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Ecological-economical aspects of the production of alternative kinds of fuel in agricultural enterprises Ukraine

Andrii V. Doronin[1], Lesia M. Karpuk[2*]

[1]*National Academy of Agrarian Sciences of Ukraine, Department of Agriculture, Melioration and Mechanization, 01010 Kyiv, Ukraine*
[2]*Bila Tserkva National Agrarian University, Bila Tserkva, Kyiv region, 09117 Ukraine*
**Corresponding author:* lesya_karpuk@ukr.net

Abstract

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The analysis of the energy share from renewable sources in gross final energy consumption in developing countries and in Ukraine is presented in the paper. It has been determined that biofuel and waste have the largest share in the production structure of renewable energy sources in Ukraine. But in the structure of energy consumption based on renewable sources the share of biofuel and waste increases constantly in Ukraine. The prospects of the use of crop production output and livestock production waste for the manufacture of alternative fuel at farm enterprises in Ukraine were considered. Preconditions for negative changes in agriculture of Ukraine were studied. The analysis of the cultivation of some agricultural crops and the number of farm animals in Ukraine in 1990-2016 was made. The production efficiency evaluation of some kinds of output at farm enterprises of Ukraine in 1990-2016 was done. Polynomial, which describe the production potential of biogas manufacture at farm enterprises in cattle and swine production in terms of natural gas for the period of 1990-2016 and envisage the increase of this indicator in future, have been worked out. Ecological-economical production aspects of alternative kinds of fuel in Ukraine were revealed. The suggestions to increase the production efficiency of alternative kinds of fuel from agricultural output were motivated. The necessity and economic expediency of the production and consumption of biofuel in the context of food and energy safety of Ukraine were proved.

Keywords: bioethanol; biodiesel; biogas; sugar beets; rape; livestock production

Introduction

Civilized countries in the world came to understanding of the necessity to widely integrate in the sphere of alternative energy source development due to a global climate change and ecological damage caused by a continued use of traditional, non-renewable hydrocarbon energy sources. Alongside with this, the energy problem of the world escalates intensively with every coming year due to constant depletion of energy sources. Mankind pays more attention to alternative energy sources for this reason. In prospect it will provide people with energy for life through foodstuff consumption and for their activity through the use of alternative fuel. That is why, at present the use of renewable energy sources has become one of the rising industries of the national economy.

Ukraine has large land resources to run farm business and is capable of satisfying its own needs in foodstuff as well as growing energy crops for their further processing into alternative fuels. And the issues of the country's energy safety, a reduced dependence on imported energy carriers, first of all, natural gas, become of great significance. The production and consumption of alternative fuels will speed up the solution of such strategic goals for the development of Ukraine as the dependence decrease of producers on fuel import and

the support of domestic manufacture of biofuel at a lower price, which in turn will ensure energy and ecology safety of the country.

Such Ukrainian and international scientists as H. Kaletnik, M. Kodenska, V. Mesel-Veseliak, M. Roik, P. Sabluk, O. Shpychak, O. Zakharchuk, V. Bondar, Yu. Kernasiuk, A. Fursa study the urgent issues of alternative fuel manufacture in Ukraine. However, the issue of production efficiency of alternative fuels in the context of food and energy safety of Ukraine requires additional research. The purpose of the research is to substantiate practical recommendations concerning the efficiency increase of alternative fuel manufacture from agricultural produce and the development of the ways of stable enhancement of an alternative fuel market in the context of food and energy safety of Ukraine.

Material and Methods

The methods of a system analysis and logical generalization to study the preconditions of the production and consumption of alternative fuels at farm enterprises were used in the process of research; economic-mathematic modeling – to work out polynomial models, which describe biogas manufacture potential at farm enterprises in cattle and swine production in terms of natural gas; comparative analysis – in the process of analyzing statistic information; calculation-constructive method – to define production cost of biofuel; induction and deduction – to generalize the research results; abstract-logical – to make conclusions and proposals.

Results and Discussion

The necessity to produce and consume alternative fuels is motivated by both the exhaustion of non-renewable energy resources and a great number of ecological problems which occur, first of all, because of the use of traditional energy sources. Energy needs in the world are met with oil by 36%, coal – by 29%, gas – by 24%, and nuclear fuel – by 7% (Dale & Kim, 2004; Blum et al., 2010).

