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ECONOMIC BASIS OF FORMING AND IMPLEMENTATION OF THE BIOFUEL PRODUCTION POTENTIAL IN UKRAINE

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Abstract: *It is shown that economic growth is impossible without a balanced innovative development of the main sectors of the national economy, the introduction of energy-saving technologies for the production of competitive products. Methodological research basis is the dialectic method of knowledge, the system approach to studying the initial methodological preconditions of forming and implementation of the biofuel production potential in Ukraine, the fundamental positions of economic theory and the groundwork of scientists. In its process, methods such as theoretical generalization, system analysis, synthesis, balanced calculations, computation, and constructive were applied. The economic base of forming and implementing the potential of biofuel production in Ukraine are systematized. The trends of the energy intensity of the gross domestic product in Ukraine and in certain regions of the world are investigated. The cause-effect relationships of the high energy intensity of Ukraine's GDP and the low energy efficiency are determined. On the basis of energy balances, the dynamics of production of biofuels and energy-intensive wastes are analyzed. The theoretical, technical and economic potentials of biomass suitable for the production of biofuels are determined. The structure and dynamics of the biofuel production potentials are analyzed, the investment support of the implementation of the energy potential of biomass in Ukraine is shown. Must to be taken substantiated measures for effective development of the biofuel production potential in Ukraine.*

Key words: *biofuel, alternative energy, biomass potential, agrarian economy.*

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1. Introduction

Despite a significant number of government initiatives, the economy of Ukraine is currently energy consuming, and the presence of temporarily occupied territories has further increased the country's energy deficit.

In such conditions, an increase in the use of alternative energy resources, in particular biofuels, is strategically important because it can create the prerequisites for diversifying energy sources, thus increasing Ukraine's energy independence. It can also ensure the preservation of natural resources, the reduction of emissions into the environment, full use of the available biomass potential, the creation of new jobs, especially in rural areas, and others.

In the 18th century, physiocrats were based on the fact that the only independent and primary factors of production were nature and earth (soil). In particular, these ideas are thoroughly developed in [15], where the laws of the relationship between human labour and the distribution of solar energy on the earth's surface are investigated. It is shown that the growth of the total energy potential of humankind is due to solar activity, intensive human work, and raising cattle on the ground.

Based on the works of physiocrats, the formula for the energy of progress: capital + entropy was substantiated in [16]. In this case, energy flows are created exclusively in agriculture and form the main measure of value - grain.

Products which are produced on earth are "energy" because they are created by nature and solar energy. Their rational distribution is the actual basis for socio-economic development. According to [16], in general, this distribution is as follows: 1/5 (straw and grass) - for feeding livestock, 1/5 (straw and grass) - for fertilizing the soil with organic matter, 3/5 (grain) - for final consumption (distributed on 1/5 - to grain producers, workers in industry, and for state needs). Accordingly, therefore, 3/5 of the products from the agrarian sector of the economy are considered the basis for socio-economic progress, 2/5 of which are in the form of organic biomass and 1/5 in the form of grain consumed by agricultural producers. However, the remaining 2/5 determine the level of entropy in society. In general, this distribution of organic biomass determines its rational volume, which can be used as a source of bioenergy.

The biomasses suitable for the production of biofuels include:

- Woody biomass (firewood, logging residues, sawdust, bark, shavings, chips, other waste);
- Cultivated bioenergy plants (willow, poplar, miscanthus, sorghum, triticale, corn, sunflower, etc.);
- By-products of plant growing (straw, leaves, stalks, baskets, rods, etc.);
- Waste from crop production (husks, shells, grape cake, pulp etc.);
- By-products of animal husbandry (dry dung, manure, biodiversity animal debris waste from poultry farms and slaughterhouses);
- Charcoal (solid residues from the distillation and pyrolysis of wood and other plant materials);
- Industrial waste (solid residues from the distillation and pyrolysis of wood and other plant materials);
- Recoverable and non-renewable solid municipal and household waste.

Depending on the type of biomass, anaerobic digestion, gasification, pyrolysis, burning, leaching, fermentation of sugars, pressing and granulation are used to obtain various biofuels [2].

Currently, the main types of biofuels are bioethanol, biobutanol, biomethanol, bio-dimethyl ether, bio-diesel fuel, biogas, bio-hydrogen, bio-oil, cold-pressed vegetable bio-oil.

Solid biomass includes wood biomass, charcoal, crop by-products, selected secondary processing waste from agricultural products, dry manure, and residues from treatment plants. In turn, each type of biofuel has its own micro type which is determined by the peculiarities of the technological process or the type of biomass from which this type of energy resource can be obtained [1].

