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ZAMULA, I. V. [1] (https://orcid.org/0000-0002-6075-095X),
ILCHENKO, A. V. [2] (https://orcid.org/0000-0001-7927-8745),
and TRAVIN, V. V. [1] (https://orcid.org/0000-0002-7386-7372)

[1] Zhytomyr Polytechnic State University,
103, Chudnivska St., Zhytomyr, 10005, Ukraine,
+380 412 24 1422, officerector@ztu.edu.ua
[2] Polissia National University,
7, Stariy Blvrd., Zhytomyr, 10002, Ukraine,
+380 412 47 1356, mail@polissiauniver.edu.ua

FINANCIAL FORECAST OF BIOFUEL PRODUCTION AND USE IN UKRAINE DURING AND AFTER MILITARY ACTIONS

Introduction. *Ukraine has possessed substantial potential for cultivating biofuel crops and producing biofuels as an innovative alternative to petroleum products. This potential has been facilitated by extensive land resources, favorable climatic conditions, the presence of major transport corridors, and the availability of essential production factors.*

Problem Statement. *The financial forecasting of biofuel production and use in Ukraine during and after military operations has required further investigation, given the critical importance of energy security and post-war economic recovery.*

Purpose. *The objective of this study has been to assess, through financial forecasting, the prospects for the production and use of biofuels derived from rapeseed oil during the period of military conflict and the subsequent post-war recovery of Ukraine's economy.*

Materials and Methods. *The analysis has been conducted using diesel fuel blended with rapeseed oil and/or its derivatives as the principal case study. The study has applied methods of analysis and synthesis, induction and deduction, classification, generalization, and graphical and tabular representation.*

Results. *The main advantages of rapeseed oil have included its renewability and environmental sustainability. Agricultural producers have demonstrated strong interest in cultivating rapeseed due to the consistently high demand for its seeds and oil, as well as favorable market prices. With regard to environmental performance, it has been empirically established that smoke emissions from diesel exhaust gases with rapeseed oil admixtures have been lower than those from pure diesel fuel. Nevertheless, the environmental impact has not been completely eliminated, which remains a limitation of biofuel use. Another key advantage has been the contribution to national*

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energy independence. However, the energy efficiency of rapeseed-based fuel has been shown to be lower than that of fossil fuels, which can be considered a drawback. In addition, the production cost of biofuels has exceeded that of conventional fossil fuels.

Conclusions. *The assessment of the advantages and disadvantages of using diesel fuel blended with rapeseed oil has demonstrated a clear predominance of benefits over limitations. This outcome has provided grounds to recommend rapeseed-based biofuels as a viable alternative to fossil fuels in Ukraine's energy system, both during ongoing military operations and throughout the post-war recovery period.*

Keywords: financial forecasting, alternative fuels, biofuels, biodiesel, fuel consumption, rapeseed oil, post-war recovery, sustainable development.

In recent decades, human activity has exerted a significant impact on the natural environment. Traditional motor vehicles powered by internal combustion engines have accounted for 20—30% of total atmospheric air pollution. Despite global security instability, both in Ukraine and worldwide, the implementation of the principles of sustainable development has remained a pressing priority. Particular attention has had to be given to the introduction of innovations in the search for and use of alternative energy sources, especially biofuels.

Biofuel is fuel produced from biological energy raw materials. It can be used independently or as a component or feedstock for the production of blended fuels through mixing with conventional petroleum-based fuels, in accordance with established standards.

The production of biofuels worldwide has increased annually (Fig. 1) and has become an increasingly important foundation for combating climate change and ensuring the sustainability of the energy sector.

During the period 2000—2022, the global biofuel production has shown steady growth. In 2022, it has reached 102 million tons of oil equivalent, which is 11.2 times higher than in 2000. Based on the constructed linear trend equation, with a reliability of 97.4%, further growth has been forecast.

A significant number of countries have actively invested in biofuel production as an innovative energy alternative to petroleum products and as a means of reducing greenhouse gas emissions. Many European Union countries have set ambitious targets for increasing the share of renewable energy sources, particularly biofuels, in their energy balances.