One of the urgent problems is the increase of carbon dioxide concentration and global warming also due to the increase of getting and processing of carbohydrates of a technological progress. The concentration of toxic elements in the atmosphere increases due to the continuous growth in the mineral consumption (gas, coal, oil). It is necessary to use biomass energy to manufacture solid, liquid and gaseous fuels in the conditions when reserves of traditional fuels are decreasing and potentials to increase natural renewable energy resources are limited.

The amount of biomass in the world is about 110 bln t/year, including 4 bln t/year which are produced in cultivated lands. According to the latest estimations of energy needs, only about 3% of energy biomass potential is used in the world. And biomass fuel takes the fourth place in the world as to the amount of its energy use. The share of biomass in total supply of primary energy is 10%, which is 1272 mln t of oil equivalent per year (Ihnatenko, 2016).

The majority of the industrialized countries of the world develop the programs of manufacture and consumption of biofuel from crop raw material intensively. Directive 2009/28/EC of the European parliament and of the Council determines 10% of the use of renewable energy in transport and 20% of renewable energy in the structure of total energy consumption as mandatory indicators, and up to the year of 2030 the EU plans to satisfy 25% of its needs in fuel for road transport using clean and effective kinds of alternative fuels. In 2015 the share of energy from renewable sources in gross final energy consumption was 16.7% in the EU, almost twice as much compared with the year of 2004 (8.5%) (Energy consumption on the basis of renewable sources for the years of 2007-2016. State Statistic Committee of Ukraine [E-resource].). In Ukraine the share of energy from renewable sources in gross final energy consumption was 3.0% in 2015, we observe a gradual rise of this indicator (Energy consumption on the basis of renewable sources for the years of 2007-2016. State Statistic Committee of Ukraine [E-resource].) (Table 1).

In the EU renewable energy sources will continue to play a key role in satisfying the needs in energy after the year of 2020. For this reason the member-countries of the EU agreed on a new aim of renewable power engineering in the EU – at least 27% up to 2030. Ukraine is obliged to take into consideration European norms concerning the consumption of biofuel in connection with its entry to the European Energy community in 2011. According to the National plan of energy renewal for a period up to 2020, Ukraine is to ensure the condition when a biological component of motor fuel reaches 10% and renewable energy in the structure of total energy consumption – 11% (Resolution of Ukraine's Cabinet of Ministers № 902-p, 2014). A special attention is paid to the issue of Ukraine' joining the Statute of the International agency in charge of renewable energy sources (IRENA) (The Law of Ukraine on Ukraine's joining the Statute of the agency of renewable energy sources (IRENA), 2018). This decision will have a positive impact on the investment image of our country and will favor its presence among players of a renewable energy market in the world arena. In particular, the participation in IRENA makes it possible to place ap-

Table 1. Share of energy from renewable sources (in % of gross final energy consumption)

	2004	2012	2013	2014	2015	2020 target
EU	8.5	14.4	15.2	16.1	16.7	20
Belgium	1.9	7.2	7.5	8.0	7.9	13
Bulgaria	9.4	16.0	19.0	18.0	18.2	16
Czech Republic	6.8	12.8	13.8	15.1	15.1	13
Denmark	14.9	25.7	27.4	29.3	30.8	30
Germany	5.8	12.1	12.4	13.8	14.6	18
Estonia	18.4	25.8	25.6	26.3	28.6	25
Ireland	2.4	7.2	7.7	8.7	9.2	16
Greece	6.9	13.5	15.0	15.3	15.4	18
Spain	8.3	14.3	15.3	16.1	16.2	20
France	9.4	13.4	14.1	14.7	15.2	23
Croatia	23.5	26.8	28.0	27.9	29.0	20
Italy	6.3	15.4	16.7	17.1	17.5	17
Cyprus	3.1	6.8	8.1	8.9	9.4	13
Latvia	32.8	35.7	37.1	38.7	37.6	40
Lithuania	17.2	21.4	22.7	23.6	25.8	23
Luxembourg	0.9	3.1	3.5	4.5	5.0	11
Hungary	4.4	15.5	16.2	14.6	14.5	13
Malta	0.1	2.8	3.7	4.7	5.0	10
Netherlands	2.1	4.7	4.8	5.5	5.8	14
Austria	22.6	31.4	32.3	32.8	33.0	34
Poland	6.9	10.9	11.4	11.5	11.8	15
Portugal	19.2	24.6	25.7	27.0	28.0	31
Romania	16.3	22.8	23.9	24.8	24.8	24
Slovenia	16.1	20.8	22.4	21.5	22.0	25
Slovakia	6.4	10.4	10.1	11.7	12.9	14
Finland	29.2	34.4	36.7	38.7	39.3	38
Sweden	38.7	51.1	52.0	52.5	53.9	49
United Kingdom	1.1	4.6	5.7	7.1	8.2	15
Ukraine	н/д	2.0	2.7	2.6	3.0	11

Source: Eurostat; State Statistic Committee of Ukraine

plications to Abu Dhabi Development Fund (ADFD) as to receiving preferential credits for renewable energy projects (at interest rate 1-2% for the period of 20 years, including a 5-year grace period, provided joint financing 50/50 is applied).