Thus, it can be argued that the biomass potential is multifaceted. It's forming and subsequent implementation is the urgent tasks of Ukrainian agro- economic science.

2. Methodology

When calculating the energy balance of Ukraine, biofuel is taken into account along with energy-intensive industrial, recoverable and non-renewable municipal and household waste.

The energy potential of biomass suitable for the production of biofuels in Ukraine can be assessed differently.

In this study, an approach based on the calorific value of biomass was chosen. Then the total energy potential can be determined by the formula (1).

$$TEP = \sum_{i=1}^{n} Q_i Cwp_i Coe_i, \qquad (1)$$

where:

- *TEP* is the total energy potential of biomass suitable for the production of biofuels [tons of oil equivalent];
- Q_i – the volume of production of the i-th type of main bioproduction [tons];
- Cwp_i – the coefficient of waste generation or the conversion of the i-th species of the main bioproduction into biofuel;
- Coe_i – the conversion factor of the i-th type of biomass (biofuel) into tons of oil equivalent;
- n – the number of types of biomass suitable for the production of biofuels.

At the same time, the biomass energy potential is divided into theoretically possible (theoretical), technically accessible (technical) and expedient (economic) potentials [6].

In turn, the theoretical potential is the total maximum amount of terrestrial biomass theoretically available for energy production in fundamental biophysical limits [6].

The technical potential is the fraction of theoretical potential available under certain technical and structural conditions and current technological capabilities [6].

The economic potential is the share of technical potential that meets the criteria of economic feasibility under these conditions [6].

In assessing the total energy potential of biomass suitable for the production of biofuels, we do not share the (sometimes encountered) view of the need to consider peat (as it is a separate type of combustible mineral, not biomass).

For the economic comparison of different types of biofuels and energy carriers, it is advisable to calculate the unit cost of energy units (2):

$$SEFC_i = \frac{AFP_i / AER}{LCV_i}, i = 1,...,n, \quad (2)$$

where:

- $SEFC_i$ is the unit cost of an energy unit of biofuel and (or) energy carrier of the i-th type [euro/gigajoule];
- AFP_i – the average selling price (excluding VAT) of a biofuel type and (or) energy in Ukraine (UAH/ton, for natural gas UAH/thousand-cubic meters, for electric energy UAH/kilowatt-hour);
- *AER* – the average annual exchange rate of the National Bank of Ukraine [UAH/Euro];
- LCV_i – the minimum calorific value of the i-th type of biofuel and (or) energy carrier [megajoule/kg];
- *n* – the number of biofuels and (or) energy sources included in the calculation.

The information base of this study is the official statistics of the State Statistics Service of Ukraine regarding the energy balances, macroeconomic indicators, and production volumes of the main types of bioproduction (which form the potential of the national bioenergy) [18-22].

The average selling price of natural gas for industrial consumers was defined as the average chronological (based on the price lists of the National Company "Naftogaz") [13].

The average retail price for the sale of electrical energy for legal entities is defined as the average chronological (based on information from the National Energy and Utilities Regulation Commission of Ukraine) [14].

The source of the data on wholesale selling prices for coal and certain types of biofuels was the reporting of the Ministry of Energy and Coal Industry of Ukraine [11].

3. Baseline Initial Data and Sources

As is well known, with the proclamation of independence of Ukraine, the course for market transformations and integration into the world economic system was chosen. However, the low energy efficiency of industrial production, the high energy intensity of the GDP (compared to other countries), caused by the technological lag behind the market leaders, became one of the reasons for the crisis in the Ukrainian economy in the early 1990^s.

Thus, the energy intensity of the gross domestic product of Ukraine in 1990 was 3.5 times higher than the corresponding value in the member countries of the European Union, 2.6 times the average world level, 2.1 times the level of the least developed countries of the world (Table 1).

In this table, the GDP is estimated in international dollars at the purchasing power parity of 2011, the countries are divided by level of development according to the UN classification.

Due to a number of unfavourable conditions in Ukraine, since 2014 there has been a significant drop in the production of the gross domestic product and a long period of recession has come.

Therefore, the annual decrease in the energy intensity of Ukraine's GDP in 2011–2017 was mainly caused by a decrease in the production volumes of energy-intensive industrial products, a general economic decline, rather than the effect of energy saving.

