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Bioenergy potential of agricultural enterprises

Scientific problem. Under the conditions of globalization of the economy, the problems associated with increasing of the efficiency of agricultural production along with reduction of the negative impact on the environment are becoming more important. This requires agricultural enterprises to make economically balanced decisions based on using of renewable energy sources of plant origin in the production process and implementation of the available bioenergy potential of agricultural production along with compliance with the criteria of sustainable development. One of the essential component of the sustainable development of Ukraine is the provision of the national economy with diversified energy resources, including ones to be supplied by agrarian sector. All these factors combined are forming preconditions for creation of an independent supplier of energy resources both at the national and local levels on the basis of agricultural sector of Ukraine. At the national level this will promote diversification of sources of energy supply, at the local level it will stimulate the development of rural areas through the development of infrastructure and the creation of new jobs in rural areas.

Analysis of recent researches and publications. The use of agricultural bioenergy potential if one of the key components of a stable development. The investigations and analysis of trends in the development of agricultural enterprises' bioenergy potential helps to create new conceptual approaches to its determination, statistic recording, use and implementation. Nowadays the investigations, with regards to methods of determining energy potential in primary remnants of agricultural products in Ukraine, are reflected to a certain extent in the studies of many Ukrainian scientists, such as: Guelyetukha G.G. [13], Klymchuk O.V. [9], Kliuss S.V., Zabarnyi G.N. [10], Messel-Veselyak V.Y. [17], Savchuk V.K., Makarchuk O.G. [11], Sinchenko V.M. [7] et al. The quick change of the conditions on the energy markets and ongoing progress in renewable energy science and technology including change of the price component (cheapening), require focusing on researching of the economics of formation of bioenergy potential of agricultural enterprises.

The objective of the article – to research the economical essence of formation and utilization of bioenergy potential of agricultural enterprises and to give guidance of how to apply it practically.

Statement of the main results of the study. The agricultural industry of Ukraine is forming the food supply security of the country, however it does not play an effective role in energy security. Holding the substantial potential to supplying agricultural residues, agro sector of Ukraine shows slow pace of development of supply of renewable energy resources.

In the context of this the Member of the NAAS of Ukraine V.Y.Mesel-Veselyak emphasizes that primary goal of the strategy of development of alternative sources of energy in agricultural sector is to reduce dependence, in respect of energy import and diversify of the supply of energy resources for bioenergy production with agricultural residues [17]. According to V.Y.Mesel-Veselyak the main strategic goals of development of production of alternative sources of energy by agricultural

sector are: 1. increasing of output of biogas and organic fertilizers production from animal industry by-products; 2. increasing of output of biodiesel and bioethanol from crop industry residues; 3. Increasing the amount of straw utilization.

According to Bioenergy Association of Ukraine the existing biomass potential in agrarian sector of Ukraine is capable to provide more than 27 mln t of eqv. fuel/year. The economical potential of agricultural biomass makes up 12.2 mln t eqv.fuel/year, including 10 mln t eqv.fuel/year of energy crops [13]. The key components of bioenergy potential of agricultural enterprises include primary wastes from the production of cereal and industrial crops (wheat straw, wastes from grain maize production, sunflower) and energy crops, which are strongly developed in Ukraine in industrial scales during last years.

The use of biomass as an alternative energy source is more and more practically applied in the business activities of enterprises in Ukraine. Taking into account a high value of fossil energy resources and instability of their price environment, the enterprises would like to replace the "classic" sources of carbohydrate fuel with the energy, which is generated from biomass [11].

In accordance with the forecasts, the primary energy consumption will increase almost twice [2, page 17] all over the world till the year of 2050, in this case almost 40% of energy requirements will be covered at the expense of renewable energy sources, including 30% at the expense of bioenergy, which will be based on biomass of several agricultural and another high-effective bioenergy crops (silvergrass, willow, poplar, etc) [7, page 4].

