PROFESSIONAL PAPER
UDK: 338.512:662.756.3(497.11)"2017/2021"
DOI: 10.5937/EKOPRE2308460K
Date of Receipt: May 6, 2023

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ECONOMIC FEASIBILITY OF SMALL-SCALE BIODIESEL PRODUCTION IN SERBIA

Analiza ekonomske opravdanosti proizvodnje biodizela u pogonima malog kapaciteta

Abstract

This paper examines the economic feasibility of producing biodiesel in a small-scale production plant with an annual capacity of 1,000 tons. Based on average raw material prices (rapeseed oil, sunflower oil, soybean or sunflower seeds) in the period 2017-2021, the production cost of biodiesel ranges from 101 to 114 RSD per litre, depending on the raw material used. Using oilseeds as raw materials instead of vegetable oils results in lower unit cost of biodiesel, due to revenue from oil cakes, but requires extra investment in oil presses and silos, which significantly increases investment costs. Moreover, the economic advantage of using oilseeds as raw materials is lost even with a small drop (by 5% in the case of soybean) in the selling price or sales volume of the oil cake. Manufacturing biodiesel for producers' own fuel needs is economically feasible as the unit cost of biodiesel was 25-34% lower than the retail price of Eurodiesel in the observed period. However, at the estimated production costs, the retail price of biodiesel, which would also include sales costs, excise duties and value-added tax, cannot be lower than the retail price of Eurodiesel. Assuming the complete exemption of biodiesel from excise, it could become price-competitive with fossil diesel in the domestic fuel market.

Keywords: *biodiesel, cost of production, oilseeds, Serbia*

Sažetak

U radu se ispituje ekonomska opravdanost proizvodnje biodizela u pogonu godišnjeg kapaciteta od 1.000 tona biodizela. Pri prosečnim cenama polaznih sirovina (ulje uljane repice ili suncokreta, seme suncokreta ili soje) u periodu 2017-2021. cena koštanja biodizela se kreće u rasponu od 101 RSD/l do 114 RSD/l u zavisnosti od sirovine. Niže cene koštanja se postižu kada je umesto ulja polazna sirovina seme uljarica (zbog prihoda od prodaje uljanih pogača), međutim presovanje ulja zahteva dodatna ulaganja u nabavku opreme i silosa. Pored toga, prednost semena kao polazne sirovine gubi se već pri manjem padu (npr. za 5% u slučaju soje) prodajne cene ili stepena valorizacije uljane pogače. Proizvodnja biodizela za vlastite potrebe je ekonomski opravdana jer je u posmatranom periodu cena koštanja biodizela bila 25-34% niža od maloprodajne cene evrodizela. Međutim, maloprodajna cena biodizela, koja bi uključivala pored cene koštanja i troškove prodaje i državne namete u vidu akcize i poreza na dodatnu vrednost (PDV), ne može biti niža od maloprodajne cene evrodizela. Pod pretpostavkom potpunog oslobađanja biodizela od akciza biodizel bi mogao biti cenovno konkurentan fosilnom dizelu na domaćem tržištu goriva.

Ključne reči: *biodizel, troškovi proizvodnje, uljarice, Srbija*

Introduction

Biodiesel is a liquid fuel primarily produced from crude or used vegetable oils and animal fats [7]. It can be used in certain diesel engines with minimal or no modifications required for the engine or its equipment [23]. The main advantage of biodiesel over fossil diesel is that it is derived from renewable and locally available raw materials. Recognizing the vital role of renewable energy sources in achieving Serbia's strategic objectives, the National Assembly approved the Energy Sector Development Strategy in 2015, which aims to increase the utilization of biofuels in the transport sector and achieve a 10% share in final consumption by 2020. To meet this goal, the National Action Plan for the Use of Renewable Energy Sources in Serbia set a target of introducing approximately 255,000 tons of biodiesel into the market, with the majority expected to be imported (60%) and the remainder produced domestically (40%, or about 100,000 tons). Serbia has modern industrial capacities to produce around 130,000 tons of biodiesel annually [7], however, the strategic goals were not achieved, and biodiesel production has decreased in recent years to very small quantities produced by small-capacity facilities. The literature suggests that the primary obstacles to larger biodiesel production in Serbia are the high cost of raw materials, relatively low prices of fossil fuels, and lack of state incentives [23].

Previous studies examining the economic feasibility of biodiesel production in Serbia have primarily focused on large (100,000 tons of biodiesel per year)]6] and medium-sized (5,000-20,000 tons) industrial plants [10], [13], with little attention paid to small-scale facilities (1,000-5,000 tons). While it is generally acknowledged that the unit cost of biodiesel increases as production capacity decreases [14], small-scale facilities possess certain advantages over large-scale industrial facilities. These advantages include lower investment and fixed costs, the ability to quickly adjust production volumes to market conditions, and greater tolerance for variations in raw material quality. As a result, some small-scale facilities have been able to maintain production, albeit at reduced capacities, during periods of market volatility. Hence, small-scale biodiesel production may have considerable potential in Serbia, particularly regarding its adaptability to the dynamic market environment.