Table 1

Intersectoral Energy intensity of the gross domestic product in Ukraine and selected regions of the world in 1990–2015, kg of oil equivalent per $ 1,000 of the GDP in PPP-2011 (Source: compiled and calculated by the authors according to the World Bank Development Indicators, and the Ukraine State Statistics Service, estimates for Ukraine in 2015)

Year	Ukraine	Germany	China	USA	Canada	OECD	EU	The most developed countries	Under developed countries	World on average
1990	464.1	141.3	502.5	207.0	242.9	155.9	134.2	155.7	223.1	180.9
1991	507.4	131.8	447.8	208.8	247.6	155.9	134.0	155.6	225.1	180.1
1992	488.8	126.9	405.4	205.7	251.1	154.6	131.4	154.3	226.9	177.2
1993	505.1	126.9	377.1	203.7	252.8	154.8	131.6	154.7	228.5	175.1
1994	558.4	123.2	349.3	199.5	250.5	152.7	127.5	152.7	231.2	171.3
1995	628.0	122.4	338.1	196.7	247.2	152.2	128.7	151.8	228.2	170.2
1996	639.3	125.5	316.1	193.7	248.1	151.9	130.4	151.8	219.0	168.0
1997	630.6	122.2	289.1	187.2	240.4	147.9	125.6	147.8	214.6	163.1
1998	607.9	119.1	269.9	180.8	230.2	144.2	122.7	144.7	212.5	159.8
1999	606.3	114.1	255.5	177.4	225.1	142.1	118.2	142.8	211.0	157.6
2000	567.1	111.4	242.9	175.2	220.2	139.5	114.5	140.3	204.2	153.9
2001	520.5	112.8	233.3	170.3	213.2	137.3	114.6	138.5	201.9	152.2
2002	500.3	110.3	228.2	169.2	207.6	136.0	112.8	137.7	199.1	151.2
2003	487.8	110.5	237.0	164.9	214.7	135.0	113.5	136.2	195.9	151.0
2004	432.8	110.0	245.5	162.2	213.1	133.1	111.6	134.5	185.9	149.6
2005	418.6	108.4	243.7	157.7	207.7	130.2	109.6	131.0	176.6	146.8
2006	375.0	107.4	236.3	152.1	200.0	126.4	106.2	127.5	169.8	143.4
2007	352.6	98.5	223.8	152.1	197.2	123.7	101.1	124.9	160.0	139.8
2008	333.0	98.5	210.5	148.6	196.9	121.9	100.0	123.4	156.0	137.7
2009	332.5	97.7	205.6	145.3	195.3	120.8	98.5	122.4	155.1	137.4
2010	369.0	98.9	205.2	145.0	191.4	121.2	100.3	123.3	151.0	137.8
2011	334.3	90.6	200.9	141.2	190.3	116.6	94.8	118.3	149.5	134.5
2012	322.9	90.5	193.4	136.0	184.8	114.3	94.4	116.4	146.8	132.6
2013	306.2	91.8	185.2	135.3	182.5	113.0	93.1	115.1	143.8	130.0
2014	298.1	86.8	175.3	134.0	182.8	109.9	88.0	112.7	144.6	126.5
2015	281.7	86.9	no data	128.2	176.2	107.0	86.8	109.4	no data	no data
2015 to 1990	60.4 %	61.5 %	no data	61.9 %	72.5	68.6 %	64.7 %	70.3 %	no data	no data

In general (if not to take into account the structural transformation of the national economy) in 1990-2017, the Ukrainian economy (in the context of the energy intensity of the gross domestic product) developed in accordance with global and European trends. However, the expenditure on energy resources per 1,000 dollars of the GDP remained too high.

This led to the preservation of the gap in energy efficiency and production technologies at the level of 1990.

In the context of globalization and European integration, this led to the noncompetitiveness of Ukraine's products in the world and on domestic commodity markets.

According to [10], the production of biofuels as a sub-industry in Ukraine (in commercial volumes) began in 1997. At that time, in the structure of industrial production costs, the energy was about 42% of material costs.

At this time, the reconstruction of two distilleries in the Vinnitsa regional state association of alcohol and distillery industry was carried out.

The production of bioethanol (a biological high-octane oxygen-containing additive to automobile gasoline) started [10].

However, until now, the share of biofuels and energy-intensive wastes in the structure of the total supply and consumption of Ukraine's energy resources remained low (Table 2). In turn, energy-intensive wastes are wastes that occur in households, industries, medical facilities and services, include substances that are decomposed by microorganisms, and are burned in special installations [1].

