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Diagnosics of the efficiency and assessment of the possibilities of bioethanol production at sugar beet industry enterprises and distilleries in Ukraine

ABSTRACT: In modern conditions of economic globalization, strengthening market relations and aggravated competition, the economic development of an enterprise directly depends on the introduction of innovations. The transition to an innovative path of development requires the enterprise to determine its readiness and assess the possibility of development and the further implementation of innovations. Modern trends in the production of conventional liquid fuels in Ukraine, in particular, analysis of the production of motor gasoline and primary oil refining in Ukraine, the share of motor gasoline produced in Ukraine in the total volume of gasoline used, the volume of bioethanol production by Ukrainian distillery factories have been analyzed in the article. An assessment of the resource production potential for the production of bioethanol in Ukraine has been carried out. Possibilities of bioethanol production in Ukraine at distilleries have been investigated. An analysis of molasses production in Ukraine and theoretically possible volumes of bioethanol production from mo-

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lasses in Ukraine have been calculated. The scheme of key strategic priorities for the development of the food ethanol and bioethanol in Ukraine has been proposed. The advantages of using bioethanol in the gasoline-ethanol blends for vehicles have been noted, a SWOT analysis map for organizing the production of bioethanol at sugar beet processing plant and distilleries has been generated. The needs of Ukraine in the production of bioethanol have been calculated and, according to the results obtained, the volumes of bioethanol production have been predicted.

KEYWORDS: distilleries, bioethanol, sugar beets, feedstock

Introduction

The dependence of modern societies on a constant, reliable, and inexpensive supply of energy is the cause of many political problems and reactions, both domestically and internationally (Kytaiev et al. 2020). The current task of the European Union and other industrialized countries is to overcome the energy and natural resources deficit as well as stabilize the increasing costs of their import. Therefore, a number of actions are undertaken, the most important of which is to increase the share of recycled raw materials (including fuels) in the material and energy balance of individual national economies (Gołowicz and Wojciechowski 2020). Therefore, at the present stage of economic development, the issues of using alternative types of energy are of particular relevance (Kaletnik et al. 2019).

According to International Renewable Energy Statistics forecasts, by 2050 the structure of energy consumption in the transport sector will change significantly, even if the number of vehicles increases. This will be achieved by increasing the efficiency of the use of fuel and energy resources by the transport sector by at least 30%. In the “energy mix”, non-conventional energy sources will predominate for the transport industry, including hydrogen (8% of consumption), biofuels and biogas (22% of consumption), as well as electricity from renewable energy sources. Such changes will reduce the level of CO₂ emissions into the atmosphere by at least 70%, compared to the level of 2015. To meet the growing demand, liquid biofuel production is expected to grow from 129 billion liters in 2015 to more than 900 billion liters in 2050. Almost half of this volume will come from first generation biofuels, the other half – from second generation biofuels, which can be produced from a wider range of feedstock. At the same time, a sharp increase in biofuel production will require careful planning and ensuring the sustainability of the supply of primary feedstock, as well as compliance with food safety requirements.

Bioethanol is the largest renewable energy contributor in global transportation. In 2019, the production of this biofuel reached 110,000 million liters globally. Ethanol can be blended with gasoline in different proportions. Mixtures of gasoline with ethanol at 10% (E10) cover the majority of the international demand, although higher ethanol blends (E15–E85) can also be found in minor proportions due to limitations in the fuel-supply structure and vehicle compatibility (Susmozas et al. 2020).

Since 2019, the world's largest ethanol producers were the United States – 48.2% of the world market, Brazil – 26.2%, the European Union – 4.9%, other countries – 20.7% (OECD-FAO Agricultural Outlook 2020–2029). In addition to direct economic benefits, domestic biofuel production also provides social benefits (reduced air pollution and dependence on oil imports, rural development).

In the EU countries the main feedstock for bioethanol production is sugar beets (39.9%), wheat (27.3%) and corn (24.5) (EU Biofuels Annual 2019). For over 10 years France has been the leading EU producer of bioethanol. This country has similar climatic and soil conditions as Ukraine and can be a good example for Ukraine of the successful combining sugar and ethanol industries.

Ukraine has a strong agricultural potential both for ensuring food security, satisfy import demand and increase biofuels production. In 2019, Ukraine was among the top 10 world producers of sunflower (1st place, 15 million Mg), sugar beets (5th place, 18.43 million Mg), corn (6th place, 35.5 million Mg), soybeans (9th place, 3.7 million Mg), wheat (8th place, 25.1 million Mg) (FAO 2020). Despite the strong agricultural potential, the production of liquid biofuels is quite low.

In 2019, the share of biofuels in the structure of energy consumption in Ukraine was 3.8% (State Statistics Service of Ukraine 2020). The largest share of biofuels is provided through the use of biomass energy (solid biofuels) and the processing of organic waste into biogas.

At the same time, Ukraine is an energy-deficient country, as it imports 68% of the required volume of natural gas and crude oil and petroleum products (Ministry of Energy and Industry of Ukraine 2020).

With the dynamic development of Ukraine's economy, its integration processes into the globalized world market, problems with energy supply, as well as the exacerbation of the crisis in recent years, is one of the most important tasks that requires the development of radical strategies to ensure sustainable development of the agricultural sector (Tokarchuk et al. 2020).

The scope of the research is to investigate the possibilities of bioethanol production from sugar beets and molasses. Therefore, the purpose of the study is to assess the potential for the development of the distillery industry and the sugar beet complex through the production of bioethanol and its impact on the achievement of energy efficiency and energy supply in Ukraine.

The importance of choosing sugar beets as a feedstock for bioethanol production is determined by the low efficiency of the sugar-beet industry distilleries functioning (Pryshliak 2014; Pryshliak and Tokarchuk 2020). At the same time, the use of free capacities of sugar beet factories and distilleries by converting them to the production of bioethanol will allow meeting the demand for bioethanol and resuming the work of a significant number of enterprises in the distillery industry, improving the financial condition of the distilleries, and increasing budget revenues at all levels.

Improving the efficiency of the distillery industry in Ukraine is possible through the diversification of production by implementing the production of bioethanol with subsequent use in a mixture with gasoline. The production and use of bioethanol is able to reduce the dependence of the state on the imports of crude oil products, stimulate agricultural production and improve the environmental situation (Palamarenko 2018).

1. Trends in the production of conventional gasoline in Ukraine

With proper organization of the production of alternative fuels based on bioethanol, with the implementation of measures to harmonize Ukrainian legislation with the requirements of Directive 2009/28/EC of the European Parliament and the European Council in terms of promoting the use of biofuels or other renewable fuels for transport, the production of liquid alternative fuels based on bioethanol in Ukraine will increase to 320–360 thousand Mg per year (14–16% of gasoline consumption in the domestic market).

