ANALYSIS OF THE PRODUCTION COST OF A UNIT OF BIODIESEL PRODUCTION IN THE BIODIESEL PLANT

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ABSTRACT

Biodiesel is defined as mono-alkyl ester of fatty acids obtained from vegetable oils or animal fats. In this paper, an analysis of the cost of the production of a unit of biodiesel is given. It is shown which parameters affect the cost price of the unit of this product produced in the biodiesel plant. Analyzed biodiesel plant is in Skopje in North Macedonia with a projected capacity of 20,000 tons of biodiesel per year. Also, a comparative analysis of different cases was done: the case where during the design and implementation of the production plant the capacity of the production plant would be increased to the level of 25,000 tons, as well as to the level of 30,000 tons of produced biodiesel. It was also shown how the use of a sufficient level of soybean oil would affect the cost of the unit of the biodiesel product.

Introduction

Oil reserves are constantly decreasing at the world level, so in the developed countries of the world, in the last twenty years, intensive work has one on the development and application of processes to produce biofuels from biomass. Exhaustion of crude oil reserves, permanent increase in crude oil consumption, price increase as well as environmental problems related to oil processing and use such as global warming are the main reasons why the population should turn to biofuels such as biodiesel.

In Europe, rapeseed oil (82.8%) is used as the dominant raw material for biodiesel production and sunflower oil (12.5%), while in the United States of America soybeans are used for biodiesel production (Petrović and Babić I., 2013). State policy and biofuel production costs, as well as the demand for competitiveness, can significantly affect the prices of biofuels and agricultural raw materials (increases in the price of raw materials affect the increase in biofuel production costs). Serbia has accepted international obligations and has the available potential of biomass, so it is necessary to

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take all the above incentive measures as soon as possible to reach the binding goals in transportation for biofuels (Petrović and Babić I., 2013).

Biodiesel is used as a substitute for mineral diesel because the use of pure biodiesel reduces the emission of harmful gases (NOx, CO_2, SO_2) and solid particles because biodiesel does not contain sulfur. The production trend of this fuel is constantly increasing. Its production in 2005 exceeded several million tons. The European Union (EU) predicted that the share of biofuels in the EU countries after 2020 will be 10%.

As input raw materials, more than half of the plants built in the United States of America and Europe use “clean” crude oil and high-quality methanol. Most of the plants built so far that use vegetable oils for the production of biodiesel use crude refined vegetable oil. Depending on the applied technology, some factories also use unrefined vegetable oil. Various alternative input raw materials require changes in the production process itself.

Biodiesel is a motor fuel that is obtained by transforming rapeseed, soybean or other vegetable oils into methyl esters of fatty acids through an esterification reaction with methanol. The characteristics of biodiesel are very similar to the characteristics of diesel fuel obtained from mineral oil. For this reason, biodiesel is a non-toxic, biodegradable and ecologically clean substitute for mineral diesel fuel or in a certain mixture with it (Babić I., 2013).

Biodiesel is defined as mono-alkyl ester of fatty acids obtained from vegetable oils or animal fats. Biodiesel is obtained when vegetable oil or animal fats chemically react with alcohol producing a new substance, which is known as fatty acid monoalkaline ester (Fatty Acid Methyl Ester - FAME) according to (Standard, EN 14214, 2004). This reaction requires the presence of a catalyst, and glycerol is obtained as a by-product. For example, from 100 kg of vegetable oil and 10 kg of methanol we get 100 kg of biodiesel and 10 kg of glycerol (Babić I., Đurišić, 2008).

The advantage of using biodiesel is reflected in the fact that the consumer can get reliable and high-quality fuel at a lower price. We can count on more widespread use of biodiesel only if it is competitive with fossil diesel, which means that it is its price is 8-10% lower than the price of diesel. This difference is appreciated explains the lower energy value of biodiesel in comparison on mineral diesel as a result of which there is proportional increase in fuel consumption (Jovanović et al., 2005, Kiš et al., 2023).