Table 2

The share of biofuels and energy-intensive wastes in the structure of the total supply and final consumption of energy resources of Ukraine [%]

(Source*: calculated by the authors)*

Indicator	**Years**							
	2010	2011	2012	2013	2014	2015	2016	2017
Production	1.9	1.8	2.0	2.2	3.1	4.2	5.0	6.1
Import	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0
Export	0.0	0.0	0.9	0.8	7.2	37.2	38.8	27.9
Total primary energy supply	1.1	1.2	1.4	1.6	1.8	2.3	3.0	3.4
Final consumption	1.3	1.4	1.4	1.6	2.0	2.5	3.3	3.8

State plans for the development of alternative energy and energy conservation (approved by the Cabinet of Ministers of Ukraine in 2014, the National Renewable Energy Action Plan for the period up to 2020, the Energy Strategy of Ukraine for the period up to 2035 "Safety, energy efficiency, competitiveness" etc.) are not effective enough.

The increase in the share of biofuels and waste in the structure of final consumption in 2014-2017 led to an increase in the production of woody biomass. It began to be actively used in the domestic sector as a substitute for coal and natural gas (due to the substantial increase in prices of the latter).

Thus, the specific cost of electrical energy for legal entities (despite the significant potential of nuclear energy in Ukraine) in 2018 was 8.6 times higher than the similar value of biofuels made from straw and corn stalks, 5.5 times higher than the value of biofuel pellets made from husks.

Somewhat smaller, however, a rather

significant gap in the unit cost of energy is also observed between natural gas of own production and alternative fuels (Figure 1).

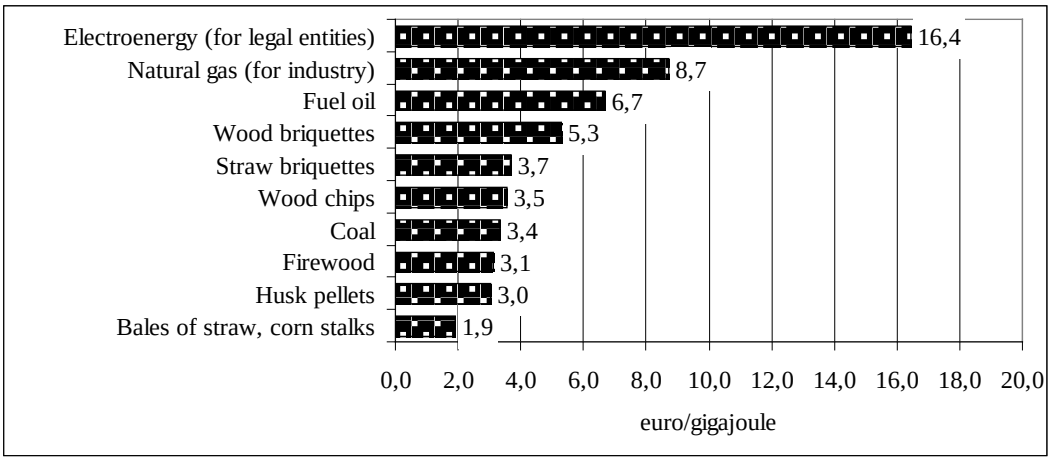

Fig. 1. *The unit cost of energy of certain biofuel types and energy in Ukraine in 2018 [Euro/gigajoule] (Source: calculated by the authors using [4])*

In general, between 2010-2017, the volume of biofuel and energy-intensive waste production increased threefold, its transformation for primary or secondary energy conversion for processing into energy derived derivatives increased 2.3 times, and the final consumption increased 1.8 times (Table 3).

The export-import balance is active with the 15-time predominance of export operations, without the use of international bunkering.

Table 3

The energy balance of biofuels and energy-intensive wastes in Ukraine in 2010-2017 [thousand tons of oil equivalent]

Indicator	**Years**							
	2010	2011	2012	2013	2014	2015	2016	2017
Production	1458	1580	1738	1924	2399	2606	3348	3618
Import	0	0	1	4	25	30	38	0
Export	0	0	75	65	502	539	554	542
International bunkering	0	0	0	0	0	0	0	0
Stock change	18	-17	31	16	12	5	-1	-30
Total primary energy supply	1476	1563	1695	1879	1934	2102	2832	3046
Transformation	492	523	665	756	733	819	1108	1154
Final consumption	984	1040	1030	1123	1201	1283	1724	1892
Non-energy use	0	0	0	0	0	0	0	0

(Source: compiled by the authors)

The consumption of biofuels as a raw material in various industries (non-energy use) during the study period was not-existent.

The increase in biofuel production over the study period is accompanied by a significant increase in its exports.

At the same time, the average price for solid biofuel in the EU in 2017 was 167 euro/ton, but in Ukraine - 55 euro/ton (3 times less), which led to an increase in exports at reduced prices.

Also of concern is the export of quality wood (suitable for further production or processing) as fuelwood or wood waste.

In total, in 2017 Ukraine exported 1.9 million tons of fuelwood in the amount of 130 million euros.