The existing data [5] show that nowadays biomass, as a fuel, occupies the forth place in the world in accordance with the generation amount and energy consumption. The share of biomass in the total primary energy supply reaches 10% and is equal to 1272 mln t o.e./year. Biomass occupies the forth place in the sector of heat energy generation after natural gas, coal and oil. It is worth noting that the significant successes have been achieved by the European Union in developing bioenergy potential at the expense of biomass. The share of biomass in the general energy consumption in EU has increased from 3% in the year of 1995 almost up to 10% nowadays, and the share of energy consumption from renewable sources has increased from 6.3% in the year of 1990 up to 16.5% in 2014 [14]. This indicator in much higher in some countries as compared with average European. In Latvia, in particular, the share of biomass in the gross domestic energy consumption makes up around 28%, in Sweden – 22%, in Finland – 21%, in Denmark – 17% and in Austria – 16%. Regarding Ukraine, in accordance with the data of Ukrainian energy balance for the year of 2015 [8] the share of energy from biofuel was 3.6 % from the final energy consumption, or 2.3% in the total primary energy supply, and in the year of 2015 the relative share of biofuel was the highest (81.3%) in the production profile of renewable energy sources". In accordance with the calculations of the Bioenergy Association of Ukraine, the replacement of gas with biofuel was 3.26 bln m3/year in 2015 according to "biofuel and wastes generation" indicator, and the average growth rate in the period of 2010-2015 was 38%/year [4]. This points accordingly at a positive trend in replacing carbohydrate fuels with bioenergetic ones and mastering technologies of their conversions.

As to the distribution of bioenergy resources (Figure 1) in total heat energy generation in Ukraine, the existing statistic data [15] point at the beginning of prevailing agricultural bioenergy resources over bioenergy resources of forest-based sector, which stipulates the availability of a trend toward the development of agricultural enterprises' bioenergy potential.

Also it is worth mentioning that Ukraine demonstrates a positive trend toward the increase of electrical power generation with the use of biomass. For example,18,547 thousand kW/h of electrical energy was generated in the year of 2012, at the same time this indicator was 163,729 thousand kW/h in 2016. The data on trends in electrical power generation from biomass are shown in Figure 2.

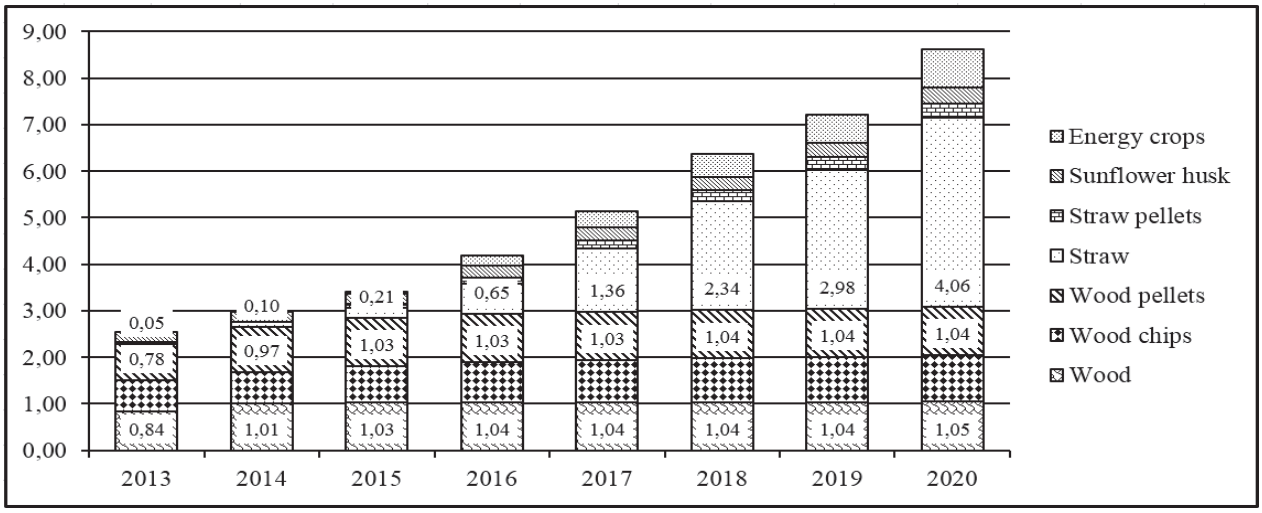

Figure 1. The share of bioenergy resources in heat energy generation in Ukraine, mln t oil.equiv.

Source: Bioenergy Association of Ukraine [15].