The difference in the prices of diesel and biodiesel at gas stations in the EU is about 10 euro cents, with the fact that it fluctuates depending on the prices of oil and petroleum on the world market. The upward trend in the price of crude oil is significantly higher than that of edible oils, so we can expect that biodiesel will be even more competitive in the future (Hu et al., 2025, Mohammadshirazi et al., 2014, Gebremariam AND Marchetti, 2018). Also, it should be noted that competitiveness in the price of biodiesel was also achieved by reducing taxes because excise duties on biofuels were abolished, as well as by receiving subsidies to producers of input production raw materials (Tamas and Gyarmat, 2021).

Renewable fuels reduce dependence on fossil fuel imports. This affects exports at the same time, and as far as Serbia is concerned, it is possible to export part of the biodiesel production to the nearest EU market. For biodiesel to be profitable, experts have estimated that it must have an 8% lower price than fossil fuels. At the same time, 5% is an indicator of lower energy efficiency of this fuel, and 3% is the estimated required level to attract consumers (Babić M., 2024).

Materials and methods

The biodiesel plant with a projected capacity of 20,000 tons of biodiesel per year is analyzed in this paper. The analyzed biodiesel plant is located in Skopje in North Macedonia. These annual capacities satisfy domestic needs and enable export. The data from the from this biodiesel plant project were used as a data source in this research (Babić M., 2024).

In this paper, as part of the economic analysis, an analysis of the cost price of the production of a unit of biodiesel products is given. Also, a comparative analysis of different cases was done: the case where during the design and implementation of the production plant the capacity of the production plant would be increased to the level of 25,000 tons of produced biodiesel, as well as to the level of 30,000 tons of produced biodiesel.

The costs of producing a unit of biodiesel fuel products depend on the value of the costs of input raw materials, energy costs, and the cost of human labor. In relation with that, it was also shown how the use a sufficient level of soybean oil as input of raw materials, would affect on the cost price of the unit of the biodiesel product.

Biodiesel is being produced from crude oil obtained from rapeseed, according to a world standard (Standard, EN 14214, 2004) that allows mixing with fossil diesel fuel. The fuel quality is being controlled in the factory laboratory. The entire production process in the biodiesel plant is automated.

Analysis of the production cost of a unit of biodiesel product

The cost price of the unit of the product produced in the biodiesel production plant C_K is:

$$C_K = \frac{T_P}{Q_P} \qquad (1)$$

where: T_P − cost of production, Q_P − plant capacity.

The cost of production T_P is the sum of the cost of input raw materials T_{US}, the energy costs T_{EN} and the cost of human labor T_R:

$$T_P = T_{US} + T_{EN} + T_R \quad (2)$$

The cost of input raw materials is the total realized cost in the process of procuring input raw materials, namely: purchase cost, transportation cost, customs and other state fees, shipping cost, insurance cost, financing cost and labor cost with associated costs of the procurement process. The total cost of input raw materials can be defined as:

$$T_{US} = \sum_i C_i \, Q_i \ (3)$$

where: C_i – the gross i price of that input raw material, Q_i – gross amount of i input raw material.

The cost of energy is the cost of consumed electricity, which on an annual basis amounts to $T_{EN} \approx 57{,}000.00$ EUR, while the cost of human labor is the cost of the gross personal income of employees and other overhead costs, which on an annual basis amounts to: $T_R \approx 224{,}400.00$ EUR. These values are given from Makpetrol biodiesel plant in Skopje, Macedonia (Babić M., 2024).

The annual cost of production T_P must be reduced by the income obtained from the sale of glycerine solution, a by-product, which is obtained during the production process, and it amounts to:

$$P_{GL} = Q_{GL} C_{GL} \ (4)$$

where : Q_{GL} is gross amount of glycerin, C_{GL} is cost price of the unit of the glycerin.