In Ukraine the largest share in the structure of the production of renewable energy sources in 2016 were biofuel and waste – 81%. And the share of biofuel and waste based on renewable sources in the structure of energy consumption is increasing with years from 63.2% in 2007 to 78.3% in 2016 (Energy consumption on the basis of renewable sources for the years of 2007-2016. State Statistic Committee of Ukraine [E-resource]) (Table 2).

Herewith in the structure of final energy consumption of renewable energy sources in the EU countries, heating and cooling are 49.7%, and in Ukraine – 66%; power energy - 42.2%, in Ukraine – 31%; transport – 8.1% and 3% in Ukraine, respectively (Energy consumption on the basis of renewable sources for the years of 2007-2016. State Statistic Committee of Ukraine [E-resource]); Report from the commission to the European parliament, the Council, the European economic and social committee and the Committee of the regions: Renewable Energy Progress Report, 2017) (Table 3).

In the countries of the European Union two kinds of biofuel are widely used: bioethanol (for gasoline engines) and biodiesel – methyl ethers of lipid acids (for diesel engines). Bioethanol can be produced from corn, wheat, sugar beets, cane, sorghum and barley or from other starch-bearing crops. To produce biodiesel, sunflower oil is used in most cases (Spain, Italy, and Greece) and rape oil (in the rest of the European countries). Raw materials for biogas plants are

Table 2. Energy consumption on the basis of renewable sources in Ukraine in 2007-2016

Indicators	2007	2012	2013	2014	2015	2016
Total energy supply from renewable sources, th t of oil equivalent	2384	2476	3166	2797	2700	3616
Share of total supply of primary energy, %	1.7	2.0	2.7	2.6	3.0	3.9
Hydropower engineering, th t of oil equivalent	872	901	1187	729	464	660
Share of total supply of primary energy, %	0.6	0.7	1.0	0.7	0.5	0.7
Share of total energy supply from renewable sources, %	36.6	36.4	37.5	26.1	17.2	18.2
Energy of biofuel and waste, th t of oil equivalent	1508	1522	1875	1934	2102	2832
Share to total primary energy supply, %	1.1	1.2	1.6	1.8	2.3	3.1
Share of total energy supply from renewable sources, %	63.2	61.5	59.2	69.1	77.8	78.3
Wind and sun energy, th t of oil equivalent	4	53	104	134	134	124
Share of total supply of primary energy, %	0.003	0.04	0.1	0.1	0.1	0.1
Share of total energy supply from renewable sources, %	0.2	2.1	3.3	4.8	5,0	3.4

Source: State Statistic Committee of Ukraine

Table 3. Comparison of the structure of final energy consumption of renewable energy sources in the EU countries and in Ukraine, %

Indicator	EU countries - 28	Ukraine
Heating and cooling	49.7	66
Power energy	42.2	31
Transport	8.1	3

agricultural substrates, such as liquid and stall manure or energy crops (sugar and fodder beets, corn, sugar sorghum, etc.) Also the substrates which are by-products of processing industry and organic waste of public utility companies are used.

The most promising kind of bio power engineering for Ukraine is phyto-power engineering, which is based on raw material of plant origin. It has to be stated that in Ukraine at the beginning of the 90-ties of XX century during a transition period to market economy, free pricing conditions were created for all industries of the national economy, and indicative prices were introduced for agriculture; they grew at lower rates than those of goods and services used by agriculture which caused disparity of prices not in favor of agrarians producers. This in turn influenced the volumes of agricultural crop production, namely, the increase of industrial crops as more profitable ones (Crop production of Ukraine, 2017) (Table 4).

In 1990-2016 we have the increase of industrial crop production, in particular, soybeans by 43 times – up to 4277 th t in 2016, the increase of rape production by 9 times – up to 1154 th t in 2016, that of sunflower by 5 times – up to 13627 th t, respectively. Herewith, a serious decrease of the production volume of corn for silage and green fodder was recorded – by 14 times up to 6968 th t in 2016, which affected the development of livestock production in Ukraine.