The feasibility of implementing investment projects to increase the production of bioethanol and alternative motor fuels in Ukraine is also due to the excessive dependence of the national economy on fuel imports, which makes it vulnerable to numerous global challenges in terms of unpredictable fluctuations in the world hydrocarbon markets. A significant volume of imports of gasoline is due to the fact that there has been a downward trend in domestic production of this fuel in recent decades (Fig. 1).

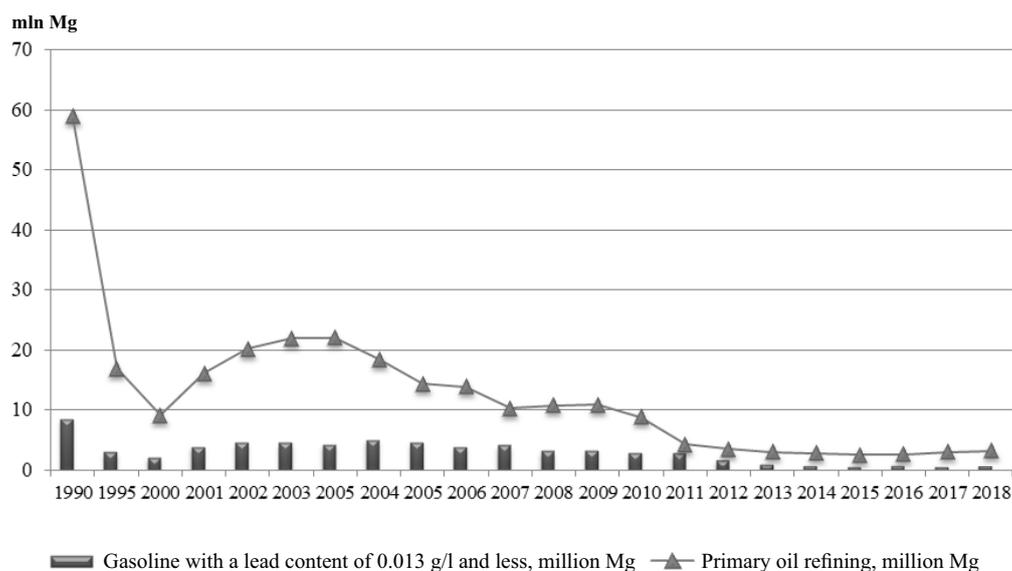


Fig. 1. Production of gasoline and primary oil refining in Ukraine
Source: formed by the authors according to the State Statistics Service of Ukraine 2020

Rys. 1. Produkcja benzyny i rafinacja ropy naftowej na Ukrainie

The downward trend in the dynamics of the production of gasoline also had a corresponding impact on the dynamics of domestic production of conventional fuels in the total volume of used fuels. In 2007 the share of motor gasoline produced in Ukraine in the total volume of used fuel was 87.5%, in 2012 – 38.1%, in 2018 – 32.0% (Fig. 2).

Reducing the dependence on gasoline import and combating constantly growing prices on conventional fuel might be possible due to an increase in bioethanol production in Ukraine.

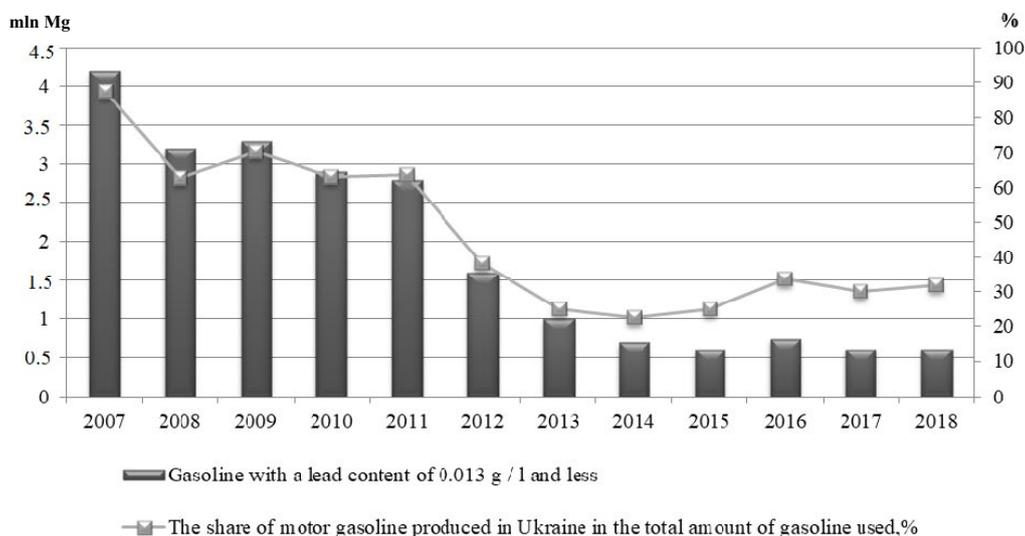


Fig. 2. Dynamics of gasoline produced in Ukraine in the total volume of used gasoline
Source: formed by the authors according to the State Statistics Service of Ukraine 2020

Rys. 2. Dynamika zmian udziału produkcji benzyny na Ukrainie w całkowitym wolumenie zużytej benzyny

2. Assessment of bioethanol production capacities in Ukraine

2.1. Analysis of bioethanol production capacities at the sugar beet industry enterprises

The next stage of the research will focus on the bioethanol production at sugar beet processing plants. It should be noted that bioethanol, at the lowest cost, is produced by Brazil and the United States, and the most expensive cost is recorded in Germany (Fig. 3).

The calculations (Fig. 3) show that in Ukraine the cost of bioethanol produced from sugar beets is EUR 58.9 per 100 liters, in Germany – EUR 59.5 per 100 liters. This testifies to the economic feasibility of bioethanol production at sugar beet processing plants.

In Ukraine, favorable climatic and soil conditions and historical experience for growing sugar beets in volumes that greatly exceed the current production are present.