The aim of this research is to assess the production costs and competitiveness of biodiesel produced in small-scale biodiesel plants in Serbia. This topic is particularly relevant in light of a recent government decision mandating a share of biofuels in transport fuels sold domestically between 2022 and 2024, which ensures a steady market demand for biodiesel. Hence, it is interesting to investigate whether small-scale biodiesel producers have the potential to become profitable suppliers to the domestic fuel market.

Method and data sources

As part of the economic analysis, the feasibility of producing biodiesel in a plant with an annual capacity of 1,000 tons was examined. Biodiesel production is carried out by batch process using alkaline transesterification of triglycerides of vegetable oils [24]. Four possible production scenarios were considered, depending on the type of raw material used (rapeseed and sunflower oil, sunflower and soybean seeds). Table 1 presents the basic characteristics of each

Table 1: An overview of the main material flows associated with the four scenarios of biodiesel production depending on raw material (in tons per year)

Type of raw material	Scenario A	Scenario B	Scenario C	Scenario D
	Rapeseed oil	Sunflower oil	Sunflower seed	Soybean seed
INPUTS				
Raw material	1026	1026	3058 (d)	7297 (e)
Methanol	118 (b)	118 (b)	118 (b)	118 (b)
OUTPUTS				
Biodiesel	1000 (a)	1000 (a)	1000 (a)	1000 (a)
Crude glycerol	139 (c)	139 (c)	139 (c)	139 (c)
Oil cake	0	0	1977 (f)	6062 (f)

Assumptions:
(a) The assumed biodiesel yield is 0.98 kg per 1 kg of oil, and the losses in the mass of the oil feedstock due to sediments are assumed to be 0.5% in Scenarios A and B, and 6% in scenarios C and D [5, 19];
(b) The calculation is based on the assumed stoichiometric oil to methanol molar ratio of 1:3;
(c) Determined from the mass balance;
(d) The average oil and water content of sunflower seed is 41% and 7%, respectively [18], and the assumed crude oil yield, including sediments, is 0.36 kg per kg of seed [18]. Total losses in seed mass during storage, handling, and cleaning are assumed to be 2% [8];
(e) The average oil and water content of soybean is 21% and 11%, respectively, and the assumed crude oil yield, including sediments, is 0.15 kg per kg of seed [17]. Total losses in seed mass during storage, handling, cleaning and processing are assumed to be 2% [8];
(f) The yield of oilseed cake was calculated using a mass balance approach, which took into account the blending of the separated sediments with the oilcakes, as well as a minor loss in mass of soybean oil cakes due to water evaporation.

scenario with the main material flows calculated based on the average yields of biodiesel achieved in similar biodiesel plants and the typical oil content in oilseeds produced in Serbia.

Assessment of investment costs

The investment required for fixed assets was estimated based on the defined specifications for necessary buildings, equipment, and other assets needed for production and business operations, as well as their respective purchase prices. The costs of acquiring equipment used for oil transesterification were estimated using data obtained from domestic manufacturers and suppliers. The investment cost for buildings and storage capacities, such as grain silos and oil tanks, was estimated by the authors based on available price lists from domestic companies. The transesterification plant is expected to operate for 300 days per year, and the tank capacities are designed to store biodiesel, oil, and methanol for up to 14 days and glycerol for up to 30 days. Biodiesel and oil are stored in steel tanks with individual capacities of 60 m^3, while methanol is stored in a tank with a capacity of 6 m^3. Raw glycerol is stored in rigid IBC plastic tanks with a capacity of 1,000 litres. A building with an area of 60 m^2 is required to accommodate the transesterification plant, excluding tanks.

Scenarios C and D require investments in oil pressing equipment and grain silos, in addition to the transesterification plant and storage tanks defined previously. For these scenarios, it was assumed that oil pressing is carried out continuously (24 hours a day) for 300 days per year, processing 10.0 tons of cleaned sunflower seed and 23.8 tons of cleaned soybean seed daily. To process 417 kg of sunflower seed in one hour, a press with a processing capacity of 500 kg of grain per hour and an installed power of 22 kW is required. For soybeans, approximately 993 kg of seeds need to be processed in one hour, requiring the purchase of two extruders with an individual capacity of 500 kg of grain per hour (55 kW each) and two presses with a capacity of 500 kg per hour (22 kW each). The grain storage silo's capacity is determined to provide autonomy for about 21 days, with two and three silo cells with an individual capacity of about 300 m^3 being sufficient for sunflower and soybean storage, respectively, considering the typical bulk density of sunflower (400 kg/m^3 [1, p. 306]) and soybeans (720 kg/m^3 [1, p. 306]). The presses, extruders, and auxiliary equipment's (grain cleaners, receiving hoppers, screw conveyors, elevators, pumps, coolers for extruded mass, tanks for oil reception and settling) technical specifications and purchase prices are obtained from domestic manufacturers and suppliers of oil extraction equipment. The cost of the grain silos, which includes all expenses associated with acquiring the silos and auxiliary equipment, as well as the value of construction works, is estimated by the authors based on data provided by a domestic silo construction company. In addition to the silo itself, the total cost covers the expenses associated with constructing foundations and a grain pit, as well as the purchase of necessary conveyors and elevators for filling and emptying the silos. In scenarios C and D, additional space is required to accommodate oil pressing equipment (presses, extruders, auxiliary equipment) with a total estimated area of 60 m^2 and 150 m^2, respectively. The oilseed cake left after oil has been extracted from oilseeds is stored on a floor in a designated closed area. The required area is estimated at 73 m^2 for sunflower cake and 143 m^2 for soybean cake, assuming a bulk density of sunflower and soybean cake of 420 kg/m^3 [20] and 660 kg/m^3 [2], respectively, and that the cake is stored up to a height of 3 m for a maximum of 14 days.