Ukraine has had considerable potential in cultivating biofuel crops and producing biofuels. Between 2020 and 2023, production volumes have continuously increased. In 2023, production has reached 6,270 thousand tons of oil equivalent, which is 1,832 thousand tons, or 41.3%, more than in 2020. A linear relationship has been observed, and on the basis of the constructed equation, further growth of biofuel production in Ukraine has been forecast, with a reliability of 99.9%, as reflected by the trend line.

Even during Russia's full-scale invasion of Ukraine, domestic producers have not only preserved but have increased biofuel output. Consequently, Ukraine can become a key player in this sector globally. This has been facilitated by the availability of large areas of agricultural land resources, favorable climatic conditions, strategic transport corridors, and the presence of essential production factors.

The development of the biofuel market has been identified as one of the state's priorities for ensuring energy security and independence, both at the national and community levels, particularly under wartime energy challenges and during post-war recovery. In Ukraine alone, agricultural residues have had the potential to substitute approximately 9 billion m^3 of natural gas annually [3].

The arguments in favor of biofuels as an alternative to fossil fuels have included: the substitution of natural gas and budget savings ranging from 30% to 60%, the reliable energy supply for social facilities and critical infrastructure during wartime and post-war reconstruction, and the stimulation of economic activity in the country [4].

Furthermore, the production and use of biofuels, as renewable resources, have not only had econo-

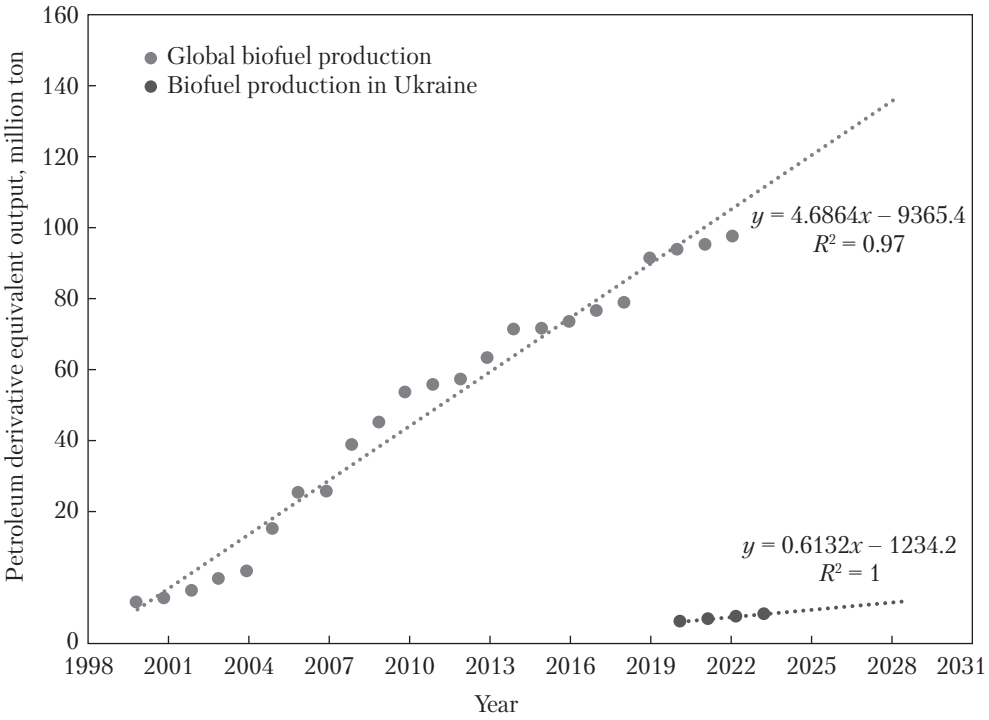

Fig. 1. Dynamics of biofuel production worldwide and in Ukraine

Source: based on [1, 2].

mic implications but also social and environmental dimensions, thereby contributing to the sustainable development of both the global economy and individual national economies [4]. At the same time, the excise tax rate that directly influences fuel prices, has introduced a political dimension into the production and use of biofuels. High excise tax levels have affected consumption volumes by reducing demand through higher prices. This, in turn, has reduced environmental pollution and stimulated the adoption of more environmentally friendly alternative energy sources.