According to State Statistics service of Ukraine, in 1991, there were 192 enterprises in Ukraine that processed sugar beets into sugar, in 2019 there were only 31 operating. The reason for

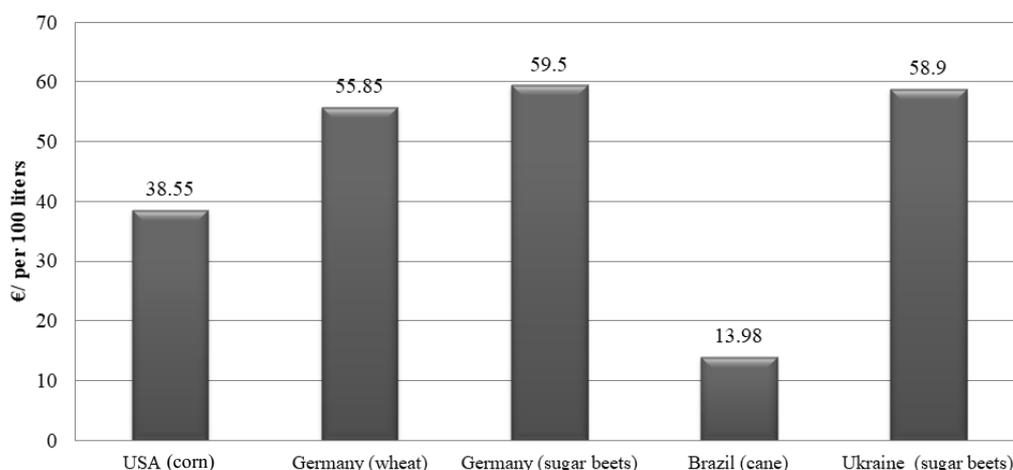


Fig. 3. Results of the comparative analysis of the cost of bioethanol by producer countries and by the direct method of feedstock processing, 2018

Source: calculations of the authors based on research methods of processing different types of feedstock (Hareba 2012)

Rys. 3. Wyniki analizy porównawczej kosztów bioetanolu według krajów producenckich i metodą bezpośredniej przeróbki surowców, 2018

the closure of the sugar factories was a decrease in the production of sugar beets (from 18.73 million Mg in 1990 to 7.04 million Mg in 2019). The decrease in the production of sugar beets was associated with the loss of foreign markets for the sale of products. At the same time, in case of a significant increase in the acreage of sugar beets, beet-growing enterprises will face the problem of product sales. This is due to the fact that the quota for sugar production in Ukraine annually remains at the level of the state's internal needs for sugar. That is why increasing the volume of sugar beet production with the prospect of processing the resulting products exclusively for sugar production is impossible.

Nevertheless, despite the downward trend in performance, sugar industry enterprises have the appropriate infrastructure to provide logistics, service, energy management, specialized business service sectors, etc. for both producing sugar and bioethanol.

Despite the fact that the efficiency of the sugar beet industry has improved, the performance of the sugar beet processing factories remains significantly lower than they were in the early 1990s. Over the past five years, the average duration of the sugar factories' operation was 65 days, and the daily processing volumes amounted to about 200 thousand Mg per day, which is twice less than in 1999. The experience of the Czech Republic, France and Poland shows that the prolongation of the work of sugar beet processing factories can be achieved by expanding production, as well as installing additional lines at the plant, in particular for the production of bioethanol. Thus, in France, sugar beet processing plants that have a bioethanol production line operate from 6 to 9 months a year. Considering the fact that the majority of workers at sugar beet

processing factories are employed predominantly during the period of operation, this allows an additional 25–30 thousand people to be employed (Kaletnik 2018).

The technological scheme for the production of bioethanol from sugar beet and molasses at a sugar factory is shown in Figure 4.

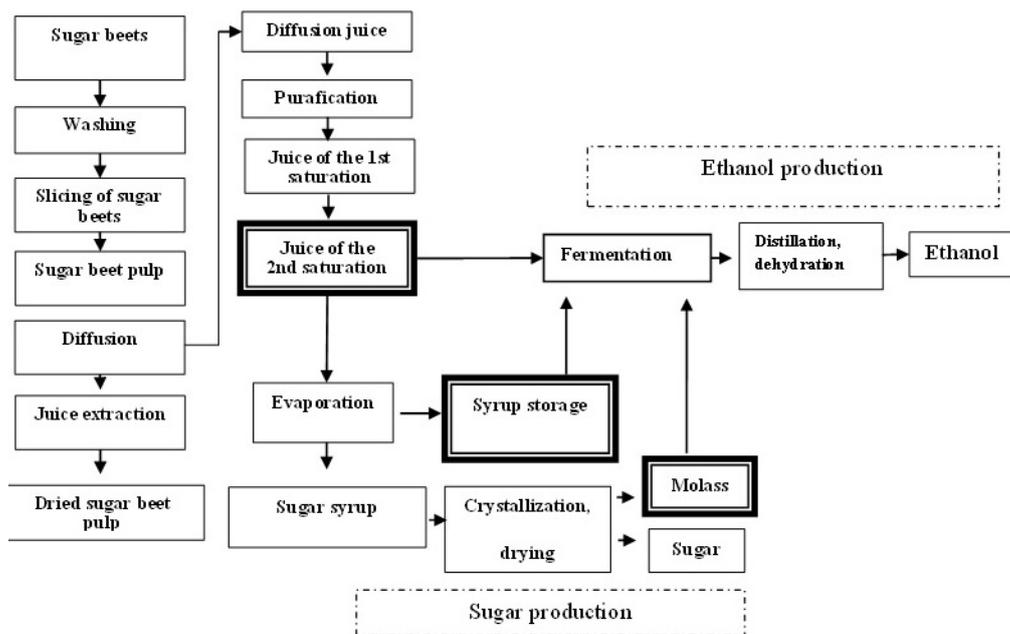


Fig. 4. Technological scheme for the production of sugar and bioethanol from sugar beet at a sugar beets processing plant

Source: formed by the authors according to previous studies (Kaletnik and Pryshliak 2013; Pryshliak 2014)

Rys. 4. Schemat technologiczny produkcji cukru i bioetanolu z buraków cukrowych w zakładzie przetwórstwa buraków cukrowych

2.2. Analysis of production capacities for biofuel production at distilleries

The alcohol industry in Ukraine is not only a source of high-quality raw materials for manufacturers of alcoholic beverages, pharmaceuticals, food and energy industries, but also a “gray” zone of abuse in the production and sale of alcohol (Explanatory note to the draft Law of Ukraine “On Amendments to the Law of Ukraine” 2019). These abuses have social and economic consequences for the country. The social consequences are, first of all, the morbidity and mortality of the population from poisoning with low-quality alcohol. The economic consequences encompass the spread of smuggling and the lack of tax revenues for the state budget from the trade in alcohol and spirits.

The alcohol industry includes 79 state production sites, including 41 (of which only 12 are operating) – part of the State-Owned Enterprise “Ukrspirt” (State Statistic Service of Ukraine 2020). The total unprofitability of enterprises that form the alcohol industry in 2018 reached almost USD 1 million, only 8 out of 21 state-owned enterprises had a profit, and 11 enterprises were in a state of bankruptcy (Ministry of Economic Development and Trade of Ukraine 2020).

Between 2015–2019, there was a significant reduction in the production of ethyl alcohol in Ukraine. The annual rate of decline varied from 6 to 15% (State Statistic Service of Ukraine 2020).

Under such conditions, the effective functioning of the alcohol industry is impossible without significant reform, which aims to create a transparent, diversified competitive industry, that ensures the production and sale of a wide range of high-quality ethanol and alcohol-containing products with a high share of added value.