Assessment of production costs

The main direct costs that arise in the production of biodiesel are costs related to the use of fixed assets (depreciation, insurance, and maintenance costs), interest payments, labor expenses, costs of raw materials and auxiliary materials (chemicals), and energy expenses. Depreciation costs are calculated using the proportional method, and depreciation rates are determined based on the expected useful life of individual groups of fixed assets (see Table 2). The costs of equipment and building insurance are determined by multiplying their purchase price with standard insurance rates. The yearly maintenance and repair expenses are calculated as a percentage of the purchase price of the corresponding assets using standard values suggested by equipment manufacturers or suppliers (see Table 2).

Table 2: Overview of rates used to estimate annual depreciation, maintenance, and insurance costs

Fixed assets	Depreciation rate	Maintenance costs (a)	Insurance costs (a)
Equipment for transesterification	10%	4%	1%
Oil presses and extruders	10%	20%	1%
Auxiliary equipment (in oil pressing plant)	10%	10%	1%
Buildings	2.5%	1%	0.5%
Storage tanks	5%	2%	0.5%
Grain silos	3.3%	2%	0.5%
Other fixed assets (e.g. design)	20%	-	-

Note: (a) Relative to the acquisition value of the fixed asset.

The study assumes that the investment is fully financed by borrowed funds, specifically a bank loan that will be repaid in ten equal annual instalments with an annual interest rate of 7.6%. Annual interest costs are calculated using the proportional interest calculation method. The costs of raw materials, which may be either grain or oil depending on the context, are calculated as the product of the required quantity and the procurement cost. In the domestic market, oilseed prices can fluctuate widely depending on the period and region, so this study uses average annual purchase prices available from the Statistical Office of the Republic of Serbia (SORS) database. Since data on the price of crude sunflower and rapeseed oil in the domestic market is not available, this study uses average export prices as an approximation [21]. This study assumes that the procurement cost of raw vegetable oils is equal to export prices because export prices already include transportation costs, loading and unloading costs, and other handling costs (Regulation on Customs Procedure, Official Gazette of the Republic of Serbia, no. 8/2017). The procurement cost of oilseeds in Serbia is calculated by adding procurement-related expenses, such as transportation and handling costs, to their respective purchase price. Handling costs increase the purchase price of oilseeds by an average of 7%, according to Ćurović [4]. Transportation costs are estimated at 6 euros per ton of grain, based on data obtained from carriers. This assumes that the grain is transported by trucks with a capacity of 25 tons of grain and a distance of 30-50 km in one direction.

The costs of auxiliary materials, such as methanol, potassium hydroxide, and sulfuric acid, are determined based on the consumption norms established during the multi-year operation of similar facilities and their prices on the domestic market in 2021 (Table 4). By measuring the energy consumption in a similar transesterification plant with a yearly capacity of 1,000 tons of biodiesel, it was determined that the specific electricity consumption is approximately 60 kWh per ton of oil. The electricity consumption in the oil pressing plant is estimated based on the total installed power of the equipment, which is 26.4 kWh in scenario C and 166.1 kWh in scenario D, assuming an average load factor of 70%. To estimate the electricity consumption for filling and emptying silos, it is assumed that silo filling is done 14 times a year using a chain conveyor and elevator with a total power of 15 kW, and that 8 hours are required to fill all of the silo cells. Silo emptying is carried out continuously during the operation of the press/extruder, i.e., 7,200 hours per year, using a 2.2 kW screw conveyor with an average motor load of 70%. To account for other energy consumers, such as room lighting, the total energy consumption is multiplied by a correction factor of 1.10.