Thus, during this period the number of agricultural animals decreased considerably in Ukraine: cattle by 7 times – to 3682 th head in 2016, pigs by 3 times – to 6669 th head in 2016, sheep and goats by 6 times – to 1315 th head, horses by 2.5 times – to 292 th head, and also poultry number decreased slightly – from 246.1 th head in1990 to 201.7 th head in 2016 or by 18.04% (Livestock production in Ukraine, 2017) (Table 5).

The efficiency analysis of producing meat of cattle, swine, sheep and goats confirms the loss-making nature of the industry in recent years which has led to the decrease in the number of agricultural animals in Ukraine (Annual statistical bulletin of Ukraine for the year of 2007; State Statistic Committee of Ukraine., 2017) (Table 6).

Table 4. Production of some agricultural crops in Ukraine in 1990-2016

Agricultural crops	Years					2016 in %	
	1990	2000	2010	2015	2016	1990	2015
Wheat, th t	30374	10197	16851	26532	26043	85.74	98.16
Corn for grain, th t	4737	3848	11953	23328	28075	592.67	120.35
Corn for silage and green fodder, th t	98372	24183	7511	6843	6968	7.08	101.83
Sugar beets (factory), th t	44264	13199	13749	10331	14011	31.65	135.62
Sunflower, th t	2571	3457	6772	11181	13627	530.03	121.88
Rape, th t	130	132	1470	1738	1154	887.69	66.40
Soybeans, th t	99	64	1680	3931	4277	4320.2	108.8

Source: calculations according to the data of the State Statistic Committee of Ukraine

Table 5. Number of agricultural animals in Ukraine in 1990-2016

Agricultural animals	Years					2016 in %	
	1990	2000	2010	2015	2016	1990	2015
Cattle, th head	24623	9424	4494	3750	3682	14.95	98.19
Swine, th head	19427	7652	7960	7079	6669	34.33	94.21
Sheep and goats, th head	8419	1875	1732	1325	1315	15.62	99.25
Horses, th head	738	701	414	306	292	39.57	95.42
Poultry, mln head	246.1	123.7	203.8	204.0	201.7	81.96	98.87

Source: calculations according to the data of the State Statistic Committee of Ukraine

Table 6. Production efficiency of some kinds of output at the agricultural enterprises in 1990–2016

Kind of output	Profitability level (sacrifice) by years, %					
	1990	1995	2000	2010	2015	2016
Grain crops	275.1	85.6	64.8	13.9	43.1	37.8
Sunflower seeds	236.5	170.9	52.2	64.7	80.5	63.0
Sugar beets	29.5	31.2	6.1	16.7	28.2	24.3
Cattle for meat	20.6	–19.8	–42.3	–35.9	–17.9	–24.8
Swine for meat	20.7	–16.7	–44.3	–7.8	12.7	–4.5
Sheep and goats for meat	2.3	–31.9	–46.4	–29.5	–29.6	–35.2
Poultry for meat	17.0	–18.4	–33.2	–4.4	–6.1	5.0

Source: calculations according to the data of the State Statistic Committee of Ukraine

Taking into consideration that the efficiency of farm enterprise performance in livestock production has serious declines and is of risky nature, it is expedient to diversify the output, in particular its use for biogas manufacture.

Raw materials for biogas plants are agricultural substrates, such as liquid and stall manure or energy crops (sugar and fodder beets, corn, sugar sorghum, etc). The substrates which are by-products of processing industry and organic waste of public utility companies are also used. The most promising agricultural crops whose raw can be used for biogas manufacture are sugar sorghum (biogas output – 17.6 th m^3/ha), corn for silage (16.0 th m^3/ha), sugar (10.9 th m^3/ha) and fodder (10.8 th m^3/ha) beets (Royik et al., 2014).

However, the use of food crops with energy purpose may cause the decrease of the quantity of food stuffs and fodder. In view of the necessity to ensure the food security of the country, it is expedient to use corn for silage to fatten cattle, and corn for grain to fatten swine. In this case meat production is supported for the nutrition of the population, as well as biogas manufacture as alternative fuel.