Now the actual cost of production T_P^1:

$$P_P^1 = \sum_i C_i \, Q_i + T_{EN} + T_R - P_{GL} \ (5)$$

Based on the above-mentioned equations, finally, we get an expression for the cost price of the production of a unit of product, that is, the cost price of the production of one ton of biodiesel:

$$C_K = \sum_i \frac{Q_i}{Q_P} C_i + \frac{T_{EN}}{Q_P} + \frac{T_R}{Q_P} - \frac{Q_{GL}}{Q_P} C_{GL} \ (6)$$

or in its developed form, the equation of the cost price of producing one ton of biodiesel on an annual basis is:

$$C_K = w_{SU} C_{SU} + w_{ME} C_{ME} + w_{NH} C_{NH} + w_{KH} C_{KH} + w_{LK} C_{LK} + \frac{T_{EN}}{Q_P} + \frac{T_R}{Q_P} - \frac{P_{GL}}{Q_P} \ (7)$$

Where we have: weight function of crude rapeseed oil w_{SU}, weight function of methanol w_{ME}, weight function of sodium hydroxide w_{NH}, weight function of potassium hydroxide w_{KH}, weight function of citric acid w_{LK}.

The weighting functions w_{XY} in the equations determine the share of the gross price of certain input raw materials in the cost price of the product and they reflect the efficiency, the quality and the optimization of a technological procedure.

The weighting functions w_{XY}, i.e. their values, depend on several important factors :

1. Technologies of the production process, expressed through the efficiency of the technology

2. Quality of incoming raw materials

3. The quality of managing the production process, expressed through the level of automation and optimization of the production process.

The values of the weighting functions determined on the basis of the projected material balance, that is, the projected efficiency of the technology, the quality of the input raw materials specified in the technological requirements and the level of the projected automation of the production process are given in the Table 1 (Babić M., 2024).

Table 1. The values of the weighting functions

The weighting functions	**Value**
The weight function of crude rapeseed oil (w_{SU})	1.018
The weight function of methanol (w_{ME})	0.11785
The weight function of sodium hydroxide (w_{NH})	0.00753
The weight function of potassium hydroxide (w_{KH})	0.0018135
The weight function of citric acid (w_{LK})	0.000125

Source: Author's interpretation

The values of the weighting functions which are given in Table 1. are obtained based on the following expressions:

- The weight function of crude rapeseed oil: $w_{SU} = \frac{Q_{SU}}{Q_P}$

- The weight function of methanol: $w_{ME} = \frac{Q_{ME}}{Q_P}$

- The weight function of sodium hydroxide: $w_{NH} = \frac{Q_{NH}}{Q_P}$

- The weight function of potassium hydroxide: $w_{KH} = \frac{Q_{KH}}{Q_P}$

- The weight function of citric acid: $w_{LK} = \frac{Q_{LK}}{Q_P}$.

Starting from the data on the costs of input raw materials, energy and human labor costs, specified in the business plan for the construction of a Makpetrol biodiesel plant in Skopje, Macedonia and based on the cost price equation, we got the prices in the Table 2. (Babić M., 2024).

All prices shown in the Table 2. are updated for the year 2010 according to (Product Exchange ad Novi Sad - NSCOMEX, 2010).

Table 2. Price values of input quantities

The values of input quantities	The price (EUR)
The crude rapeseed oil (C_{SU})	661
Methanol (C_{ME})	317
The sodium hydroxide (C_{NH})	419
Potassium hydroxide (C_{KH})	450
Citric acid (C_{LK})	750
The energy (T_{EN})	57,000
The human labor (T_{R})	224,400
Glycerin (C_{GL})	350

Source: Author's interpretation

The values from the table, which we obtained on the basis of the actual data of the biodiesel plant, need to be multiplied by the values of the weighting functions, in order to obtain the cost price of producing one ton of biodiesel on an annual basis:

- The crude oil share: $C_K^{SU} = w_{SU} C_{SU} = 672.898$ EUR
- The methanol share: $C_K^{ME} = w_{ME} C_{ME} = 37.35845$ EUR
- The sodium hydroxide share: $C_K^{NH} = w_{NH} C_{NH} = 3.15507$ EUR
- Potassium hydroxide share: $C_K^{KH} = w_{KH} C_{KH} = 0.816075$ EUR
- Citric acid share: $C_K^{LK} = w_{LK} C_{LK} = 0{,}09375$ EUR
- The energy share: $C_K^{EN} = \frac{T_{EN}}{Q_P} = 2.85$ EUR
- The human labor share: $C_K^{R} = \frac{T_R}{Q_P} = 11.22$ EUR
- Glycerin share: $C_K^{GL} = \frac{Q_{GL}}{Q_P} C_{GL} = 25.9399$ EUR