The strategic goals of reforming the distillery industry include: taking the alcohol industry out of the shadow; strengthening the international competitiveness of domestic enterprises; diversification of production (establish production of different products, e.g. food ethanol and bio-ethanol and processing different feedstock, e.g. grain and molasses; such practice is successfully being used by distilleries in France (Cristal Union 2021).

The experience of the EU countries is important for Ukraine. In EU countries, the share of biofuels in transport is constantly growing (Fig. 5).

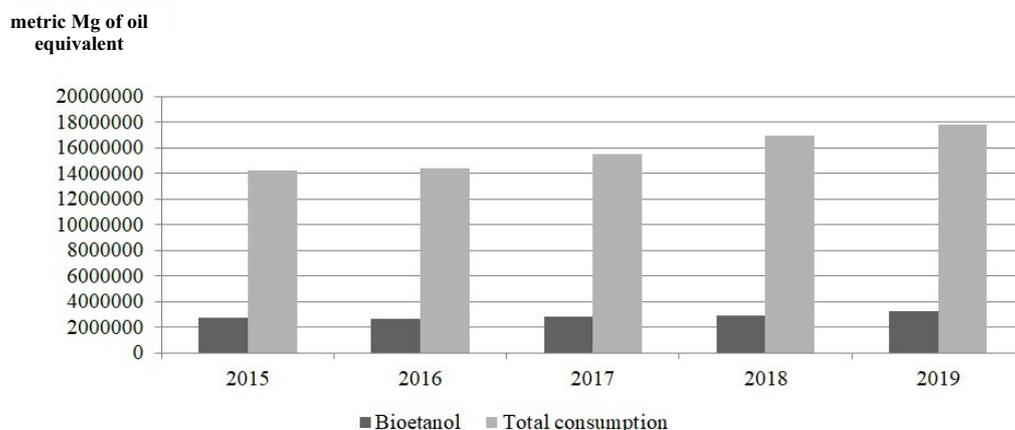


Fig. 5. Consumption of biofuels for transport in the European Union (EU-28) from 2015 to 2019
Source: data from the official website Statista 2021

Rys. 5. Zużycie biopaliw w transporcie w Unii Europejskiej (UE-28) w latach 2015–2019

In accordance with EU-Ukraine Association Agreement which includes the Deep and Comprehensive Free Trade Area (DCFTA), Ukraine has preferences within the framework of free trade between Ukraine and the EU to establish duty-free EU tariff quotas for ethanol. Consequ-

ently, the total volume of the EU tariff quota for Ukraine as of 2018 amounted to 56,200 Mg, and in 2021 the tariff quota will grow to 100,000 Mg.

According to Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, sugar beet ethanol has greenhouse gas emissions saving (typical value) of 67% (in comparison the greenhouse gas emissions saving from corn as a feedstock is 48%, from other cereals, excluding corn ethanol (53%). Thus, among agricultural crops that is now being produced in Ukraine sugar beets have the highest greenhouse gas emissions saving (in terms of first-generation biofuels).

The most attractive EU countries for the export of bioethanol by Ukrainian companies are: Romania, Poland, Lithuania, Slovakia, Hungary, Bulgaria, Italy and Spain.

Currently volumes of bioethanol produced in Ukraine are much lower than the installed capacities. In the period from 2010 to 2013 a rapid increase in bioethanol production was recorded in Ukraine – from 1975 Mg to 43450 Mg. In the context of the acute economic and political crisis in 2014, bioethanol production fell (Fig. 6). According to data from Ukrainian State Owned Enterprise “Urkspiirt”, as for 2019, the installed capacities for bioethanol production are 162.96 thousand Mg with an actual production of 13.43 thousand Mg.

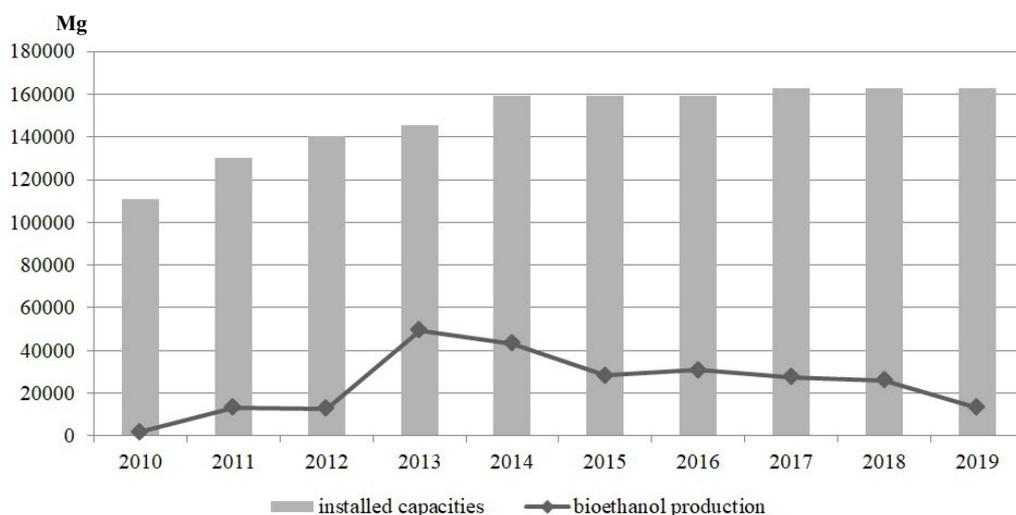


Fig. 6. Volumes of bioethanol production by Ukrainian distilleries and installed capacities, 2010–2019 [Mg]
Source: data from the official website of the Ukrainian State Owned Enterprise “Urkspiirt”

Rys. 6. Wolumeny produkcji bioetanolu przez ukraińskie gorzelnie i zainstalowane moce w latach 2010–2019 [Mg]

The high level of competition in the alcohol industry requires the implementation of a complex of technical, organizational, financial, economic and other measures in the domestic alcohol industry. This will ensure an increase in the production of alcohol, bioethanol and components based on it, alcohol-containing products for technical purposes, raw materials for the production

of perfumes, alcoholic beverages, ethyl alcohol and other types of products, reduce the cost of their production, improve the quality and competitiveness of products both in the domestic and foreign markets. Accordingly, the strategic priorities for improving the performance of the distillery industry should include the modernization and reorganization of all production sites of the enterprise.

Therefore, the production of bioethanol is a strategic component of the development of the distillery industry (Fig. 7).