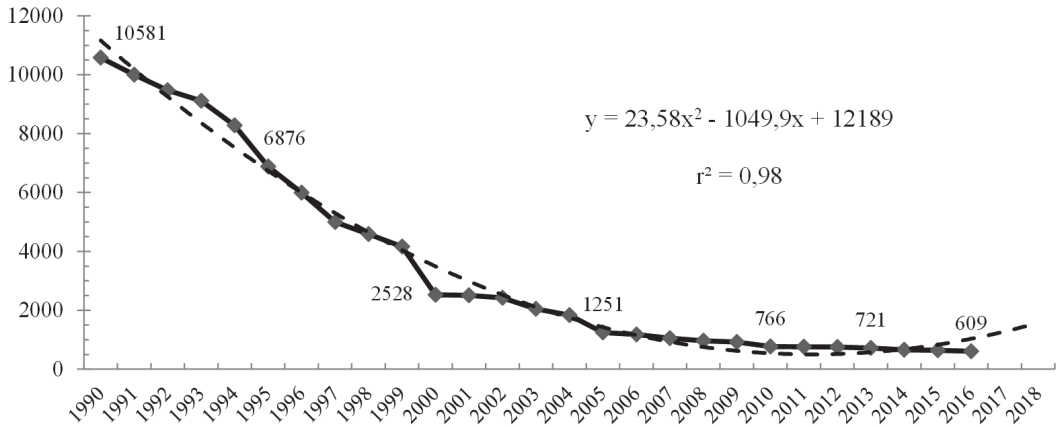

Fig. 1. Potential of biogas production at farm enterprises in cattle farming of Ukraine in terms of natural gas in various years, mln m^3

Source: our calculations

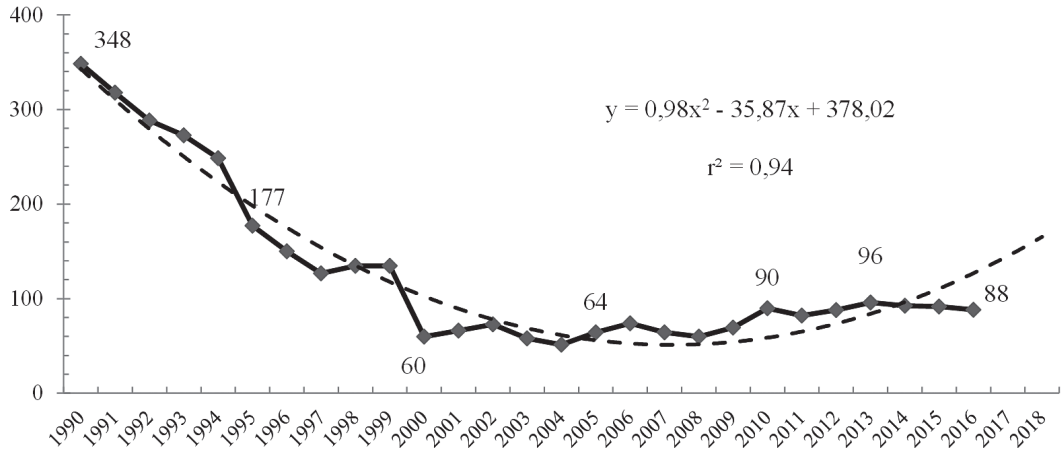

Fig. 2. Potential of biogas production at farm enterprises of swine farming in Ukraine in terms of natural gas by years, mln m³

Source: our calculations

Despite the decrease in the number of cattle and swine at farm enterprises of Ukraine in 1990-2016, the potential of biogas production from cattle substrates can reach the level of 10 bln m³ in terms of natural gas (Figure 1), which is 30% from the amount of gas consumption in Ukraine in 2016, respectively, the potential of biogas production from swine substrates can be 348 mln cubic meters in terms of natural gas or 1% from the amount of gas consumption in Ukraine in 2016 (Figure 2) (State Statistic Committee of Ukraine. 2017).

In 2016 the potential of biogas production from cattle substrates at farm enterprises in terms of natural gas was 609 mln m³. With the average price of 1000 m³ of natural gas UAH 8900, the industry could get about UAH 5.4 bln additionally.

Accordingly, the potential of biogas production from swine substrates at farm enterprises in terms of natural gas was 88 mln m³. With the average price of 1000 m³ of natural gas UAH 8900, the industry could get about UAH 783.2 mln additionally.

Hence, at the expense of biogas production from cattle and swine substrates, in 2016 farm enterprises could have substituted over 800 th t of equivalent fuel or 31% from total consumption in agriculture to the amount of UAH 6 bln (US$ 222 mln). Herewith, a considerable amount of biogas can be used, first of all, for the needs of farm enterprises themselves. Besides, it is possible to use plants for simultaneous production of electric energy and heat, and special equipment for biogas purification and its use as conventional fuel for automobiles and other farm machinery.