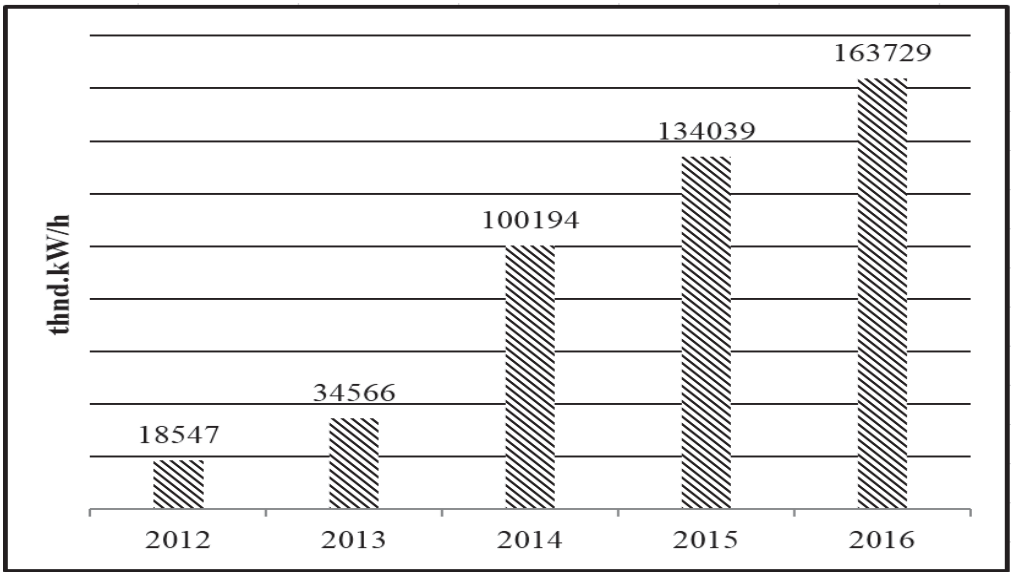

Figure 2. Actual amount of electrical energy, which was generated from biomass in the year of 2016, thousands kW/h.

Source: Ukrainian association of renewable energy, (UARE) [15].

As on April 01, 2017, the electrical power generation in Ukraine from renewable sources is distributed in the following way in the energy balance: biomass – 9%, solar power stations 22%, wind power stations 54%, small hydroelectric plants – 15%. Totally since the beginning of 2017 480.2 mln kW/h of energy was generated from renewable sources as on April 01. The data are graphically represented in Figure 3.

For the sake of comparison, it is worth mentioning the data [16] on generating electrical energy from biomass by Germany, the EU leader in using renewable energy sources. For example, 19.5 TW/h of electrical energy was generated in Germany from renewable energy sources in March, 2017. The share of biomass was 4.5 TW/h. In general Germany provided 49% of electrical energy generation at the expense of renewable energy sources in March 2017.

As to Ukraine, the use of energy from biomass of primary wastes from cereal and industrial crops production is considered to be perspective in this aspect, namely: sunflower, maize and wheat This is explained by the fact that Ukrainian agriculture is capable to provide a considerable amount of primary wastes from the relevant crops production for energy generation purposes. During several years Ukraine

holds the leading positions in the world production of sunflower, producing 11.1 thousand t (the years of 2015 – 2016), at an average crop yield of 21.6 centner/ha, which makes up 28.4% of the world gross collection of sunflower (table 1). The relevant data on the biggest sunflower producers in the World are shown in table 1.

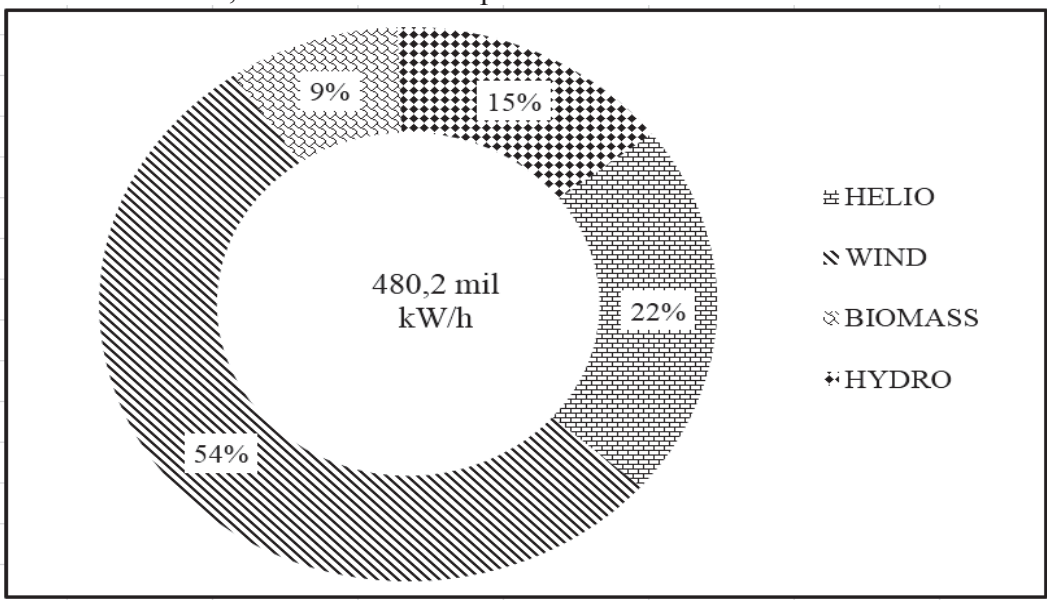

Figure 3. Energy generation from renewable sources in accordance with the energy sources type as on 2017.