Research on the production and use of biofuels has directly aligned with several Sustainable Development Goals (SDGs) that outline global development priorities. Specifically, it has corresponded to SDG 7 "Affordable and Clean Energy," by promoting renewable energy sources and reducing reliance on fossil fuels. It has also advanced SDG 9 "Industry, Innovation, and Infrastructure," through the implementation of advanced bioenergy technologies and modernization of energy infrastructure. Moreover, biofuel use has contributed to SDG 13 "Climate Action," by lowering greenhouse gas emissions and mitigating environmental impacts, and has correlated with SDG 15 "Life on Land," by encouraging rational land use and supporting the development of environmentally sustainable agriculture.

The economic rationale for adopting innovative transport technologies has been highlighted in the works of L. Melnyk, O. Matsenko, T. Sakhnenko, and M. Tsynka [5]. The evaluation of enterprise efficiency during the transition to alternative energy sources has been conducted by I. Perevoza, T. Maksymenko, and S. Bondarenko [6], as well as T. Maksymenko [7]. The prospects for advanced biofuel production in Ukraine have been investigated by H.H. Heletukha, T.A. Zhelezna, S.V. Drahniev, and P.P. Kucheruk [8]. The ecological and economic aspects of alternative fuel management have been addressed in the research

of V. Havrysh, V. Nitsenko, I. Perevozov, T. Kulyk, and O. Vasylyk [9]. The social component of the efficiency of transitioning to alternative energy in the framework of the "economy of the future" has been analyzed by I.V. Podberezna [10]. The concept of consolidating marketing efforts in the global automotive market has been studied by O. Savych and T. Shkoda [11].

The analysis of these studies has shown that the issue of financial forecasting of biofuel production and use in Ukraine during and after military actions has remained insufficiently addressed.

The purpose of this study has been to evaluate, based on financial forecasting, the prospects for the production and application of biofuels derived from rapeseed oil in Ukraine during the period of ongoing military actions and in the postwar recovery of the national economy.

Globally, the leading producers and consumers of biofuels have been the United States, Brazil, and the European Union [12]. The United States has remained the largest producer of bioethanol, primarily from corn and sugarcane. Brazil has led in biodiesel production from soybean oil. EU countries have actively developed biofuel production from a variety of biomass sources, including wood, straw, and algae [13].

The principal factors that have stimulated the development of the global biofuel market include:

- the rising environmental awareness of societies and the desire to reduce greenhouse gas emissions, since biofuels are regarded as more sustainable fuels derived from renewable energy sources;
- government support, as many states have introduced incentive policies to improve the availability and competitiveness of biofuels;
- innovation and technological advances that have enabled more efficient and cost-effective production of biofuels from diverse feedstocks.

However, the development of the biofuel market has faced certain challenges:

- **food security,** as increased biofuel production has posed the risk of reducing the land area available for food crops, with potentially negative consequences for global food supply;
- **land-use change,** since the cultivation of biomass for energy purposes has led to deforestation, soil degradation, and other ecological problems;

Table 1. **Advantages and Disadvantages of Biofuels as Compared with Other Types of Fuel**

No.	Advantages		Disadvantages	
	Property	Characteristic	Property	Characteristic
1	Environmental friendliness	Biofuel burns with fewer harmful emissions compared to fossil fuel, which can help reduce air pollution and combat climate change	Pollution	Burning biofuel can still cause air pollution, although to a lesser extent than fossil fuels
2	Renewability	Biofuel is produced from biomass that is a renewable resource, meaning it can be continuously replenished without depletion, unlike fossil fuels	Competition with food	Some types of biofuels are produced from edible crops, which can lead to competition with food and rising food prices
			Change in land use	Cultivation of feedstock for biofuels can result in deforestation and other land-use changes that may negatively affect the environment
3	Energy independence	Reducing dependence on fossil fuel imports and stimulating the development of the domestic energy sector	Inefficiency	Biofuels may be less energy-efficient than fossil fuels
			High cost	The production of biofuels can be costly, making them not always affordable

Source: prepared by the authors.