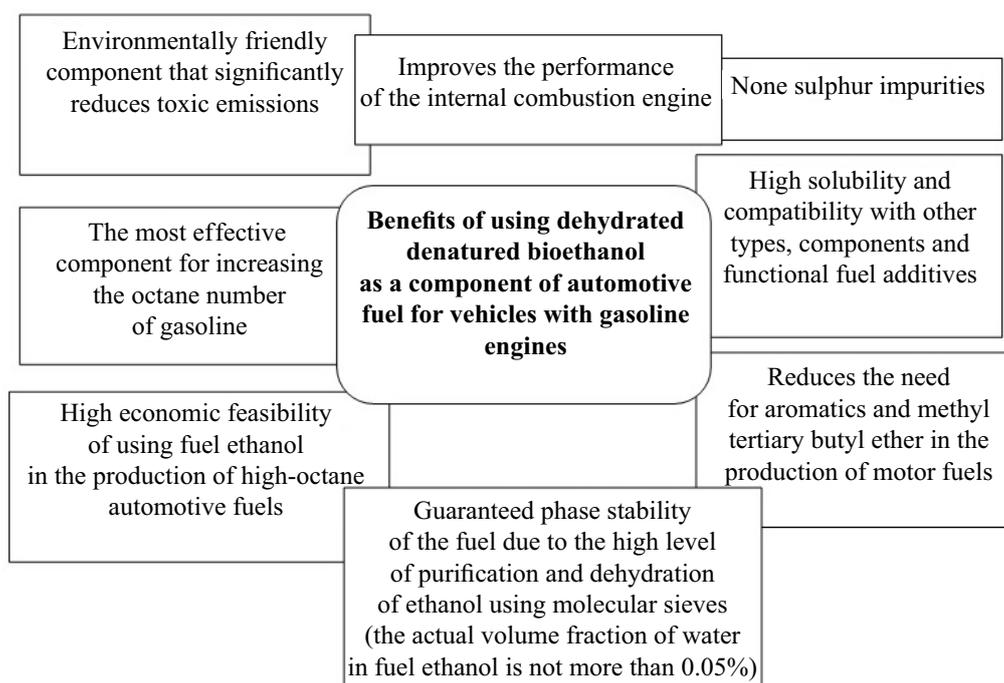


Fig. 7. Scheme of factors for the effective production of bioethanol as a component of the development of the distillery industry

Source: formed by the authors on the basis of the studied literature (Palamarenko 2016)

Rys. 7. Schemat czynników efektywnej produkcji bioetanolu jako składnika rozwoju przemysłu gorzelniczego

Thus, the production of bioethanol is a component of the strategic development of the distillery industry in Ukraine. The organization and establishment of bioethanol production will improve the fuel and energy balance, reduce the country's dependence on imported energy carriers, and optimize the structure of energy resources, which will positively affect the energy security of the state.

3. Prospects for replacing conventional gasoline fuel with bioethanol

3.1. Benefits of Bioethanol Production

Organization of motor alternative fuel production with bioethanol content provides an opportunity to use an environmentally friendly component in motor fuel, which significantly reduces emissions of toxic substances, reduces dependence on energy imports, and improves the overall environmental situation in the country (Fig. 8). According to the press releases of the State Owned Enterprise “Ukrspirt”, the excise tax on alternative motor fuel, which contains fuel bioethanol, is 41% lower (by EUR 51.5 per 1000 liters) than conventional gasoline. Prices in Ukraine for the main feedstock used for bioethanol production are stable. At the same time, the use of 10% gasoline-ethanol blends can significantly reduce the total cost and sales price of the product.

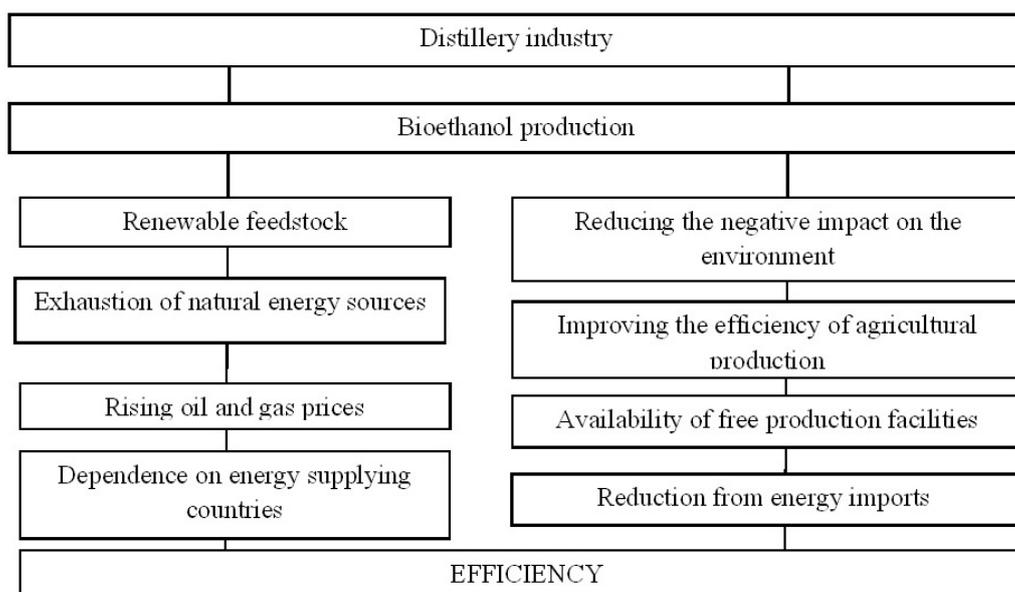


Fig. 8. Advantages of using bioethanol in the production of fuel for vehicles
 Source: formed by the authors on the basis of previous studies (Kaletnik 2018; Pryshliak et al. 2019)

Rys. 8. Zalety stosowania bioetanolu do produkcji paliwa do pojazdów

According to the Remap 2030 Renewable Energy Program, Table 1 shows the costs that indicate the replacement of capacities in the distribution by technology for 2030 for the state and

business. This proves the fact that for Ukraine today the development of technologies for the use of biomass, biogas and biofuels is very promising, because these technologies are innovative and competitive.

The analysis of Table 1 showed that the cost of replacement capacity in the transport sector, which is associated with the use of traditional bioethanol, is the lowest for the state and is USD 1.1/gJ, while the indicators for the business sector for this type of product are the highest and is equal to 3.1 dollars/gJ. The opposite situation is observed for fuel ethanol of improved quality.

TABLE 1. Costs for replacement of capacities according to REMAR Options, by technology, for 2030, for the state and business

TABELA 1. Koszty wymiany mocy do 2030 roku, według technologii dla państwa i przedsiębiorcy zgodnie z Opcjami REMAR

No	Type of production	For the state [USD/gJ]	For business [USD/gJ]
1.	Traditional bioethanol	-1.1	3.1
2.	Bioethanol of the improved quality	-3.1	-0.5

Source: REMAP – 2030; State Agency for Energy Efficiency and Energy Saving.