The largest importers (Figure 2) were Romania (28.3%), Turkey (20.3%) and Poland (11.7%).

The price of exports of wood biofuels from Ukraine was higher for Germany and Italy, which was due both to the transportation factor and to the greater purchasing power in these countries, compared to others (Figure 3).

At the same time, the main importing countries of fuel granules (wood, straw, and sunflower pellets of domestic production) were Germany (40.0%), Poland (19.0%), Czech Republic (13.0%), Denmark (6,5 %),

Slovakia (4.5%), Hungary (4.0), and Belgium (3.0%).

The product balance of biofuels in 2014-2017 had a positive trend. Thus, the production of solid biofuels increased by 1.5 times, and biogas increased absolutely.

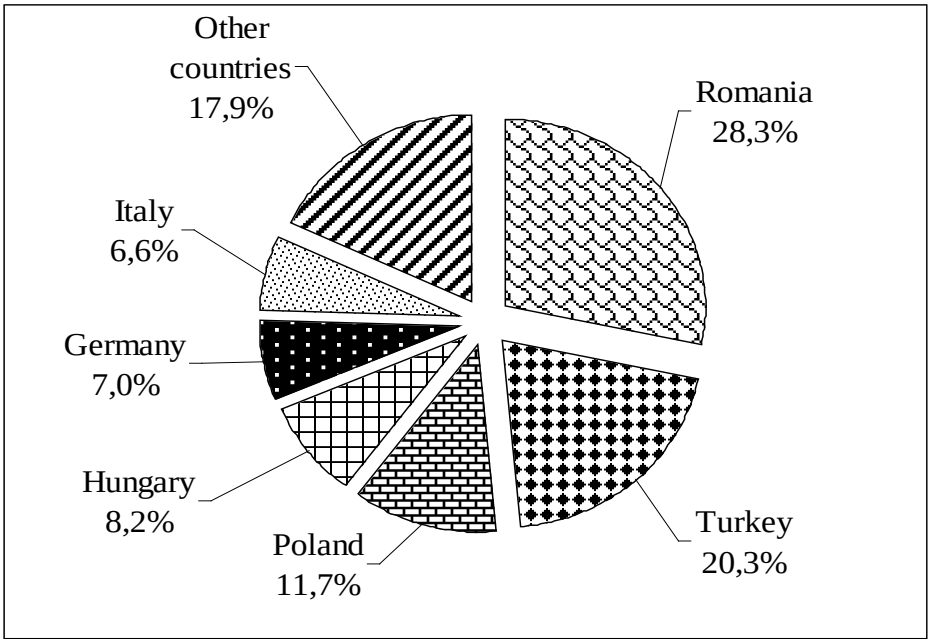

Fig. 2. *Ukraine's foreign trade in wood biofuel in 2017, Export structure [%] (Source: calculated by the authors)*

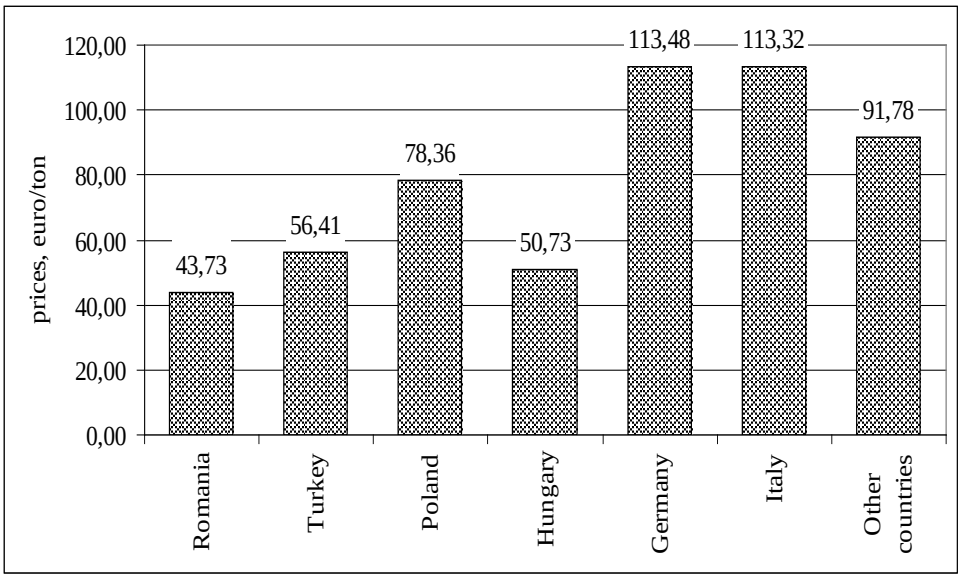

Fig. 3 *Ukraine's foreign trade in wood biofuel in 2017, Export prices [Euro/ton] (Source: calculated by the authors)*

Similarly, the volumes of their domestic supplies and processing were increased (Table 4).