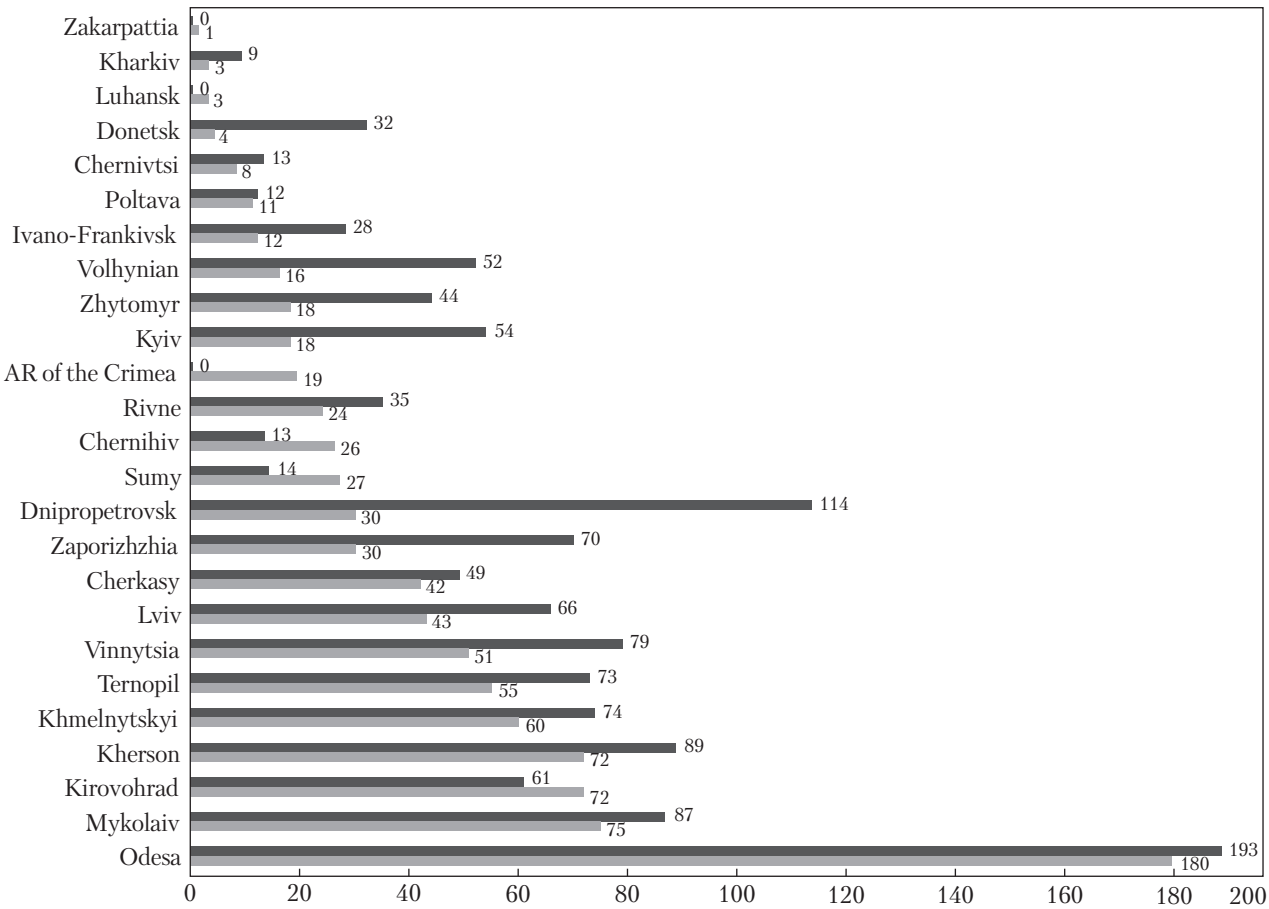

Fig. 2. Areas under Rapeseed in 2010 and 2020

Source: based on [16].