The Energy Strategy of Ukraine for the period up to 2035 provides for several scenarios of switching to the use of gasoline with 10% ethanol until 2035. One of the most expensive elements of bioethanol production technology is its dehydration. Even if the production potential of the distillery is used, the problem of dehydration remains. This will require an investment of USD 200–300 million.

The advantages of bioethanol as a fuel include the fact that it has high anti-knock properties (octane number is 113 (Renewable fuels Association 2020)). Mixing it with low-octane gasoline increases the octane number of the fuel. Ethanol burns more slowly in the engine cylinder than gasoline due to its high oxygen content. As a result, carbon monoxide emissions into the environment are reduced. However, ethanol has its drawbacks. One of them is the lower calorific value compared to gasoline (29.7 MJ/kg) (McAllister et al. 2011) versus 44–46 MJ/kg for gasoline (World Nuclear Association 2020). Therefore, engine power decreases and fuel consumption increases. The specific heat of vaporization of ethanol is almost three times higher than that of gasoline, and, consequently, its volatility is less. The air must be heated for the engine to run on bioethanol and bioethanol-gasoline mixtures. This makes it difficult to start the engine at low temperatures. In addition, bioethanol and bioethanol-gasoline mixtures are very hygroscopic.

Bioethanol has passed a full cycle of bench and operational tests and is approved for use in Ukraine in accordance with the established procedure. The test results of mixed gasoline – gasoline with the addition of a high-octane oxygen-containing additive – confirmed that the energy

and economic performance of mixed gasoline does not deteriorate compared to standard gasoline with an overall improvement in environmental performance (Kaletnik 2018).

The program for the development of the alcohol industry for the near future provides for the establishment of large-scale production of alternative energy sources, including bioethanol.

3.2. SWOT analysis of bioethanol production industry in Ukraine

We use the SWOT analysis method to determine the strengths and weaknesses of sugar beet and distillery enterprises on the possibility of organizing the production of bioethanol, taking the market situation, as well as to analyze the opportunities and threats that come from the external environment of the enterprise into account (Fig. 9).

	Strength	Weaknesses
Internal origin	<ul style="list-style-type: none"> - advantageous location of sugar factories in the center of beet-growing zones; - experience in growing and processing sugar beets for over 100 years; - availability of feedstock; - close ties with beet-growing enterprises for the supply of products; - experience in responding to crisis situations; - availability of the necessary production infrastructure and logistics support; - low level of costs for obtaining feedstock for the production of bioethanol; - fast return of investment (due to the profitability of bioethanol production and growing demand); - using the potential of by-products. 	<ul style="list-style-type: none"> - insufficient level of qualifications of personnel in the field of bioethanol production; - lack of contacts with buyers of bioethanol; - unstable financial condition of the enterprise; - high capital investment.
	Opportunities	Threats
External origin	<ul style="list-style-type: none"> - a small number of competitors; - reduction of the tax burden; - availability of national programs aimed at the development of alternative energy; - high prices for gasoline with the prospect of further growth; - decrease in the number of unemployed population; - availability of demand for bioethanol; - safety in relation to the environment. 	<ul style="list-style-type: none"> - high inflation rate; - imperfection of the current regulatory framework in the field of biofuel production; - complex predictability of the cost of energy resources (in particular, natural gas).

Fig. 9. Map of SWOT analysis on the organization of bioethanol production at sugar and alcohol factories in Ukraine

Source: own study

Rys. 9. Analiza SWOT organizacji produkcji bioetanolu w cukrowniach i gorzelniach na Ukrainie

This, on the one hand, will make it possible to increase the investment attractiveness of enterprises in the alcohol industry and thereby increase the inflow of investments, and on the other hand, it will solve the long-term problem of ensuring the country's energy security by reducing the dependence on the imports of fossil hydrocarbons.

As a result of the analysis, it can be noted that at this stage, the reorientation of distilleries to the production of bioethanol is quite risky. This is due to the fact that distilleries belong to the state. Previous experience indicates that it is impossible to increase the volume of biofuel production only by re-profiling the idle capacities of the distilleries within the existing state monopoly.

Providing new impulses for investment activity in the processing and food segment of the agro-industrial complex will help to establish the production of bioethanol on unused areas of the alcohol industry. This will be possible if a legislative and regulatory framework is formed that will regulate the mandatory addition of biofuels.

The production of alternative motor fuel with bioethanol content will: ensure the proper functioning of the domestic market of motor fuels; reduce the state's dependence on energy imports; increase the level of energy security of the state; ensure development and stability of the agro-industrial complex of the country; create new jobs and increasing budget revenues; improve the environmental situation and reduce CO₂ emissions.

In the case of bioethanol production in distilleries, its cost may be higher due to the need for transportation costs. If the capacity of the distillery will be located near the sugar plant, it will be beneficial to cooperate between the two enterprises to establish biofuel production at the distillery.

In other cases, the production of bioethanol should be carried out in sugar-beet processing factories. In addition to saving money on transportation costs, diversification of production will help regulate the production of sugar or bioethanol depending on demand and prices in the market.

Sugar beet production volumes mainly depend on weather and climatic conditions, therefore, in years of poor harvest, sugar factories equipped with bioethanol production lines will be able to reduce bioethanol production volumes and increase sugar production volumes without a threat to sustainable plant operation. These types of plants have been successfully operating for many years in France, the Czech Republic, Great Britain and Brazil.

3.3. Perspectives of bioethanol production and consumption in Ukraine

Bioethanol in Ukraine can potentially be produced from cereals, sugar beets, and molasses. Currently all bioethanol that is being produced in Ukraine is made from molasses (Ukrainian State Owned Enterprise "Urkspirit"). Molasses production volumes in Ukraine are unstable and depend on the volume of sugar beet processing at sugar factories and sugar production. On average, the yield of molasses from 1 ton of sugar beet in the sugar production process is 4–5%. The benefit of this feedstock is that molasses does not compete with the possibility of its use in the food sector (it can be used as an additive for feeding cows but it is not very convenient in

terms of transporting, storing and adding to the mixer). Some part of molasses that is not being processed for bioethanol in Ukraine is exported to neighboring countries (Ministry of Economic Development and Trade of Ukraine). Considering that all molasses produced by sugar factories of Ukraine is processed into bioethanol, the possible production of bioethanol will amount to 90–130 thousand Mg (Table 2) (the yield of bioethanol from 1 Mg of molasses is 0.237 Mg).