Almost all liquid biofuels in the domestic market of Ukraine are imported. The production capacity of the existing enterprises in Ukraine - producers of solid biofuels are loaded and used by 60%, and, unfortunately, the total technically achievable potential of the country is used only by 17%.

Table 4

Biofuel balance in Ukraine, 2014-2016 (Source: compiled by the authors according to data)

Indicator	Solid biofuels, peta-joules			Liquid biofuels, thousand tons			Biogases, tera-joules		
	2014	2015	2017	2014	2015	2017	2014	2015	2017
Production	99.0	108.1	147.6	26.0	16.0	21.0	0.0	600.0	1601.0
Import	0.03	0.03	0.0	38.0	46.0	54.0	0.0	0.0	0.0
Export	21.0	22.3	17.4	0.0	9.0	4.0	0.0	0.0	0.0
International bunkering	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0
Stock change	-0.5	-0.2	-3.2	0.0	0.0	0.0	0.0	0.0	0.0
Domestic supply	79.3	86,0	126.8	64.0	53.0	71.0	0.0	600.0	1601.0
Transformation	30.5	33.6	53.3	0.0	0.0	0.0	0.0	600.0	1601
Total primary energy supply	0.05	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Final consumption	48.8	52.4	73.5	64.0	53.0	71.0	0.0	0.0	0.0
Non-energy use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4. Consideration and Analysis of Data

According to the energy balances of Ukraine, the structure of the biofuels use and energy-intensive waste is dual, consisting in conversion and final consumption.

Between2010-2017 the share of conversion of biofuels and waste in the total supply of primary energy was 33.3-40.2%.

More than two thirds of the transformation is in the energy sector, represented by power plants, combined heat and power plants, and heating plants.

Final consumption is the use of energy for the production of all types of non-energy products, transport, and services. During the study period, its share decreased by 4.5%, which indicates a gradual transition to alternative types of fuel (Table 5).

Table 5

Structure of use of biofuels and energy-intensive wastes in Ukraine [%] (Source: calculated by the authors)

Indicator	Years							
	2010	2011	2012	2013	2014	2015	2016	2017
Conversion (total)	33.3	33.5	39.3	40.2	37.9	39.0	39.1	37.8
including: energy sector	29.3	28.9	28.3	29.6	26.7	27.4	28.8	27.2
others	4.0	4.6	11.0	10.6	11.2	11.6	10.3	10.6
Final consumption (total)	66.7	66.5	60.7	59.8	62.1	61.0	60.9	62.2
including: production	2.8	2.8	2.7	2.0	2.5	4.1	1.8	1.7
transport	0.0	0.0	0.0	2.5	2.1	1.6	1.3	1.5
household sector	61.9	59.9	55.2	53.0	55.3	52.2	53.2	55.2
trade and services	0.8	2.7	1.6	1.3	1.4	2.2	3.8	3.0
agriculture	1.2	1.1	1.2	1.0	0.8	0.9	0.8	0.8

In the structure of the final consumption of biofuels and waste, the largest share is occupied by the household sector (85.5-92.2%), and the smallest by agriculture.

This indicates an insufficient level of development of utility energy equipment for agricultural producers (in particular, intended for heating greenhouses and livestock buildings).

The transformation structure of solid biofuels in 2014-2017 underwent significant changes.

So, in 2014, two-thirds of the solid biofuels were converted by combined heat and power plants, 4.7% by heating plants, 3.5% by thermal power plants.

In 2017, due to a significant increase in the cost of natural gas and a sharp decrease in the volume of coal mined, a large number of heating plants were transferred to solid biofuels (the consumption of which they grew by 15.6 times).

At the same time, there was a twofold increase in the consumption of solid biofuels by other conversion enterprises.

Partially, these processes occurred due to a decrease in the volume of biofuel conversion by combined heat and power plants, and power plants.

The main final consumers of solid biofuels in Ukraine in 2017 were the population (household sector), as well as trade and service enterprises.

Industrial enterprises (as well as agricultural ones) do not have enough mini-boilers for heating their premises, and therefore their consumption of this type of energy-intensive resource is insignificant.

In 2017, liquid biofuel was completely consumed in the field of automobile transport, both in pure form (biodiesel) and as an additive (bioethanol). Conversely, biogas did not reach the final consumers, but was completely transformed into thermal and electrical energy at thermal power plants and heating plants.

Despite the world experience and the history of biofuel production, there is still a lively debate on the assessment of its potential.