Bioethanol production is possible at alcohol- and sugar- mills, re-equipped for this manufacture. Starch-bearing crops, such as corn and wheat, the output of which is used in people's nutrition, can be raw materials for bioethanol production. As the problem of foodstuff shortage in the world is growing, it is inappropriate to produce bioethanol from corn and wheat. By-products of sugar beet processing are not directly used for nutrition, which confirms the expediency of its use for bioethanol production (Table 7).

Table 7. Raw material need for bioethanol production

Type of raw material	Raw material need for production of 1 t of bioethanol, t
Sugar beets	12.65–13.49
Molasses	4.22–4.50
Wheat	3.21–4.22
Corn	2.89–3.11

Source: our calculations

The necessity to diversify the production of sugar industry output is defined not only by the country's high dependence on the import of energy resources, but also by the need to have reserve production capacities for processing of the excess, considering a cyclic and risky nature of sugar beet production.

Raw materials for bioethanol production, besides molasses and sugar beets, can be by-products of sugar beet processing with high sugar content, such as green treacle and syrup. The production technology influences the re-

duction of bioethanol production cost considerably, and it increases its competitive power. Bioethanol technology consists of two stages: ethanol-raw production and its further dehydration. Azeotropic rectification, adsorption on molecular sieves and evaporation through membrane are used for ethanol dehydration (Shyian et al., 2009).

Bioethanol with the lowest production cost is obtained by evaporation through membrane, no matter what kind of raw material is used for processing. Similar correlation was recorded when bioethanol was produced from green treacle, syrup and molasses. The lowest production cost was obtained when bioethanol was produced from molasses in all there processing technologies.

It is possible to produce biodiesel from the seeds of soybeans, rape and sunflower. However, sunflower and soybeans are food agricultural crops that is why their use for biodiesel manufacture is not appropriate. It requires 2.5 t of rape seeds to produce 1 t of biodiesel. The calculation of production cost of biodiesel manufacture from rape seeds shows that it is appropriate to produce and use it for the needs of farm enterprises, which will reduce their dependence on a market price and import of diesel fuel. Hence, the construction of specialized enterprises requires some exemptions for a payback period, i.e., government support is necessary to build these companies.

According to the data of the State Statistic Committee of Ukraine, 1153.9 th t of rape were harvested in 2016 (Crop production of Ukraine, 2017). In case 923 th t of rape were processed (80%), it would be possible to produce 369 th t of biodiesel and to satisfy the needs of agrarian enterprises by 27% in 2016 (Annual statistical bulletin of Ukraine for the year of 2007, 2008).

Biodiesel has a high ignition temperature (over 100°C), which is an important technical indicator for the companies involved in fuel transportation and storage. It allows using it in diesel engines without any other substances which stimulate its ignition. Besides, when an engine works on biodiesel, lubricating of its rolling-stock is done at the same time, which results in extending a service period of an engine itself and a fuel pump by 60% on the average. Biodiesel has low sulfur content and is characterized by good lubricating indicators. During biofuel combustion, CO_2 releases in accordance with the amount taken from the atmosphere by a plant. Biodiesel is of plant origin and it is produced from oils which improve structural and chemical composition of the soil in crop rotation systems, they do not do harm to plants, animals, and when they get into water they, in fact, undergo complete biological processing.

Conclusions

Renewable energy sources in the developed countries of the world continue to play a key role in satisfying their needs in energy. In Ukraine biofuel and waste take the largest share in the structure of the production of renewable energy sources. The production of biogas from the waste of cattle and swine farming at the agricultural enterprises solves several problems of the agrarian business. In particular, it decreases the environmental pollution with hazardous substances, including liquid and solid waste of livestock farms; new potentials to get additional revenues, which will favor the increase of production efficiency of livestock output, appear; food and energy security of the country is guaranteed due to the rise of livestock output production; the dependence of agricultural producers on fuel import is reduced. Also, social problems in rural areas are solved by creating new jobs and saving the existing ones. The production and consumption of bioethanol and biodiesel will facilitate the manufacture of ecologically clean alternative fuel and the reduction of Ukraine's dependence on the import of gasoline and diesel fuel. Thus, the satisfaction of the needs of agricultural producers in biofuel at lower cost will favor the competitiveness of agricultural output production, the productivity rise of the companies which manufacture alternative energy sources.

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