Based on the equation (7) and the values given in the Tabel 2, the cost price is finally obtained:

$$C_K = C_K^{SU} + C_K^{ME} + C_K^{NH} + C_K^{KH} + C_K^{LK} + C_K^{EN} + C_K^{R} - C_K^{GL} \quad (8)$$

$$C_K = 702.45 \text{ EUR}$$

Starting from the the average selling price of biodiesel at factory parity for the year 2010 according to (Product Exchange ad Novi Sad - NSCOMEX, 2010), in the amount of $C_P = 780$ EUR/t the realized profit is obtained on an annual level in the amount of $\Delta = 1{,}551{,}000.00$ EUR for a capacity of 20,000 tons on an annual production.

Cost price and profit at a plant capacity of 25,000 tons per year

The case was analyzed when, during the design and implementation of the production plant, the carrier of the basic technology and the supplier of the technological production line would increase the capacity of the production plant to the level of 25,000 tons of produced biodiesel.

Based on the fact that during production, considering the type of technological process, the same level of energy per unit of product will be consumed as in the previous case with a plant capacity of 20,000 tons per year, as well as that the cost of human labor will not increase, i.e. it will remain the same the number of executors, and thus the cost of human labor per unit of product will be reduced, we will have that:

$$C_K^{25} = C_K^{20} - \left(\frac{T_R}{Q_P^{20}} - \frac{T_R}{Q_P^{25}}\right) \quad (9)$$

where: C_K^{25} - product cost price at a plant capacity of 20,000 tons, Q_P^{20} - plant capacity of 20,000 tons per year,, Q_P^{25} - plant capacity of 25,000 tons per year, T_R - gross labor cost.

Based on the above the equation (9), it is obtained that the unit cost price of the product at the plant capacity of 25,000 tons per year is:

$$C_K^{25} = 700.21 \text{ EUR.}$$

So the realized profit on an annual level is obtained from:

$$\Delta^{25} = \left(C_P - C_K^{25}\right) \times Q_P^{25} = 1{,}994{,}750.00 \text{ EUR.} \quad (10)$$

The percentage increase in profit is:

$$\%(\Delta) = \frac{\Delta^{25} - \Delta^{20}}{\Delta^{20}} \times 100 = 28.61\% \quad (11)$$

which is in absolute terms $\partial\Delta = \Delta^{25} - \Delta^{20} = 443{,}730.00$ EUR.

Competitiveness from the point of view of the price of input raw materials can be analyzed. If the realized amount of profit increase was put into the function of covering the costs of input raw materials, it would mean an increase in the competitiveness of production, in addition to the increase in the prices of input raw materials, e.g. the price of crude oil, up to the following price level, the maximum value of which is determined based on the equation:

$$C_{SU}^{max} = \frac{1}{w_{SU}}\left[\left(C_P - \frac{\Delta^{20}}{Q_P^{25}}\right) - \left(\sum_{i \neq SU} w_i\, C_i + C_K^{EN} + \frac{T_R}{Q_P^{25}} - C_K^{GL}\right)\right] \quad (12)$$

By substituting numerical values into the above equation, we get that $C_{SU}^{max} = 678.44$ EUR.

It can be concluded that if the production process is entered with the gross price of crude oil $C_{SU} = 678.44$ EUR at the plant capacity of $Q_P^{25} = 25{,}000\ t/year$, the profit will be the same value, as in the case of the production process with the gross price crude oil $C_{SU1} = 661$ EUR at plant capacity of $Q_P^{20} = 20{,}000\ t/year$, $\Delta^{25} = \Delta^{20} = 1{,}551{,}000.00$ EUR.