- **sustainable development concerns,** as biofuel production shall not harm the environment and should comply with the principles of sustainability, including environmental protection, social equity, non-discrimination, and the improvement of living standards [14].

Advantages and disadvantages of biofuels compared to other types of fuel are presented in Table 1.

The extent to which the indicated advantages and disadvantages manifest depends on the type of biofuel used. One of the most widely applied vegetable oils for biofuel production is rapeseed oil. In the EU, the biodiesel standard EN14214 defines the chemical and physical parameters of the fuel, which is particularly important for the production of winter-grade biofuels, for which rapeseed oil is the most suitable [15]. Moreover, about 5% of the biodiesel produced in Europe has been derived from Ukrainian rapeseed [16]. Therefore, further analysis of the extent to which the advantages and disadvantages of biofuel production and use apply in Ukraine is conducted using the example of diesel fuel blended with rapeseed oil and/or its derivatives.

The advantage of rapeseed oil, as with other plant-based oils, lies in its renewability. Ukraine has favorable conditions for rapeseed cultivation, as evidenced by the steady increase in sown areas (Fig. 2), as well as in gross yields and productivity (Fig. 3).

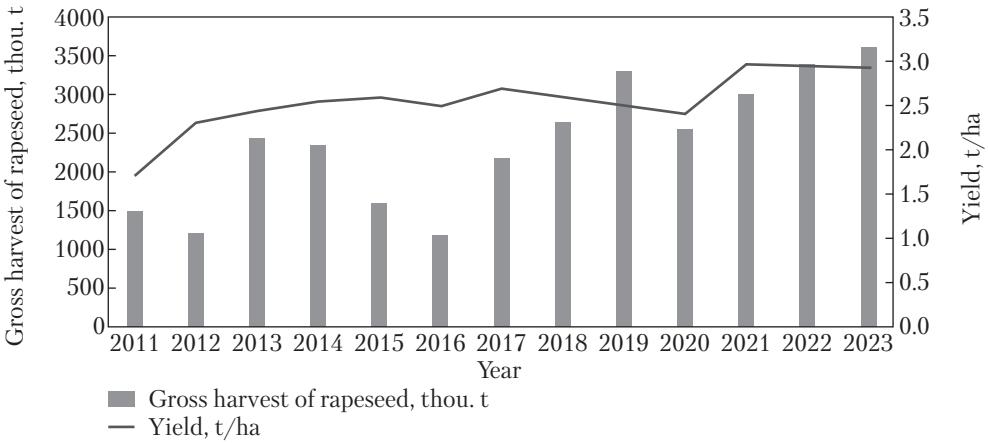

Fig. 3. Total harvest and yield of rapeseed in Ukraine, in 2011—2023

Source: based on [17].

In 2020, rapeseed sowing areas amounted to 1,283 thousand ha that is 42.7% more than in 2010. Throughout the entire analyzed period, the largest sowing areas were concentrated in the steppe zone of Ukraine, driven by soil quality and climatic conditions that provide the highest yields of this crop.

Rapeseed yields in Ukraine demonstrated a steady upward trend during 2011—2023, reaching 2.85 t/ha, in 2023. Gross harvest volumes, however, directly depended on changes in sowing areas. For instance, in 2012 and 2016, a significant reduction in rapeseed sowing areas led to a decline in gross harvest to 1,300 thousand tons and 1,200 thousand tons, respectively.

Looking ahead, as of early 2024, expert estimates indicated that up to 4 million ha of agricultural land in Ukraine remained unused, while over 5 million ha were unsuitable for farming due to contamination, mining, and other consequences of military actions [18]. These areas could potentially be employed for cultivating energy crops.