TABLE 2. Theoretically possible volumes of bioethanol production from molasses in Ukraine, 2000–2018

TABELA 2. Teoretycznie możliwe wielkości produkcji bioetanolu z melasy na Ukrainie w latach 2000–2018

Year	Production volumes of molasses [Mg]	Possible volume of bioethanol production [Mg]
2000	564578.4	133805.1
2001	674861.8	159942.2
2002	600702.8	142366.6
2003	586755.6	139061.1
2004	631196.8	149593.6
2005	627501.5	148717.9
2006	900890.0	213510.9
2007	648554.7	153707.5
2008	497135.7	117821.2
2009	370362.9	87776.0
2010	534836.1	126756.2
2011	676441.4	160316.6
2012	635851.5	150696.8
2013	375725.0	89046.8
2014	550690.0	130513.5
2015	413232.0	97936.0
2016	560452.0	132827.1
2017	595264.0	141077.6
2018	558708.0	132413.8

Source: calculated by the authors according to the official website of the National Association of Sugar Producers of Ukraine “UkrSugar”

Now only 10–20% of the total amount of molasses produced is processed into bioethanol. The syrup, which is not used in the process of processing into bioethanol, is exported to the nearest countries, where it is later used for bioethanol production.

It should be noted that the demand for sugar and food alcohol in Ukraine is approximately the same every year. So, the annual consumption of sugar in Ukraine fluctuates between 1.8–2.1 million Mg, Ukraine’s need for food alcohol is 200–250 thousand Mg. At the same time, the po-

tential capacity of sugar production in Ukraine is 5.0–5.4 million Mg, the capacity of Ukrainian distilleries is 450 thousand Mg of alcohol per year. At the same time, considering the limited possibilities of the internal market, as well as the lack of access to external markets, it is not rational to increase the production of sugar and alcohol without entering foreign markets. The solution for the improving the performance of the sugar and alcohol industry in Ukraine could be the production of bioethanol.

Taking the volumes of gasoline consumption in 2018 in Ukraine into account, to replace 5% of gasoline, it is necessary to produce 199.25 thousand Mg of bioethanol, 7% – 279.0 thousand Mg, 10% – 398.5 thousand Mg (Table 3).

TABLE 3. Potential demand for bioethanol production in Ukraine

TABELA 3. Potencjalny popyt na produkcję bioetanolu na Ukrainie

	Gasoline consumption in 2018* [thousand Mg]	To replace 5% of gasoline [thousand Mg]	To replace 7% of gasoline [thousand Mg]	To replace 10% of gasoline [thousand Mg]
Ukraine	3985.0	199.25	279.0	398.5
For the needs of agriculture	300.0	15.0	21.0	30.0

Source: own study.

*gasoline consumption volumes taking according to State Statistics Service of Ukraine.

By establishing the production of bioethanol, the theoretically possible volume of bioethanol production could reach from 199 to almost 400 thousand Mg per year, which will make it possible to replace from 5 to 10% of gasoline respectively and meet the EU requirements.

Conclusions

The analysis of the sugar beet and distillery industry in Ukraine showed that the demand for sugar and food alcohol in Ukraine is practically the same every year. The annual consumption of sugar in Ukraine fluctuates between 1.8–2.1 million Mg, Ukraine’s need for food ethanol is 200–250 thousand Mg. At the same time, the potential sugar production capacity in Ukraine is 5.0–5.4 million Mg, the capacity of Ukrainian distilleries is 450 thousand Mg of ethanol per year. Therefore, considering the limited possibilities of the domestic market, as well as the lack of access to foreign markets, it is not advisable to increase the production of sugar and food alcohol without access to foreign markets.

Currently, bioethanol in Ukraine is mainly produced from molasses and remains at a very low level. Only 10–20% of the total amount of molasses produced in Ukraine is processed into

bioethanol. If processing all molasses for bioethanol, which is produced by sugar beet processing plants in Ukraine, the possible volume of bioethanol production will be 90–130 thousand Mg.

An assessment of the potential for the production of bioethanol at the sugar beet enterprises and distilleries showed that these industries have free capacities and, after re-equipment, can become a powerful base for the production of bioethanol in Ukraine. The feasibility of bioethanol production at beet processing plants is that the feedstock for bioethanol production (molasses) can be processed directly at the place of its production. In addition, bioethanol can be produced from other intermediate products of sugar beet processing.

The introduction of bioethanol production at the enterprises of the distillery industry is very perspective. Currently, the volumes of bioethanol production in Ukraine are only at 8% of the installed capabilities. At the same time, Ukraine has a huge feedstock potential for production bioethanol without threatening food production. The production of bioethanol at the currently unused capacities of the distillery could restore the operation of a significant number of enterprises, improve the financial condition of the industry, and increase budget revenues at all levels

The main advantages of sugar beet processing plants and distilleries in the biofuel market are the availability of appropriate equipment, highly qualified workers, developed infrastructure, provision of the required amount of technical water, availability of feedstock.

In addition, the key role is played by the favorable geographical location of Ukraine. It gives an opportunity to create a highly developed logistics system that should unite Ukraine with the EU. Ukraine has a large and powerful agro-industrial sector, to satisfy both internal consumption, external trade and bioethanol production.

References

- Association agreement between the European Union and its Member States, of the one part, and Ukraine, of the other part, 2014. [Online] https://trade.ec.europa.eu/doclib/docs/2016/november/tradoc_155103.pdf [Accessed: 2021-04-03].
- Cristal Union 2021. [Online] <https://www.cristal-union.fr/en/group/profile/> [Accessed: 2021-04-03].
- Directive (EU) 2018/2001 of the European parliament and of the council of 11 December 2018 on the promotion of the use of energy from renewable sources. [Online] <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=fr> [Accessed: 2021-04-03].
- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. [Online] <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0028> [Accessed: 2021-04-03].
- EU Biofuels Annual 2019. [Online] https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Biofuels%20Annual_The%20Hague_EU-28_7-15-2019.pdf [Accessed: 2021-04-03].
- Explanatory note to the draft Law of Ukraine “On Amendments to the Law of Ukraine” On State Regulation of the Production and Turnover of Ethyl, Brandy and Fruit Alcohol, Alcoholic Beverages, Tobacco Products and Fuel “on Liberalization in the Sphere of Production and Turnover of Ethyl Alcohol” 2019. [Online] <https://ips.ligazakon.net/document/GI00658A> [Accessed: 2021-04-03].