Competitiveness from the point of view of the price of the output product, biodiesel, can be analyzed. If the realized amount of profit increase based on the increase in production capacity were put into the function of increasing the competitiveness of the final product, the selling price of biodiesel at factory parity could have a minimum value of:

$$C_P^{min} = C_K^{25} + \frac{\Delta^{20}}{Q_P^{25}} = 762{,}21\text{ EUR} \quad (13)$$

This would mean that if the production capacity is $Q_P^{25} = 25{,}000\ t/year$ and if the cost price is $C_K^{25} = 700.21$ eur per unit of the final product, then at the above-mentioned selling price of biodiesel, the same profit is achieved as with the production plant with the capacity $Q_P^{20} = 20{,}000\ t/year$ and at the selling price of biodiesel of $C_P = 780$ EUR.

Cost price and profit at a plant capacity of 30,000 tons per year

During the design of the system of measurement, supervision and management of the technological process of production, certain improvements were suggested and new measurement methods were introduced, which should affect the additional increase of the capacity of the plant. $Q_P^{30} = 30{,}000\ t/year$.

The cost price of a product unit at a plant capacity of 30,000 t/year is:

$$C_K^{30} = C_K^{20} - \left(\frac{T_R}{Q_P^{20}} - \frac{T_R}{Q_P^{30}}\right) = 698.71\text{ EUR}. \quad (14)$$

The annual profit at this production price, and the selling price as in previous cases, would be:

$$\Delta^{30} = (C_P - C_K^{30}) \times Q_P^{30} = 2{,}438{,}700.00\text{ EUR}. \quad (15)$$

The percentage increase in profit is:

$$\%(\Delta) = \frac{\Delta^{30} - \Delta^{20}}{\Delta^{20}} \times 100 = 57.23\%. \quad (16)$$

which is in absolute terms: $\partial\Delta = \Delta^{30} - \Delta^{20} = 887{,}700.00$ eur.

During this analysis, among other things, one can observe a very strong influence of the weight function of the input raw material, crude oil, on the production price of the final product, that is, on the overall economy of the biodiesel production plant.

As shown $\partial\Delta = \Delta^{25} - \Delta^{20} = 443.730{,}00$ eur can be lost, for example, if the basic input raw material, crude oil, is procured with twice the content of free fatty acids, i.e. with twice the acid number than prescribed by the technological specification, which causes a change in the value of the weight function w_{SU} from the value $w_{SU}^{(1)} = 1.018$ to the value $w_{SU}^{(2)} = 1.045$. This is one of the main strengths of the chosen technologies. With an increase in annual production capacity comes a decrease in of the cost price of producing one ton of biodiesel on an annual basis.

Using the permitted level of soybean oil

One of the factors on which the production costs of a unit of biodiesel fuel depend is the value of the costs of input raw materials (Apostolakou A.A. et al., 2009, You et al., 2007). As we have already mentioned in this research, the impact of the type of input raw material is huge and it has a very strong influence on the production price of the final product, i.e. on the overall cost-effectiveness of the biodiesel production plant (Myint, L.L. and El-Halwagi M.M, 2009, Barreiros T. et al., 2020). Regarding that fact, now we will analyze how using the permitted level of soybean would affect the cost price of the unit of the biodiesel product.

As it was described in the previus chapters of this research, it is possible to calculate the cost price of the product unit, ie. production price of biodiesel based on the equation (8). It is necessary to determine what should be the selling price of glycerine C_{GL}, that is, the income from the sale of glycerine C_K^{GL}, in order to cover the costs of sodium hydroxide, potassium hydroxide, citric acid, electricity and labor, or expressed mathematically:

$$C_K^{GL} = C_K^{NH} + C_K^{KH} + C_K^{LK} + C_K^{EN} + C_K^{R} \qquad (17)$$

Starting from the cost price, at factory parity for: $C_{NH} = 385$ eur/t, $C_{KH} = 825$ EUR/t and $C_{LK} = 680$ EUR/t as well as the cost of electricity and the cost of human labor $C_K^{EN} = 2{,}85$ EUR/t and $C_K^{R} = 11{,}22$ EUR/t it is obtained that $C_K^{GL} = 18{,}55$ EUR/t and $C_{GL} \approx 250$ EUR/t. All prices are for the year 2010 from (Product Exchange ad Novi Sad - NSCOMEX, 2010).