Agricultural producers are interested in rapeseed production due to strong demand for its seeds and oil, as well as favorable price levels. In 2023—2024, rapeseed became significantly more popular in Ukraine, driven by sustained demand from European importers for Ukrainian oil. As a result, rapeseed has become one of the most profitable crops for domestic producers. Prices on the domestic market remain attractive to farmers and competitive compared with other oilseed crops (Table 2).

The average purchase price of rapeseed seeds on the domestic market steadily increased during

Table 2. **Average Purchase Price of Rapeseed Seeds in the Domestic Market and Quantities Processed into Oil, 2014—2022**

Year	Average purchase price at the beginning of the year		Processed from the beginning of the year		
	UAH per 1 t	% with respect to the corresponding period of the previous year	Quantity, t	% with respect to the corresponding period of the previous year	% of the output
2022	c	c	c	c	c
2021	16266.3	151.1	388026	152.2	13.0
2020	10768.8	113.0	254953	80.2	10.0
2019	9368.9	93.0	305434	136.2	9.0
2018	10071.4	101.2	224230	287.5	8.5
2017	9948.0	112.9	77989	61.4	3.5
2016	8809.0	124.6	127057	56.8	10.6
2015	7069.3	179.7	223549	127.5	13.4
2014	3934.1	129.7	168681	149.2	7.7

Note: c is confidential information.

Source: based on [18].

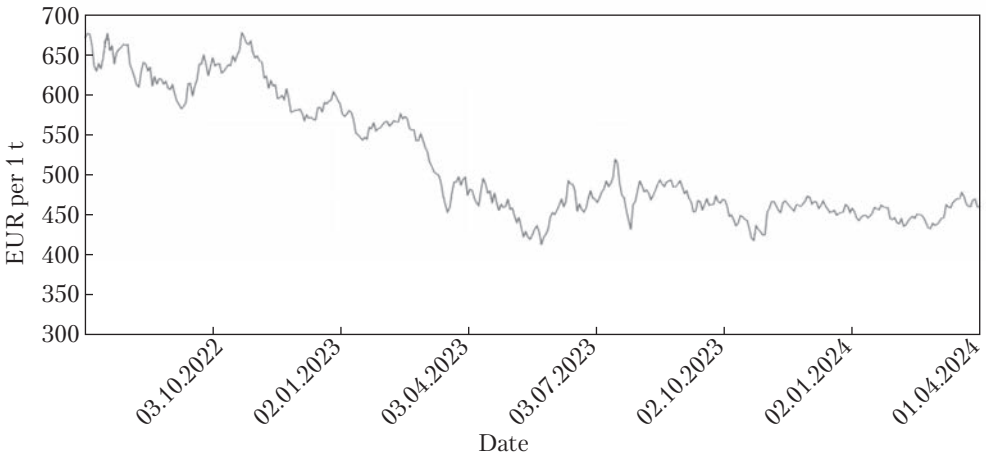

Fig. 4. Dynamics of global exchange prices for rapeseed

Source: [19].

2014—2021, reaching 16,266.3 UAH/t in 2021, which further stimulated agricultural producers to expand production volumes.

Regarding the processing of rapeseed seeds into oil, no stable trend has been identified. During the analyzed period, the volume of processed rapeseed fluctuated significantly, depending on the gross harvest. On average, only 9.5% of the total rapeseed harvest was processed domestically between 2014 and 2021, which can be considered a relatively low indicator. A potential reserve for increasing Ukraine's export revenues lies in rapeseed oil sales, as oil has a higher market value compared with seeds that are currently exported mostly in unprocessed form.

However, rapeseed prices may vary depending on global production and price dynamics in the European market (Fig. 4).

During the 2022—2023 marketing year, rapeseed prices gradually declined from EUR 660/t to EUR 435/t. However, in the 2023—2024 marketing year, the price remained relatively stable, averaging €448/t. Experts predict that in 2024 Ukrainian rapeseed exports may benefit from reduced oil production in EU countries, which has already led to increased demand on the market [20].

