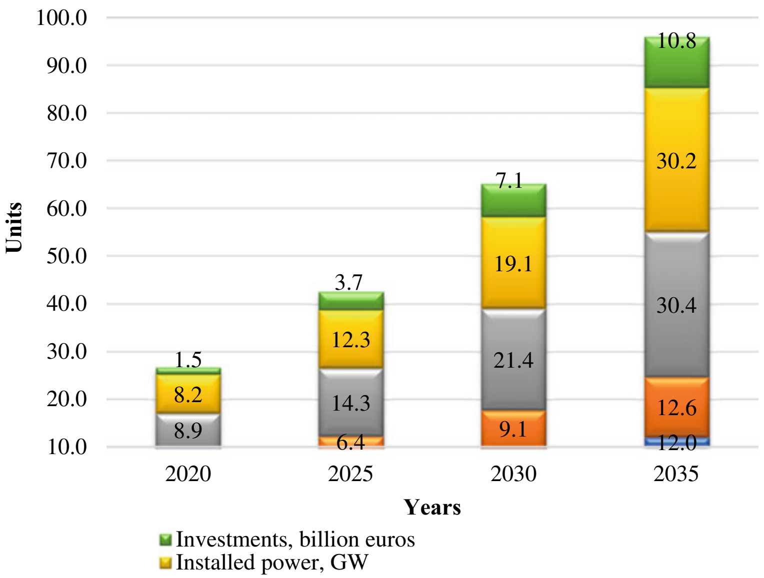


Fig. 7 Forecast of bioenergy development until 2035 [36, 37]

The pioneers in this direction are agricultural holdings, which have invested significant funds in the modernization of existing facilities and construction of new bioenergy ones. According to preliminary estimates, there are more than 90 large agricultural holdings in Ukraine, which control about 27.8% of arable land and are the largest producers of grain and industrial crops.

Agricultural holdings usually cover the entire cycle of production, processing and sale of products and provide targeted reproduction of the industry on a new technological, organizational and economic basis [40]. The raw material base of Ukraine allows the production of about 40,114 tons of phosphatide concentrate per year, at the same time, at the moment, this potential is being developed by only 28.1%, about 10,512 tons of the finished product suitable for sale are sold (see Fig. 3). Projected investments in the modernization of the industry are estimated at 35–55 million dollars [2]. In terms of the amount of carbon dioxide emissions when burning sunflower husks, it can be equated to natural gas, while (ash content) does not exceed 3.1% [41]. It is possible to solve the disposal of ash formed after burning by producing complex fertilizers from them.

Granulated ash is an environmentally friendly fertilizer suitable for use in organic production. When using 1 ton of granular ash, 90 kg of calcium, 50 kg of magnesium, 40 kg of sulfur, 260 kg of total potassium can be added to the soil [2]. The current potential of ash from sunflower husks in Ukraine is estimated at 50,283 tons. Approximate investments in the modernization of the industry are estimated at 30.4 million dollars.

4 Discussion

The agro-industrial production of Ukraine needs changes in the policy of environmentally unlimited, irrational and unbalanced use of production resources, the absence of an ecological culture of production. Of particular concern is the extremely unsatisfactory ecological condition of agricultural lands. Over the past three decades, the area of eroded arable land in Ukraine has almost doubled. At the same time, researchers [42–45] note that the functioning of the system "soil–plant–animals" necessitates the inclusion of waste in the cycle of substances. Researches confirm the need to ensure ecologically clean and rigid parameters of the obtained electricity when burning sunflower husks [46, 47]. To implement these tasks, scientists recommend using an automated control system for all technological production cycles.

The restraining factors for entering the market are: limited information on the assessment of the regional technical potential of various types of RESs; outdated Soviet energy systems and limited possibilities of connection to them; complex permission system. Also guarantees of buyout of energy produced and guarantees of imposing a "green" tariff at the planning stage of the project are not provided. A characteristic feature of the grain production process in Ukraine is a sharp increase in yield variance in recent years. According to some authors, this trend is due to the influence of meteorological factors, which undergo similar changes. This behavior of the system increases the uncertainty and risk of investment decisions. If the probability of obtaining critically low yields becomes significant, the investor may decide to change the investment plans. For this reason it is necessary to have an assessment in the annual perspective. The most successful predictions are realized when an adequate mathematical model of the object is made. Methods aimed at making the model are divided into two large groups: (1) development of linear stochastic models. This area has received a special name "system identification". This approach has acquired the most complete form in the works of Box and Jenkins, who proposed the ARMA model [48, 49]. Significant capital investments at the first stages restrain the development of RES bioenergy [50]. According to some researchers, it is possible to increase the efficiency of renewable energy sources in electrical distribution networks by choosing the optimal power of asynchronous generators and compensating facilities, choosing the optimal connection schemes for RES, in automation of management and optimization of its work as a part of electric system that allows to reduce losses of the electric power in electric networks, and also to reduce prime cost and to increase volumes of the generated electric power [51–53]. The roadmap for the development of bioenergy in Ukraine until 2050 should take into account [54, 55]:

- growth of the share of bioresources in the structure of solid biofuel consumption up to 60% and 20% of the total volume, respectively, in 2050;
- minimal growth in the use of wood biofuels 1.2 times in 2050;
- a significant increase in the production of biogas and liquid biofuels up to 4.7 million tons of oil equivalent per year in 2050;
- launch and growth of production of biomethane and motor biofuels of the second generation up to 2.4 million tons of oil equivalent per year and 0.43 million tons of oil equivalent per year, respectively, in 2050.

5 Conclusions

Studies show that Ukraine uses no more than 10% of its bioenergy potential of sunflower husks. At the same time, the existing bioresource potential of only sunflower husks can provide light for about 5 million people. Investments in obtaining alternative electricity from sunflower husks are estimated at 1.9 billion dollars.

The creation of agricultural holdings is a model for the further development of the agricultural sector of Ukraine's economy, which will bring it to a qualitatively new trajectory of stable, highly efficient and competitive operation that will allow solving priority tasks. In addition, this strategy is designed to revive domestic agricultural production and to ensure an ecologically balanced transformation of rural areas and settlements. Studies have proven the feasibility of using sunflower husk as an alternative fuel for the production of heat energy and electricity on this basis for the production of granular organic fertilizers from ash. Implementation of these measures on a comprehensive basis, on an industrial scale, will solve environmental, economic and energy problems of the industry: recycle waste, obtain alternative energy sources, increase profitability, ensure organic production of environmentally friendly fertilizers and increase the manufacture of organic products.

To realize competitive advantages, a constructive, more predictable state policy in the sphere of RES is needed, which should become a priority in the system of economic transformations in the conditions of the global economic crisis. First of all, it concerns the strategy design for the development of the sector; improvement of legislation and settlement of property relations; free access to credit for the development of market infrastructure and the elaboration of a range of motives for investors, especially those who invest in innovative projects for its development.

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