In particular, according to research conducted by the Institute of Bioorganic Chemistry and Petrochemistry of the National Academy of Sciences of Ukraine, if the entire world volume of produced vegetable oil were converted to biodiesel, it would replace only 3% of the oil consumed [12].

If all the grown grain were processed into bioethanol, then this would allow to get 13-15% of the world production of automotive fuel (which is equivalent to about 25% of the oil).

That is, in the global dimension, biofuel as an alternative source of energy is not able to replace oil, gas, or coal by even a third.

In addition, during its production, a large amount of carcinogenic substances, glycerin, methanol, and other chemical compounds are formed.

This has a very negative impact on the environment, disturbing aquatic ecosystems and agrobiocenoses.

Nevertheless, the production of biofuels from agricultural by-products, industrial, municipal and household waste, and woody biomass is a promising direction for the development of alternative energy in Ukraine, a direction for improving the state's energy safety.

5. Results, Overall Recommendations and Perspectives

The calculations of scientists from the Institute of Thermophysics of the National Academy of Sciences of Ukraine show that Ukraine has a significant theoretically possible potential for the production of biofuels.

In 2008, it accounted for 47.8% of the total primary energy supply, and in 2016 it rose to 74.5% [5].

In accordance with the National Action Plan for Renewable Energy for the period up to 2020 (approved by the decree of the Cabinet of Ministers of Ukraine), the potential installed capacity in the bioenergy segment is 15 gigawatt.

However, unlike the theoretical potential, the actual economic potential of the energy biomass for 2008–2017, on the contrary, decreased by 19.0%.

Among other things, the reason for this was represented by changes in the volumes of agricultural production and wood products, and the price situation on the market (Table 6).

In the structure of the energy potential of biomass suitable for the production of biofuels, the largest share is occupied by by-products of crop production, grain, and rape straw (Table 7).

Table 6

Using the energy potential of biomass and its place in the energy supply system of Ukraine (Source: calculated by the authors using data of the Institute of Thermophysics of the NASU on the energy potential of biomass in 2008-2016 [2, 3, 5, 7])

Indicator	2008	2013	2015	2016	2017
Total primary energy supply, million tons of oil equivalent [m.t.o.e.]	134.6	116.1	90.1	94.4	89.6
Final energy consumption [m.t.o.e.]	83.3	70.1	50.8	51.6	50.1
Biofuels and waste: – general primary energy supplies [m.t.o.e.]	1.6	1.9	2.1	2.8	3.0
– final energy consumption [m.t.o.e.]	1.2	1.1	1.3	1.7	1.9
Energy potential of biomass: – theoretical [m.t.o.e.]	64.4	65.0	67.3	70.3	71.8
– technical [m.t.o.e.]	44.6	51.9	57.0	41.1	45.1
– economic [m.t.o.e.]	30.6	28.1	28.8	21.1	24.8
The ratio of the theoretical potential of biomass to the total primary energy supply in Ukraine [%]	47.8	56.0	74.7	74.5	80.1
The ratio of the economic potential of biomass to the total primary energy supply of biofuels and waste [times]	19.1	14.8	13.7	7.5	8.3

Table 7

Structure and level of implementation of the energy potential of biomass suitable for the production of biofuels in Ukraine (Source: calculated by the authors)

Biomass type	Share in total theoretical biomass potential [%]	Technical realization of the theoretical potential of biomass [%]	The level of economic realization of the technical potential of biomass [%]
Haulm, straw	27.5	67.7	30.3
Crop production by-products	44.9	33.6	40.2
Secondary waste processing of agricultural products	1.4	80.0	87.5
Wood biomass	6.6	85.1	65.0
Biodiesel, bioethanol	4.4	71.0	36.4
Biogas	3.7	103.8	40.7
Energy crops	11.5	96.3	94.9

The structure of the sown areas of agricultural crops and their varietal composition significantly affect the dynamics of the energy potential.

Thus, as a result of the action of these factors, the energy economic potential of the primary agricultural waste increased by 2.2 times in 2016 compared to 1990; the woody biomass by 2.6 times compared to 1997, and so on.

In 2017 in the structure of the economic biomass energy potential, by-products of

agriculture occupied 47.1%, energy crops - 40.1%, wood biomass - 12.6%.

The greatest potential of liquid biofuels is concentrated in the Vinnitsa and Poltava regions, biogas - in the Dnipropetrovsk, Donetsk, and Kiev regions.

It should be noted once again that the energy potential of biomass in Ukraine for all the years of the study period was used unsatisfactorily.

In 2008, the level of its implementation was only 68.9%, and in 2017 - 34.5%.