Labor costs have been calculated based on the gross annual salaries of the employees. The production process is highly automated, requiring only one operator/technician

Table 3: Prices of raw materials and by-products (excluding VAT) in the period 2017-2021 (EUR/t)

Raw material	2017	2018	2019	2020	2021	Average price (2017-2021)	Average annual growth rate
Rapeseed oil (a)	764	678	730	764	1153	818	13%
Sunflower oil (a)	744	638	626	732	933	735	7%
Sunflower seed (b)	275	228	239	277	443	292	15%
Soybean seed (b)	368	297	291	340	569	373	15%
Sunflower cake (a)	399	409	342	365	505	404	12%
Soybean cake (a)	153	161	173	188	237	182	8%

Explanation: (a) Average export price; (b) Average purchase price of oilseed grains in Serbia.
Source: Based on data from the Statistical Office of the Republic of Serbia.

and one or two additional workers per 8-hour shift in scenarios A and B, and scenarios C and D, respectively. This results in a total of 5 employees for scenarios A and B, and 9 employees for scenarios C and D. The average monthly gross salaries for the operator and workers in the plant have been set at 900 euros and 650 euros, respectively. These figures are in line with the average salaries for similar qualifications in the agriculture and processing industries in 2021 [22]. The costs of laboratory analyses are estimated at 26,000 euros per year, assuming that the quality of oil and biodiesel is analyzed every other week at a cost of 500 euros per analysis.

The cost of biodiesel production is determined by subtracting the revenue from the sale of by-products from the total production costs. In the transesterification process, glycerol is obtained as a by-product, in addition to biodiesel as the main product. In the case of oilseed as the starting material, oil cake is also obtained, in addition to glycerol. The amount of revenue from the sale of by-products is obtained by multiplying the sold quantities with the corresponding unit sales prices. The study assumes that the obtained oil cake can be fully realized on the market at sales prices that are at the level of average export prices (Table 3). While pure glycerol has significant value as a product [6], the crude glycerol generated by the examined process contains numerous impurities, including water, salts, soaps, traces of alcohol, and glycerides [3]. Currently, there is no market for crude glycerol in Serbia. Consequently, small producers are compelled to store the produced quantities on their premises until a suitable disposal method or an interested buyer can be found. However, the costs of storing and disposing of crude glycerol were not considered in the study.

Results and discussion

Production cost of biodiesel

The investment required for a plant with an annual capacity of 1,000 tons of biodiesel varies significantly depending on whether the starting raw material is oil or oilseeds. In scenarios A and B, where crude oil is assumed as the starting raw material, the total investment cost is around 140,000 euros. In these scenarios, storage tanks for oil and biodiesel constitute the largest contributor to total investment costs, accounting for 37% of the total investment. Investments in transesterification equipment rank second in terms of importance, accounting for 35% of the total investment, while buildings and associated infrastructure account for about 19% of total investments.

In scenarios C and D, where oilseeds are the starting raw material, total investment costs are significantly higher due to additional investments in equipment for oil pressing and storage of seeds and cakes. The investment required for sunflower oil pressing equipment (press and auxiliary equipment) is estimated at 35,500 euros, while for soybeans, it is 114,500 euros. The higher investment in scenario D is attributed to the larger amount of seeds that need to be processed per unit of time (due to the lower oil content in soybeans compared to sunflower seeds), which necessitates the purchase of two presses and the need to extrude soybeans before pressing.

The first three scenarios have similar total annual production costs, ranging from 1 to 1.3 million euros, while scenario D incurs costs of around 3.4 million euros (Table 6). The costs of raw materials are the dominant factor in the total production costs of biodiesel, which is consistent with previous research findings [10], [13], [14],

Table 4: Specific consumption of chemicals and energy and their procurement cost

Input	Specific consumption		Price, exc. VAT
	Unit	Value	
Methanol (99.8%)	kg/kg oil	0.116	0.65 EUR/kg
Potassium hydroxide (KOH, min. 88%)	kg/kg oil	0.027	3.2 EUR/kg
Sulfuric acid (H_2SO_4, 96-98%)	g/kg oil	0.2	0.95 EUR/kg
Electricity (total)	kWh/t biodiesel	67 (A); 67 (B); 231 (C); 1021 (D) *	0.103 EUR/kWh
in the transesterification plant	kWh/t oil	66 (A-D) *	
in the oil pressing facility	kWh/t grain	49 (C); 129 (D) *	
filling and emptying of silos	MWh/year	≈14.1 (C and D) *	

Explanation: * Letters denote individual scenarios

[15], [16]. Depending on the type of raw material used, the share of these costs ranges from 73%, for sunflower seed, to 86%, for soybean (Table 5). The costs of auxiliary materials (i.e., chemicals used in the transesterification process) are the second most significant cost contributor to the total production costs. Their share is the lowest in scenario D, at around 5%, while in the other scenarios, it ranges from 13% to 16%. Based on the 2021 prices of chemicals, the specific costs of auxiliary materials amount to 0.17 euros per kg of biodiesel.