This would mean that if the price of glycerine eco-fuel was reached at the level of approx. 250 EUR/t with the income from the sale of glycerin would cover the costs of sodium hydroxide, potassium hydroxide, citric acid, electricity and human labor. In that case, the cost price, or production price of a product unit, of biodiesel is:

$$C_K \approx C_K^{SU} + C_K^{ME} \quad (18)$$

In the case of the price of crude oil $C_{ReU} = 685$ EUR/t and the price of methanol $C_{ME} = 317$ EUR/t the production price of biodiesel produced from pure crude rapeseed oil in that case is

$$C_K^{'} = w_{SU} C_{ReU} + w_{ME} C_{ME} = 734{,}69 \text{ EUR/t} \quad (19)$$

Now we will analyze the case when the produced biodiesel is a mixture of biodiesel produced from pure rapeseed oil (MERU = Rapeseed Methyl Esters - RME) and biodiesel produced from pure soybean oil (MESU = Soy Methyl Esters - SME), (Standard, EN 14214, 2004).

If the relative mass composition of biodiesel is from rapeseed oil (g_{ReU}), while the relative mass composition of biodiesel is from soybean oil (g_{SoU}), we have that the cost of crude oil is:

$$C_K^{SU} = g_{ReU} w_{ReU} C_{ReU} + g_{SoU} w_{SoU} C_{SoU} \text{ , } (20)$$

where $g_{ReU} + g_{SoU} = 1$

if the selected raw materials (rapeseed oil and soybean oil) have the same acid number (≈ 2mgKOH/g) the relation also applies: $w_{ReU} = w_{SoU} = w_{SU} = 1{,}018$.

Based on the above facts, it follows that the production price of biodiesel, obtained by mixing biodiesel from rapeseed oil and biodiesel from soybean oil, is:

$$C_K^{''} = g_{ReU} w_{SU} C_{ReU} + g_{SoU} w_{SU} C_{SoU} + C_K^{ME} \quad (21)$$

Based on the following facts:

- the allowed level of adjustment of soybean oil biodiesel, without significantly changing the essential parameters (primarily fuel filterability) of rapeseed oil biodiesel as a base fue, is currently acceptable 35%, which defines $g_{ReU} = 0{,}65$ and $g_{SoU} = 0{,}35$
- the price of raw rapeseed oil, at factory parity, is: $C_{ReU} = 685$ EUR
- the price of raw soybean oil, at factory parity, is: $C_{SoU} = 545$ EUR

we have that the production price of biodiesel in that case is:

$$C_K^{''} = 684.80 \text{ EUR.}$$

Based on the projected capacity of the plant at the level of annual production, the realized profit at the annual level, based on the use of the permitted level of soybean oil, for the input production raw material of biodiesel is: $\Delta = \left(C_K^{'} - C_K^{"}\right) \cdot Q_P = 1{,}496{,}700.00$ EUR. A significant increase in the economy of the production facility using soy crude oil can be noticed.

The price of crude rapeseed oil C_{ReU} depending on the price of rapeseed and taking the levels of defined costs, can be expressed as follows

$$C_{ReU} = K_{tr}\, C_{rep} \quad (22)$$

Where: C_{rep} is the rapeseed price (EUR/t), K_{tr} is the cost coefficient of the delivery and processing of rapeseed and its value based on the specified items in the proposed agreement and the sale of rapeseed meal at the price of 160 EUR/t and amounts to, for the value of the input raw material C_{rep} = 300 (EUR/t), K_{tr} = 2.237. For each increase in the price of rapeseed by 10%, the coefficient increases by 0.03, that is, for a price lower by 10%, the coefficient is lower by 0.03

In the Table 3. the values of the price of crude rapeseed are given for the different values of the rapeseed price and the cost coefficient of the delivery and processing. All prices shown in the Table 3. are updated for the year 2010 from (Product Exchange ad Novi Sad - NSCOMEX, 2010).