In particular, only 30.3% involved the energy potential of straw, 39.8% - solid household waste, 25.3% - industrial and municipal wastewater, and so on.

The share of implementation of the economic potential of manure and bird droppings was only 1.2%, corn stalks - 0.1%.

The reason is that the processing of such agricultural by-products, solid household and other industrial energy-intensive wastes requires specialized and expensive equipment. But Ukraine lacks the adequate capacity for processing and the necessary funding.

After all (according to the experts of a joint project on the development of bioenergy in Ukraine, the United Nations Development Program and the Global Environment Facility), to replace 10.0% of the natural gas with biomass in the field of municipal energy, investments of about UAH 14 billion are needed. At the same time, natural gas savings of 750 million cubic meters per year can be achieved.

A promising direction for the implementation of the energy potential of biomass in Ukraine is the cultivation of energy crops. As shown by research scientists at the Ukrainian Institute of Bioenergy Crops and Sugar Beet, in 2012-2016 it was quite profitable economically.

Thus, the profitability of energy willow production for the three years of the growing season is 8.0%, for the fifth year and every next two years - 128%; of miscanthus for two years of growing season - 4.5%, for the third and next years - 727%; of rod-like millet for each year from the second of the growing season - 84% [8].

To meet Ukraine's needs for bioethanol (95 million deciliters), the expediency of using up to 6% of all the sown areas is justified [17]. According to some researches and calculations for energy crops in Ukraine, it is possible to use up to 15% of the cultivated areas (with reasonable crop rotations).

For the industrial implementation of the energy potential of biomass in Ukraine (as of 01/02/2019 operational data of the State Agency for Energy Efficiency and Energy Saving of Ukraine), 89 investment projects were registered.

This represents 20.9% of the total number of investment projects in the field of renewable energy. The construction and (or) reconstruction of bioenergy facilities with a total capacity of 304.9 megawatts is expected (Table 8).

Of the total number of registered projects, investment proposals in the production of bioenergy - 55% and biogas - 39% have the largest share.

Now the total potential of power plants in Ukraine is realized on average by 68%.

Obviously, such a quantity is extremely small for the transition of the energy system of Ukraine to bioenergy and the full implementation of the biomass energy potential, which is available and suitable for the production of biofuels.

Table 8

Investment projects in the field of bioenergy in Ukraine as of 01/02/2019 (Source: summarized by the authors according to the State Agency for Energy Efficiency and Energy Saving of Ukraine)

Field of activity	**Number of investment projects**		**power plant capacity [megawatt]**	
	total	implemented	total	implemented
Biogas	35	22	75.7	58.8
Bioenergy	49	17	210.5	131.7
Biomass	5	4	18.7	18.7
Total	89	43	304.9	209.2

6. Conclusions

Obviously, in the competitive environment of the globalizing economic space, Ukraine should search for effective mechanisms to increase the energy efficiency of production, reduce the energy intensity of the gross domestic product, ensure energy security, and so on.

One of these endogenous factors is the use of the biomass energy potential for the development of biofuel production.

The analysis of the statistical data shows that in Ukraine there are opportunities to ensure in this way up to 80% of the final energy consumption.

However, at present, Ukraine's economy remains too energy-intensive, even in comparison with the least developed countries of the world.

This leads to excessive energy waste, a significant increase in the cost of production of final technological conversions. Ultimately, the level of competitiveness in domestic and foreign markets decreases.

Also the energy dependence of the national economy of Ukraine increase significantly. This causes budget overruns, their outflow from the sphere of capital accumulation to the sphere of consumption.

The analysis of the implementation of the potential of biofuels in Ukraine showed that the volumes of its production and consumption are small and are not able to meet even the needs of domestic demand.

Despite the growth of the total theoretical potential of biomass in 2008-2017, its economic potential is used at a level not exceeding 20% of the total supply of primary energy of biofuels and energy-intensive waste.

The reason for this is the lack of institutions to promote the development of bioenergy, of modern equipment for realizing the energy potential of biomass, of subsidiary energy farms in enterprises, the unsettledness of a significant amount of biofuel circulation issues, and the like.

To rectify the situation, there is an urgent need to create a favourable investment climate, provide state support and concessional loans to enhance the construction of biogas plants and plants for processing industrial and municipal waste, a mini-boiler room.

It is also necessary to introduce energy-saving technologies, and the development of production of bioenergy crops within scientifically based limits.

The systematic solution for these issues

is achievable only by the direction of the national economy of Ukraine through neo-industrialization and strategic management of value added chains [9].

This is especially relevant in the agrarian sector of the economy of Ukraine, as the main source of forming of the biofuel production potential.

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