Source: Ukrainian association of renewable energy, (UARE).

Table 1. The biggest sunflower producers in the World, gross output, (thous.t)

#	Region/ Country	Area, thous. hectares			Crop yield, ton/Ha			Gross output, thous.ton		
		2013/ 2014	2014/ 2015	2015/ 2016*	2013/ 2014	2014/ 2015	2015/ 2016*	2013/ 2014	2014/ 2015	2015/ 2016
1	Ukraine	5090	5212	5166	2,17	1,94	2,16	11050	10133	11181
2	Russia	6795	6371	6454	1,45	1,31	1,42	9842	8374	9173
3	EU (28)	4617	4289	4182	1,96	2,10	1,82	9054	9000	7611
4	Argentina	1260	1440	1250	1,64	2,19	2	2065	3160	2500
5	China	930	949	930	2,61	2,63	2,69	2424	2492	2500
6	USA	593	611	728	1,55	1,65	1,82	917	1007	1326
Total (World)		24024	23280	23077	1,72	1,76	1,74	41605	39420	39342

Source: United States Department of Agriculture, State statistics service of Ukraine.

The production of sunflower, together with the production of spiked cereals, grain legume crops and maize, is a dominating profile in Ukrainian agriculture. As compared with the year of 1990, the volume of area, from which sunflower was collected, increased more than 3 times from 1626 thousand ha to 5166 thousand ha in the year of 2015. At the same time the yield capacity of these crops increased from 15.8 centner/ha in 1990 up to more than 21 centner/ha in 2015. The sunflower production in the years of 1990 – 2015 increased more than 4 times from 2.6 mln t up to 11.1 mln t and more than 3 times as compared with the data on gross collection in 2000 (table 2).

Sunflower, being today one of the most widespread agricultural crops in Ukraine, is capable to ensure the formation of a portion of bioenergy potential both in the enterprises, which produce sunflower, and in the agricultural sector as a whole at the expense of by-product wastes during production. Taking into account the volumes of sunflower production in Ukraine and the average tailings-to-seeds ratio (1.9:1), let's calculate the theoretical potential of by-products as a product of gross collection and tailings-to-seeds ratio factor. The theoretical potential of primary wastes from sunflower production was accordingly 21.09 mln t in Ukraine.

Table 2. Production of sunflower in Ukraine, mln.ton

Index	Year							
	2000	2005	2010	2011	2012	2013	2014	2015
Gross production, mln.ton	3,5	4,7	6,8	8,7	8,4	11	10,1	11,1
Crop yield, 100 kg/Ha	12,2	12,8	15	18,4	16,5	21,7	19,4	21,6
Area, thous. Ha	2842	3689	4193	4526	4717	5090	5212	5166

Source: United States Department of Agriculture , State statistics service of Ukraine.

When calculating the technically achievable energy potential (TAEP) of primary wastes from sunflower production, it is necessary to consider the existing technological and structural conditions and technological capabilities of agricultural enterprises. Nowadays the mostly widespread technologies of sunflower harvesting in Ukraine are:

a) using combine harvesters with reapers and choppers, providing of plants, threshing of baskets and seed collection in a hopper. Stems and threshed baskets are crushed using a chopper or scattered over the field or collected in a trailer.

b) threshing of baskets and their collection as a whole in harvester-stacker with the further shocking. Sunflower stems are cut and crushed using disk harrows. The crushed mass is raked up in windrows, shocks are formed from them in its turn.

In accordance with the existing technology, technological losses occur during sunflower harvesting and its transportation, which are assumed to be equal to an average factor of 0.3 [10, page 9]. It is also worth taking into account the technical accessibility factor during calculation of the technically achievable energy potential, thus considering the existing technological peculiarities of sunflower harvesting. At the same time the technical accessibility factor allows to determine the total volume share of primary wastes of sunflower plant remains, which can be actually collected and, as the result, is accessible for further technical processing and use. It is assumed that the average technical accessibility factor is equal to 0.8 [12, page 14] for all types of agricultural plants. The technically achievable potential of primary wastes from sunflower production will be calculated in the following way:

$$TAPW = GC \times (1 - WF) \times TAF \quad (1)$$

where: GC – gross collection, WF – wastes factor, TAF – technical accessibility factor. In accordance with the calculations, the technically achievable energy potential of primary wastes from sunflower production was 12.26 mln t in Ukraine in the year of 2015.