Energy costs have a minor share in total costs in scenarios where oil is used as the starting raw material. However, in scenarios where seeds are used as the starting raw material, energy costs can constitute a significant share, primarily due to the energy requirements of the press and extruder. The specific electricity consumption for transesterification of oil into biodiesel is 60 kWh/t of oil, which is significantly higher compared to modern industrial-scale plants where more affordable energy sources are utilized for heating and other technological procedures. For instance, in a plant with an annual capacity of 100,000 t, the specific electricity consumption is around 12 kWh/t of biodiesel [16], while it amounts to roughly 42 kWh/t of biodiesel in a plant with a capacity of 10,000 t [14]. The specific electricity consumption in the oil pressing plant is estimated to be approximately 44 kWh per ton of sunflower seed or approximately 117 kWh per ton of soybean, which is in line with literature data. According to Havrysh et al. [11], the specific electricity consumption for sunflower oil production in industrial plants in Ukraine ranges from 96.6 kWh to 198 kWh per ton of sunflower oil, which translates to 38.6-79.2 kWh per ton of seed assuming an oil yield of 0.4 kg per kg of grain. Meanwhile, Helgeson and Schaffner [12] estimated that small-capacity plants consume 45-106 kWh electricity per ton of sunflower seed, depending on the oil press' capacity. Fridrihsone et al. [9], based on primary data from small-scale producers of rapeseed oil, estimated the specific electricity consumption at 45 kWh per ton of seed. Kukić [17] conducted experimental research on an industrial extruder and oil press with a capacity of roughly 900 kg of grain per hour and found that the specific electricity consumption ranges from 90 kWh to 130 kWh per ton of soybean, depending on the oil and water content of the seed and settings on the extruder and press.

The labor costs contribute around 4-6% to the total costs in scenarios A, B, and C, while their share in scenario D is around 2%. Other costs, such as costs related to the use of fixed assets and interest costs, contribute to the total costs to a small extent, cumulatively accounting for approximately 4-6% of total costs.

When assessing the competitiveness of multiple products, the unit cost is a significant factor in justifying the economic feasibility of production. Based on the average prices of raw materials and by-products from 2017 to 2021 (as shown in Table 3), the unit cost of biodiesel

Table 5: Investment in a biodiesel production plant depending on the considered scenarios and the starting raw material (in EUR)

Fixed assets	Scenario A	Scenario B	Scenario C	Scenario D
Oil pressing	0	0	119,500	216,500
Presses and extruders	0	0	22,000	88,000
Grain silos	0	0	84,000	102,000
Auxiliary equipment for oil pressing	0	0	13,500	26,500
Biodiesel production	101,700	101,700	101,700	101,700
Process equipment	42,000	42,000	42,000	42,000
Energy equipment	7,500	7,500	7,500	7,500
Tanks	52,200	52,200	52,200	52,200
Buildings	27,000	27,000	86,850	158,850
Building for transesterification plant	27,000	27,000	27,000	27,000
Building for oil pressing plant and oil cakes			59,850	131,850
Other expenses	11,583	11,583	27,725	42,935
Design and engineering (2%)	2,574	2,574	6,161	9,541
Test run costs (2%)	2,574	2,574	6,161	9,541
Unexpected expenses (5%)	6,435	6,435	15,403	23,853
Total	140,283	140,283	335,775	519,985

produced in a plant with an annual capacity of 1,000 tons ranges from 0.98 EUR to 1.11 EUR per kg (101 RSD/L to 114 RSD/L), depending on the raw material used (Table 7). The lowest unit cost is achieved by producing biodiesel from sunflower seeds, mainly due to the significant revenue generated from the sale of oil cakes. On the other hand, the least economically favorable option is the production of biodiesel from crude rapeseed oil due to the relatively high procurement costs of the raw material.

The sensitivity analysis revealed that the unit cost of biodiesel is most influenced by changes in the purchase price of raw materials (Figure 1). This was expected as raw material costs make up a significant proportion of the total production costs. The unit cost of biodiesel produced from oilseeds is more sensitive to changes in the purchase price of raw material than the unit cost of biodiesel produced from crude vegetable oil. For example, if the purchase price of raw materials increases by 10% compared to the expected value (average prices during the period of 2017-2021), the unit cost of biodiesel produced from soybean grain will rise by 30%, whereas the unit cost of biodiesel produced from sunflower oil will only rise by 7%. The sensitivity analysis results also demonstrate that the unit cost of biodiesel based on oilseed grain, especially soybean, is highly sensitive to the revenue generated from the sale of oil cake. A small decrease of 10% in the

Table 6: Total production costs of 1,000 tons of biodiesel using average prices of raw materials and by-products in the period 2017-2021 (in EUR)