- FAO 2020. Food and Agriculture Organization of the United Nations (FAO) 2020. [Online] <http://www.fao.org/home/en/> [Accessed: 2021-04-03].
- GOŁOWICZ, A. and WOJCIECHOWSKI, A. 2020. Fuels from waste for energy source diversification. *Polityka Energetyczna – Energy Policy Journal* 23(2), pp. 139–156, DOI: 10.33223/epj/124279.
- HAREBA, V.V. 2012. *Scientific aspects of bioethanol production in Ukraine*. [Online] http://www.sugarconf.com/custom/files/ua_2012_04/krugl_stol/179-184. Pdf [Accessed: 2021-04-03].
- International Renewable Energy Statistics 2020. [Online] <https://www.irena.org/publications/2020/Mar/Renewable-Capacity-Statistics-2020> [Accessed: 2021-04-03].
- KALETNIK et al. 2019 – KALETNIK, G., PRYSHLIAK, V. and PRYSHLIAK, N. 2019. Public Policy and Biofuels: Energy, Environment and Food Trilemma. *Journal of Environmental Management and Tourism* X, 3(35), pp. 479–487, DOI:10.14505/jemt.v10.3 (35).01.
- KALETNIK, G. 2018. *Production and Use of Biofuels*. Second edition, supplemented. Vinnytsia: LLC “Nilan-Ltd”. 336 p.
- KALETNIK, G.M. and PRYSHLIAK, N.V. 2013. Production of bioethanol from sugar beets – one of the main factors of sugar-beet industry stabilisation. *Ekonomika APK* (3), pp. 65–69.
- KYTAIEV et al. 2020 – KYTAIEV, A., CHALA, N. and ANDROSOV, Y. 2020. Failures of energy policy in Ukraine in the context of energy security priorities. *Polityka Energetyczna – Energy Policy Journal* 23(3), pp. 111–124, DOI: 10.33223/epj/127509.
- MCALLISTER et al. 2011 – MCALLISTER, S., CHEN, J. Y. and FERNANDEZ-PELLO, A.C. 2011. Thermodynamics of combustion //Fundamentals of combustion processes. *Springer*, New York, NY, pp. 15–47.
- Ministry of Economic Development and Trade of Ukraine 2020. [Online] <https://www.me.gov.ua/?lang=uk-UA> [Accessed: 2021-04-03].
- Ministry of Energy and Industry of Ukraine 2020. [Online] <http://mpe.kmu.gov.ua/> [Accessed: 2021-04-03].
- OECD-FAO Agricultural Outlook 2020–2029. [Online] <http://www.fao.org/3/ca8861en/Biofuels.pdf> [Accessed: 2021-04-03].
- National Association of Sugar Producers of Ukraine “UkrSugar”. [Online] <http://sugarua.com> [Accessed: 2021-04-03].
- PALAMARENKO, Y. 2016. Production of bioethanol as a component of the strategic development of the alcohol industry of Ukraine. *Ekonomika ta derzhava* 12, pp. 90–93.
- PALAMARENKO, Y. 2018. Development of bioenergetics as an innovational operator in the context of energy security of Ukraine. *Global and National Problems of Economy* 22. pp. 209–215.
- PRYSHLIAK, N.V. 2014. Perspectives of bioethanol production of sugar beets in Ukraine. *Ekonomika APK* 3, pp. 126–131.
- PRYSHLIAK, N.V. and TOKARCHUK, D. 2020. Socio-economic and environmental benefits of biofuel production development from agricultural waste in Ukraine. *Environmental and Socio-economic Studies* 8(1), pp. 18–27.
- PRYSHLIAK et al. 2019 – PRYSHLIAK, N.V., TOKARCHUK, D.M. and PALAMARENKO, YA.V. 2019. *Ensuring energy and environmental security of the state through biofuels from bioenergy crops and waste: a monograph*. Vinnytsia: Console. 336 p.
- REMAP – 2030. Prospects for the development of renewable energy in Ukraine until 2030. [Online] http://sae.gov.ua/sites/default/files/UKR%20IRENA%20REMAP%20_%202015.pdf [Accessed: 2021-01-20].
- Renewable Fuels Association 2020. [Online] <https://ethanolrfa.org/high-octane-fuels> [Accessed: 2021-04-03].
- State Agency for Energy Efficiency and Energy Saving. [Online] <http://sae.gov.ua/uk> [Accessed: 2021-04-03].
- State Statistics Service of Ukraine 2020. [Online] www.ukrstat.gov.ua [Accessed: 2021-04-03].
- Statista 2021. [Online] <https://www.statista.com/statistics/613238/biofuels-consumption-transport-eu/> [Accessed: 2021-01-20].

- SUSMOZAS et al. 2020 – SUSMOZAS, A., MARTÍN-SAMPEDRO, R., IBARRA, D., EUGENIO, M. E., IGLESIAS, R., MANZANARES, P. and MORENO, A. D. 2020. Process Strategies for the Transition of 1G to Advanced Bioethanol Production. *Processes* 8(10), 1310, DOI:10.3390/pr8101310.
- TOKARCHUK et al. 2020 – TOKARCHUK, D.M., PRYSHLIAK, N.V., TOKARCHUK, O.A. and MAZUR, K.V. 2020. Technical and economic aspects of biogas production at a small agricultural enterprise with modeling of the optimal distribution of energy resources for profits maximization. *INMATEH – Agricultural Engineering* 61(2), pp. 339–349.
- Ukrainian State Owned Enterprise “Urkspirt”. [Online] http://ukrspirt.com/en/cms/about_company.html [Accessed: 2021-04-03].
- World Nuclear Association, 2020. [Online] <https://www.world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels.aspx> [Accessed: 2021-04-03].

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Efektywność i ocena możliwości produkcji bioetanolu w przedsiębiorstwach przemysłu buraczanego i w gorzelniach na Ukrainie

Streszczenie

We współczesnych warunkach globalizacji gospodarczej, coraz mocniejszych relacji rynkowych i zaostrej konkurencji rozwój gospodarczy przedsiębiorstwa zależy bezpośrednio od wprowadzania innowacji. Przejście na innowacyjną ścieżkę rozwoju wymaga od przedsiębiorstwa określenia swojej gotowości oraz oceny możliwości rozwoju i dalszego wdrażania innowacji. W artykule przeanalizowano współczesne trendy w produkcji konwencjonalnych paliw płynnych na Ukrainie, w szczególności dokonano analizy produkcji benzyn silnikowych i rafinacji ropy naftowej, określono udział benzyny silnikowej wyprodukowanej na Ukrainie w całkowitym wolumenie zużytej benzyny oraz wolumen produkcji bioetanolu przez ukraińskie zakłady gorzelnicze. Dokonano oceny potencjału produkcyjnego surowców do produkcji bioetanolu na Ukrainie oraz zbadano możliwości produkcji bioetanolu w gorzelniach. Dokonano również analizy produkcji melasy oraz określono teoretycznie możliwe wielkości produkcji bioetanolu z melasy na Ukrainie. Zaproponowano schemat kluczowych priorytetów strategicznych dla rozwoju produkcji etanolu spożywczego i bioetanolu. Zwrócono uwagę na zalety stosowania bioetanolu w mieszankach benzyny z etanolem do pojazdów, sporządzono analizę SWOT organizacji produkcji bioetanolu w zakładach przetwórstwa buraków cukrowych i w gorzelniach. Obliczono zapotrzebowanie Ukrainy na produkcję bioetanolu i na podstawie uzyskanych wyników przewidziano wielkość produkcji bioetanolu.

SŁOWA KLUCZOWE: gorzelnie, bioetanol, buraki cukrowe, surowce