The economical potential (EP) calculation of primary wastes from sunflower production allows to determine the share of technically achievable energy potential, which conforms with economic feasibility criteria under the existing conditions [1, page 9]. This indicator is calculated together with the energy use factor, which characterizes the share of wastes (stems, leaves, etc), which can be used in order to obtain energy. In accordance with the existing calculations of Ukrainian scientists, the energy use factor is assumed to be equal to 0.25 for all types of agricultural plants [12, page 14]. As the result, the economical potential of primary wastes from sunflower production is calculated in the following way:

$$EP = TAWP \times EUF \quad (2)$$

where: EP – economical potential, TAWP – technically achievable energy potential, EUF – energy use factor. In accordance with the calculations, the economical potential of primary wastes from sunflower production was 3.06 mln t in Ukraine in the year of 2015.

The energy potential (ENP) of primary wastes from sunflower production is calculated using the equivalent fuel conversion factor (EFC) (or the coal equivalent conversion factor (ECC)). The following formula (Formula 3) is used for specifying the crop energy potential to equivalent fuel conversion factor:

$$EFC = \frac{Tv}{7000 \frac{kcal}{kg}} \quad (3)$$

where: TV - lower calorific value of the crop straw (3500 kcal for sunflower stems), 7000 kcal – equivalent fuel calorific value.

In order to specify the energy potential of primary wastes in coal equivalent (ECC), the lower calorific value of the coal, which dominates in the national industry [3], is used in Formula 3 in the denominator. For example, this is bituminous coal in Ukraine with a lower calorific value of 7500 kcal. EFC indicator for sunflower stems will be equal to 0.5 and ECC indicator will be equal to 0.46 accordingly.

The energy potential is calculated using the formula:

$$ENP = EP \times EFC, \quad (4)$$

Using the coal equivalent allows to value the actual cost of energy potential through the cost of the coil. In this case the coefficient of the coal equivalent (ECC) is used:

$$ENP = EP \times ECC, \quad (5)$$

As the result, in accordance with our calculations the energy potential of primary wastes from sunflower production in Ukraine was 1.53 mln t eqv.fuel in the year of 2015, which is an equivalent to 1.4 mln tons of coal.

For the effective use of sunflower by-products for energy purposes, it is necessary to ensure their collection and processing. This requires the following actions: drying of stems and remains in the field, their baling, transporting to the site of processing with the further use as fuel for boilers, co-combustion with coal / gas or raw material for producing granules and briquettes. Nowadays the use of sunflower by-products in not used for energy purposes (except husks) in Ukraine. The similar situation requires an all-round investigation regarding the possibilities of including not only sunflower, but also the other crops in the list of bioenergy sources, which are produced by agricultural enterprises of Ukraine.

Conclusions. The effective development of agricultural and industrial sector of Ukraine requires the all-round investigation of available sources off bioenergy resources and the development of strategy of their energy use in accordance with International commitments, undertaken by Ukraine. Methodological and technical approaches were worked out with the purpose to determine the bioenergy potential of agricultural enterprises based on the example of primary wastes from sunflower production. It was found that there is an unengaged potential of bioenergy raw materials supply sources, the value of which is almost €95 mln in the form of fuel briquettes (in accordance with the actual prices of 2016 for straw briquettes in Ukrainian market taking into account a calorific difference). The energy use of cereal and industrial crops enables to ensure two harvests for agricultural producers: food and energy, thus creating the additional sources of income. The experts think [6] that 30% of straw, which is produced in agriculture, 40% of primary wastes from sunflower and maize production are capable to replace 10 bln m3 of natural gas out of 34 bln m3, which Ukraine uses as a whole. Around 15% of all arable lands were averagely under sunflower production in Ukraine during the last 5 years, and the total planting area of this crop was more than 5000 thousand ha in the years of 2015 - 2016.

As the result, in the context of a possible energy use of primary sunflower residues and a large scale of its production it is possible to state that the significant perspectives of this alternative resource are available in Ukraine along with positive impact it can have on the country's security of energy supply.

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Рейтингова оцінка регіонального соціально-економічного розвитку аграрного сектору економіки України: методика, розрахунки

Постановка проблеми. Законом України „Про засади державної регіональної політики” від 5.02.2015 р. [6] визначено, що регіонами України є „територія Автономної Республіки Крим, області, міста Київ та Севастополь”. У наших дослідженнях оцінюється регіональний аграрний розвиток по областях за 2015 рік без урахування, як визначено Державною службою статистики України, тимчасово окупованої території Автономної