Cost category	Scenario A	Scenario B	Scenario C	Scenario D
Purchase value of raw materials	838,899	753,488	974,880	2,955,170
Quantity (t/year)	1,026	1,026	3,058	7,297
Price (EUR/t)	818	735	319	405
Other materials	166,122	166,122	175,214	175,214
Methanol	77,323	77,323	81,555	81,555
KOH	88,604	88,604	93,453	93,453
H2SO4	195	195	206	206
Electricity	6,937	6,937	23,770	105,171
Oil pressing and silos	0	0	16,833	98,235
Biodiesel production facility	6,937	6,937	6,937	6,937
Labor costs	45,600	45,600	80,400	80,400
Technician/operator	10,800	10,800	10,800	10,800
Plant workers	31,200	31,200	62,400	62,400
Administration (outsourced)	3,600	3,600	7,200	7,200
Costs related to the use of fixed assets	14,737	14,737	32,492	59,768
Depreciation costs	10,552	10,552	20,102	31,638
Maintenance costs	3,294	3,294	10,724	25,584
Insurance costs	891	891	1,666	2,546
Interest costs	10,662	10,662	25,519	39,519
Laboratory testing costs	26,000	26,000	26,000	26,000
TOTAL	1,108,957	1,023,545	1,338,275	3,441,242

Table 7: Unit cost of biodiesel (calculated with average prices of raw materials and by-products in the period 2017-2021)

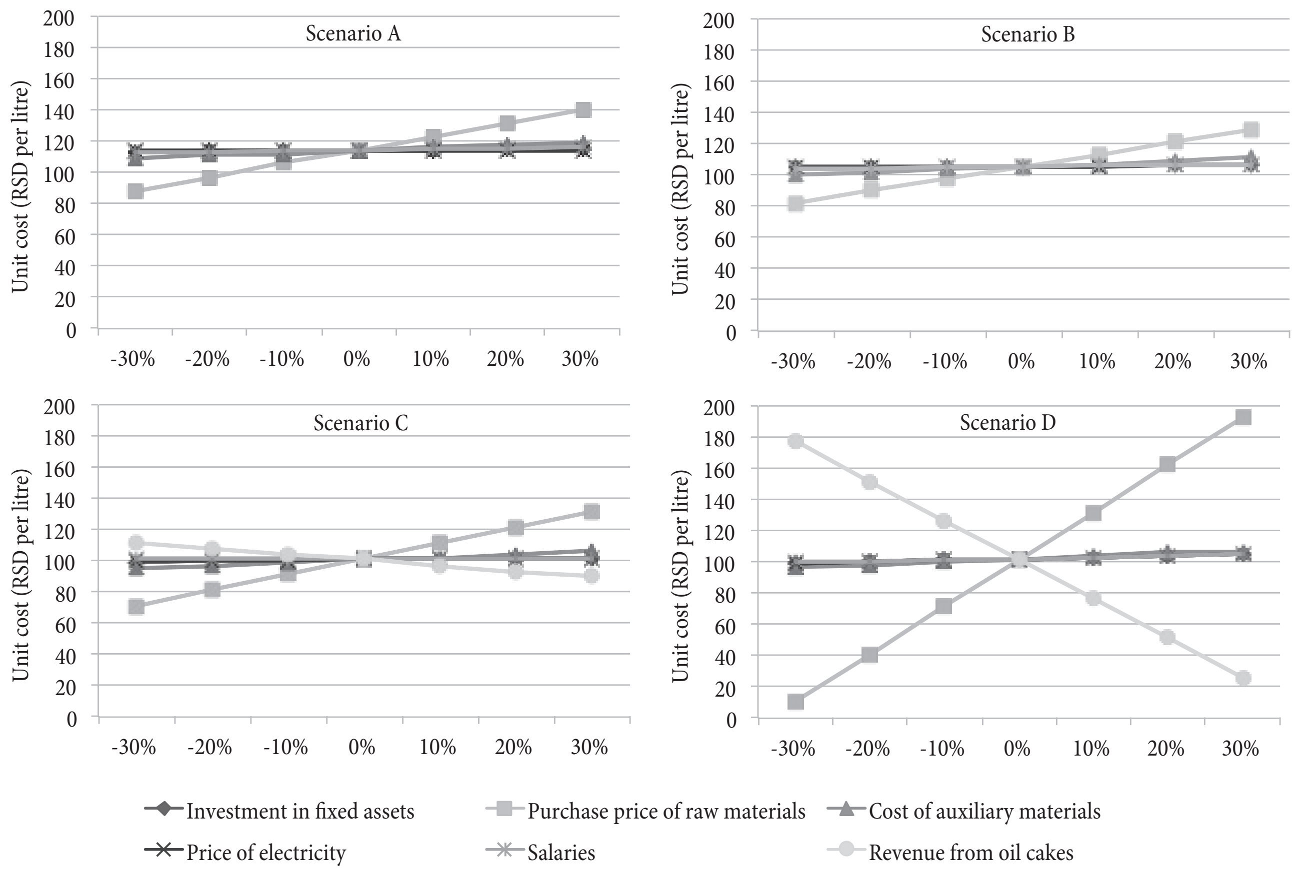
		Scenario A	Scenario B	Scenario C	Scenario D
A	Total production costs	1,108,957	1,023,545	1,338,275	3,441,242
B	Revenue from by-products	0	0	360,541	2,450,286
	Glycerol	0	0	0	0
	Oilseed cake	0	0	360,541	2,450,286
C	Production costs reduced by the value of by-products (C=A-B)	1,108,957	1,023,545	977,733	990,956
D	Unit cost of biodiesel				
	EUR/kg	1.11	1.02	0.98	0.99
	EUR/L	0.98	0.90	0.86	0.87
	RSD/L	114	105	101	102