The most favorable option for increasing foreign exchange earnings for Ukraine can be considered the export of ready biofuel. Currently, there are 14 biodiesel plants in Ukraine with a total annual capacity of 300,000 t, although a significant share of them do not operate at full capacity. In addition, there are about 50 small enterprises capable of producing up to 25,000 t of biodiesel annually, although reliable data on their activity are lacking. Cases of individual biodiesel production for personal use are also reported, typically relying on off-grade oil or fats as feedstock [21]. At present, the Ukrainian liquid biofuel market is experiencing stagnation due to the absence of a consistent state strategy and effective incentive mechanisms.

Another advantage of biofuel is the enhancement of national energy independence. The reduction of fossil fuel imports can be achieved immediately, since engines do not require technical modifications when the concentration of vegetable oils in diesel fuel reaches up to 40%. Based on empirical studies [22], it has been established that at a 20% concentration of rapeseed oil in diesel fuel, engine fuel consumption increases by only 1.2%. With each subsequent 20% increase in rapeseed oil concentration, fuel consumption rises by an additional 1.2% (Table 3). This effect is associated with the lower energy efficiency of such fuel compared with fossil diesel, which can be considered a disadvantage of biofuel use.

Regarding the environmental performance of biofuels, when diesel fuel contains 20% rapeseed

oil, the smoke opacity of exhaust gases decreases by 29.2% at idle and by 40.0% under free acceleration. These values change slightly at a 40% rapeseed oil concentration, amounting to 16.7% and 37.5%, respectively. Nevertheless, the negative environmental impact is not completely eliminated, which can also be considered a drawback of biofuel use.

If 20% soybean oil is added to diesel fuel as an alternative to rapeseed oil, fuel consumption increases by 4%, with proportional growth at higher concentrations. The smoke opacity of exhaust gases from engines operating on fuel with soybean oil additives is higher than that with rapeseed oil, though still lower compared to conventional diesel fuel in all cases except free acceleration at a 40% concentration, where smoke opacity increases by 2.5%.

An important observation is that, given the relatively minor increase in fuel consumption and the substantial reduction in smoke opacity, the overall (gross) toxicity of exhaust gases (g/km of vehicle mileage) can be reduced by selecting the optimal volumetric concentration of the biological component in diesel fuel.

Therefore, considering both fuel consumption and environmental impact, diesel fuel blended with rapeseed oil is the most favorable option, making it a promising direction for the development of the Ukrainian biofuel market.

One of the key disadvantages of using vegetable oils as biofuels is their high cost relative to fossil fuels. However, given the fuel situation in Ukraine in 2023, price parity was observed between rapeseed oil and diesel fuel. Specifically, the average price of rapeseed oil in 2023 was 50 UAH/l [23], while the average price of diesel fuel in Ukraine during the same year amounted to 50.01 UAH/l [24]. Thus, this disadvantage has currently been neutralized, although the situation may change significantly in the post-war period.

A promising way to stabilize the demand for vegetable oils as biofuels, regardless of potential price increases, is legislative regulation requiring a mandatory share of biofuels in the total volume of liquid motor fuels. An attempt to establish a target for renewable energy consumption, including biofuels, at no less than 27% of total final energy consumption has been made in the draft National Action Plan for Renewable Energy Development until 2030 [25].

Other disadvantages associated with rapeseed cultivation as a feedstock for rapeseed oil production include competition with food crops and land-use changes. These challenges can be addressed through rational land management, crop rotation practices, and compliance with agronomic requirements during cultivation. Rapeseed is not a new agricultural crop for Ukraine, and its cultivation has already been organized in ways that do not harm soil quality or other crop production [26].