selling price of oil cake or sales volume would cause the unit cost of soybean biodiesel to increase by 25% (from 102 RSD/L to 127 RSD/L), making it significantly higher than the unit cost of biodiesel produced from rapeseed oil. Furthermore, it can be observed that the unit cost is relatively insensitive to changes in investment costs, salaries, as well as fluctuations in the prices of electricity and chemicals used in the transesterification process (Figure 1).

Price competitiveness of biodiesel

The question arises whether investing in biodiesel production at the calculated cost is justified. The answer depends on the production goal, whether it is to meet producers' own fuel needs or to sell biodiesel on the market. Producing biodiesel for one's own needs can be economically justified, as the cost is 25-34% lower than the average retail price of diesel (152 RSD/L during 2017-2021). Agricultural farms and enterprises can save significantly on fuel costs if they use biodiesel from their own production instead of fossil diesel as fuel. However, an annual production of one million kg of biodiesel (1.13 million litres) significantly exceeds the needs of most domestic economic entities whose primary activity is agricultural production. Considering that around 120 litres of diesel fuel per hectare are used in crop production [10], this amount is sufficient for processing about 8,500 hectares. It is estimated that fewer than ten economic entities in Serbia manage areas larger than 8,500 hectares. Therefore, to increase investments in biodiesel production, the investors need assurance that the produced quantities of biodiesel (partially or entirely) can be sold on the market. A prerequisite for successful market penetration is the price competitiveness of biodiesel in the fuel market, that is, biodiesel can be offered at lower retail prices than fossil diesel. Market research conducted in 2008 showed that potential consumers are interested in buying pure biodiesel (B100) if its retail price is 8-10% lower than the price of corresponding fossil diesel [23]. They justified this price difference with higher biodiesel consumption, higher vehicle maintenance costs if biodiesel is used (e.g., more frequent oil filter replacement), but also with

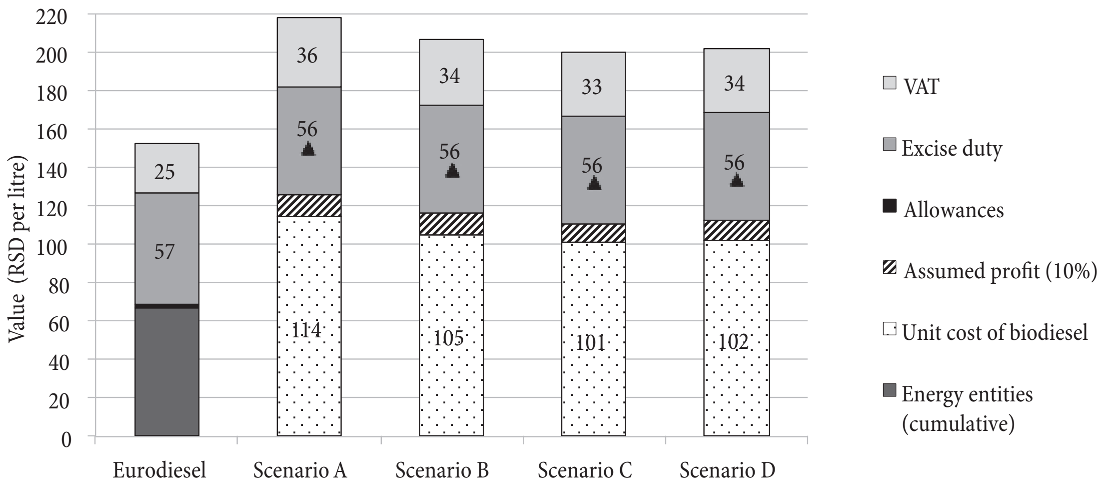
Figure 1: Sensitivity of biodiesel's unit cost to changes in the values of individual input parameters