Therefore, the introduction of biofuels into the Ukrainian market is a promising path toward re-

Table 3. **Fuel Consumption and Exhaust Gas Opacity of Diesel Engines Depending on the Concentration of Vegetable Oils in Diesel Fuel**

Fuel	Change in fuel consumption, %		Change in exhaust smoke opacity of diesel engines with vegetable oil additives compared to pure diesel fuel, %			
	At 20% concentration of vegetable oils in diesel fuel	At 40% concentration of vegetable oils in diesel fuel	At 20% concentration of vegetable oils in diesel fuel		At 40% concentration of vegetable oils in diesel fuel	
			Idle	Full acceleration (or wide-open throttle)	Idle	Full acceleration (or wide-open throttle)
Diesel fuel with rapeseed oil	1.2	2.4	70.8	60.0	83.3	62.5
Diesel fuel with soybean oil (extruder, ρ20 °C = 916 kg/m^3)	4.0	8.0	83.3	75.0	83.3	102.5

Source: based on [22].

ducing the country's dependence on fossil fuels, which is particularly relevant during wartime and in the period of post-war recovery.

The evaluation of the advantages and disadvantages of using biofuels — specifically diesel fuel with rapeseed oil additives — has shown a significant predominance of advantages over disadvantages. This makes such biofuels a viable alternative to fossil fuels.

Further research is required to provide an economic justification for transitioning motor vehicles to the use of various types of biofuels.

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І.В. Замула [1] (https://orcid.org/0000-0002-6075-095X),
А.В. Ільченко [2] (https://orcid.org/0000-0001-7927-8745),
В.В. Травін [1] (https://orcid.org/0000-0002-7386-7372)

[1] Державний університет «Житомирська політехніка»,
вул. Чуднівська, 103, Житомир, 10005, Україна,
+380 412 24 1422, officerector@ztu.edu.ua
[2] Поліський національний університет,
Старий бульвар, 7, Житомир, 10002, Україна,
+380 412 47 1356, mail@polissiauniver.edu.ua

ФІНАНСОВЕ ПРОГНОЗУВАННЯ ВИРОБНИЦТВА І ВИКОРИСТАННЯ БІОПАЛИВА В УКРАЇНІ У ВОЄННИЙ ТА ПОВОЄННИЙ ПЕРІОДИ

Вступ. Україна має значний потенціал у сфері вирощування біопаливних культур і виробництва біопалива як інноваційної альтернативи нафтопродуктам. Цьому сприяє наявність значних площ земельних ресурсів, кліматичні умови, розташування транспортних коридорів, наявність необхідних факторів виробництва.

Проблематика. Додаткового дослідження потребують питання фінансового прогнозування виробництва та використання біопалива в Україні під час і після воєнних дій.

Мета. Оцінити на основі фінансового прогнозування перспективи виробництва та застосування біопалива з використанням ріпакової олії для України у період ведення військових дій і під час повоєнного відновлення економіки країни.

Матеріали й методи. Дослідження проведено на прикладі дизельного палива з домішками ріпакової олії та/або її похідних. Використано методи аналізу та синтезу, індукції та дедукції, групування, узагальнення, графічний і табличний.

Результати. Основними перевагами ріпакової олії є відновлюваність та екологічність. Сільськогосподарські товаровиробники зацікавлені у виробництві ріпаку через високий попит на його насіння та олію, а також високу ціну на них. Щодо екологічності біопалива, то емпірично встановлено, що димність відпрацьованих газів дизеля з домішками ріпакової олії нижчі, ніж без домішок. Але все ж негативний вплив на навколишнє середовище не зведений до нуля, що є недоліком використання біопалива. Перевагою є й формування енергетичної незалежності держави. При цьому енергоефективність зазначеного палива є меншою, порівняно з викопним, що можна вважати недоліком його використання. До того ж вартість біопалива перевищує вартість викопного палива.

Висновки. Оцінюванням переваг і недоліків застосування дизельного палива з додаванням олії ріпаку встановлено значне домінування переваг над недоліками, що дозволяє рекомендувати такий вид біопалива як одну з альтернатив викопному паливу.

Ключові слова: фінансове прогнозування, альтернативне паливо, біопаливо, біодизель, витрата палива, ріпакова олія, післявоєнне відновлення, сталий розвиток.