customer distrust of a new product on the market. Based on the average retail price of diesel during the observed period, the acceptable market price of biodiesel would be around 137 RSD/L. Although the unit cost of biodiesel is significantly lower than 137 RSD/L, it is important to note that the unit cost of biodiesel does not include the producer's profit, taxes and expenses associated with the selling of biodiesel. In addition to a 20% value-added tax (VAT), biofuels in the Republic of Serbia are subject to an excise duty, as per the Law on Excise Duties. From 2017 to 2021, the average excise duty for biofuels was 56 RSD/L. Taking into account the projected 10% profit, as well as the excise duty and VAT, the retail price of biodiesel can vary between 200 RSD/L to 218 RSD/L, depending on the raw material used in production (as shown in Figure 2). The retail price of biodiesel determined by the total cost method not only exceeds the acceptable market price of biodiesel but also surpasses the retail price of fossil diesel. Moreover, to ensure the profitability of production, the retail price needs to be even higher, as it must cover other expenses such as distribution costs, quality control costs, and the reduction in revenue due to discounts granted to fuel distributors, which was between 9-13 RSD/L in 2022 for Eurodiesel. It is evident that the retail price of biodiesel that would guarantee a profit for the producer cannot compete with the price of fossil diesel in the domestic fuel market. The same conclusion can be drawn by observing the prices in individual years, as the lowest acceptable retail price of biodiesel from the producers' perspective has always been higher than the price of Eurodiesel, except for soy biodiesel in 2018 (as shown in Table 8).

The competitiveness of biodiesel depends on several factors, including the procurement cost of raw materials, the retail price of fossil diesel, and the amount of state levies in the form of taxes. From 2017 to 2021, the purchase prices of raw materials increased at an average annual rate of 7% for sunflower oil and 15% for sunflower and soy (Table 3). In the same period, there was a significant increase in the price of rapeseed oil (13% on average annually), and in 2021 it was 24% higher than the price

Figure 2: Formation of retail price of biodiesel by the total cost method depending on the starting raw material (RSD/L)



Note: The triangle indicates the retail price without excise on biodiesel

Table 8: Unit cost (UC) and the lowest acceptable retail price of biodiesel for its producers (RP) depending on the raw material in the observed period from 2017 to 2021 (RSD/L)

Fuel		2017		2018		2019		2020		2021	
		RP	UC	RP	UC	RP	UC	RP	UC	RP	UC
Eurodiesel		143	-	152	-	161	-	142	-	162	-
Biodiesel	Scenario A	212	112	199	100	207	106	212	108	267	150
	Scenario B	210	110	193	96	193	95	208	105	236	126
	Scenario C	202	104	177	84	180	85	194	94	255	140
	Scenario D	203	105	116	38	167	75	200	100	259	196

of crude sunflower oil, mainly due to the rising demand for rapeseed oil in the European Union for the needs of the biodiesel industry. Over the same five-year period, the retail price of Eurodiesel also increased (as shown in Table 8), but at a lower average annual rate of only 4%. If this trend continues, domestically produced biodiesel cannot compete in the fuel market without appropriate state incentives. One effective measure proposed by Tešić et al. [23] to encourage the domestic biodiesel industry is the partial or complete exemption of biodiesel from excise duties. The results suggest that state tax and excise policy measures significantly influence the retail price of biodiesel. Over the observed five-year period, excise duties and value-added tax accounted for 42-45% of the retail price of biodiesel, depending on the raw material. If biodiesel were entirely exempt from excise duties, the retail price would range from 133 RSD/L to 151 RSD/L, depending on the raw material, and would be lower than the retail price of fossil diesel, as illustrated in Figure 2.

Conclusions

Based on the average market prices of raw materials between 2017 and 2021, the estimated production cost of biodiesel in a plant with an annual capacity of 1,000 tons varies from 101 to 114 RSD per litre, depending on the type of raw material utilized. Lower costs can be achieved by using oilseeds instead of oil as the starting material, mainly due to significant revenues from the sale of oil cake. However, producing biodiesel from oilseeds requires investment in an oil extraction plant and storage facilities for seeds and oil cakes, which significantly increases investment costs. Moreover, the unit cost of biodiesel from oilseeds is very sensitive to changes in the price of oil cake or sales volume. Investing in biodiesel production is economically justified if the primary goal is to satisfy producers' own fuel needs since the cost of biodiesel during the observed period is significantly lower than the retail price of Eurodiesel. However, at these production costs, it is not possible to achieve a retail price that would guarantee profit for the producers and compete with the price of fossil diesel on the domestic fuel market. This is because the retail price, in addition to the production costs, must also include accumulation, excise, VAT, and often other expenses. Considering these components, the retail price of biodiesel produced in small-capacity plants cannot be lower than the retail price of Eurodiesel, making its sale impossible.

The competitiveness of biodiesel is primarily determined by three factors: the retail price of fossil diesel, the amount of state levies in the form of excise and VAT, and the unit cost of biodiesel, which largely depends on the price of the input raw material. During the observed five-year period, the purchase prices of raw materials, such as oilseeds and vegetable oils, have increased at a faster rate than the retail price of Eurodiesel. If this trend continues, small-scale domestic biodiesel producers cannot produce biodiesel at competitive prices without state incentives. One such measure that could increase biodiesel's competitiveness in the domestic fuel market is complete exemption from excise, which amounted to about 58 RSD/L in 2022.

Acknowledgment

This research was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, contract number 451-03-47/2023-01/200134.

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