Table 3. The values of the price of crude rapeseed

Rapeseed price C_{rep} (eur/t)	**Processing coefficient K_{tr}**	**Crude rapeseed oil price C_{ReU} (eur/t)**
340	2.276	773.84
330	2.267	748.11
320	2.258	722.56
310	2.247	696.57
300	2.237	671.11
290	2.227	645.83
280	2.218	621.04
270	2.207	595.89
260	2.196	570.96

Source: Author's interpretation

The most unfavorable estimate (160 EUR/t) was used for the price of rapeseed meal. The current price of rapeseed meal with 32% protein is 210 EUR/t, which is the maximum price of meal at the end of the given annual cycle. The price of the shot has a significant effecton the price of crude rapeseed oil, so it is very important to estimate its value at which it can be sold.

Conclusion

Biodiesel is a renewable and biodegradable fuel made from vegetable oils, animal fats, or recycled cooking grease. It can be used in diesel engines with little or no modification and is often blended with petroleum diesel.

In this paper, as part of the economic analysis, an analysis of the cost price of the production of a unit of biodiesel products is given. Makpatrol biodiesel plant, located in Skopje in Macedonia, with a projected capacity of 20,000 tons of biodiesel per year is analyzed. Within the framework of the economic analysis, all relevant aspects were considered costs that influence the formation of the cost price of biodiesel fuel for plant with a capacity of 20,000 tons of annual production. The costs of producing a unit of biodiesel fuel products depend on the value of the costs of input raw materials, energy costs, and the cost of human labor.

Also, a comparative analysis of different cases was done: the case where during the design and implementation of the production plant the capacity of the production plant would be increased to the level of 25,000 tons of produced biodiesel, as well as to the level of 30,000 tons of produced biodiesel.

It is shown which parameters affect the cost price of the unit of the product produced in the biodiesel production plant. With an increase in annual production capacity comes a decrease in of the cost price of producing one ton of biodiesel on an annual basis, it was concluded based on the obtained results for the cost price of the unit of the product produced in the biodiesel production plant.

The cost price of the unit of the product produced in the biodiesel production plant capacity of 20,000 tons per year is $C_K = 702{,}45 \text{ eur}$ for the plant capacity of 20,000 tons per year.

For case the plant capacity of 25,000 tons per year, the realized profit on an annual level is obtained from $\Delta^{25} = 1{,}994{,}750.00 \text{ eur}$. The percentage increase in profit is: $\Delta = 28{,}61\%$ which is in absolute terms $\partial\Delta = \Delta^{25} - \Delta^{20} = 443{,}730.00 \text{ eur}$. It is obtained that the unit cost price of the product at the plant capacity of 25,000 tons per year is $C_K^{25} = 700.21 \text{ eur}$.

For case the plant capacity of 30,000 tons per year, the annual profit at this production price, and the selling price as in previous cases, would be: $\Delta^{30} = 2{,}438{,}700.00 \text{ eur}$. The percentage increase in profit is: $\Delta = 57.23\%$ which is in absolute terms $\partial\Delta = \Delta^{30} - \Delta^{20} = 887{,}700.00 \text{ eur}$. The cost price of a product unit at a plant capacity of 30,000 t/year is $C_K^{30} = 698.71 \text{ eur}$.

During this analysis, a very strong influence of the weight function of the input raw material, crude oil, can be observed on the production price of the final product, that is, on the overall economy of the biodiesel production plant. With an increase in annual production capacity comes a decrease in of the cost price of producing one ton of biodiesel on an annual basis.

In this paper, it is also shown that using a sufficient level of soybean oil can achieve a range of the cost price of the unit of the biodiesel product. The allowed level of adjustmen of soybean oil biodiesel, without significantly changing the essential parameter of rapeseed oil biodiesel as a base fuel, is currently acceptable 35%. In that case a production price of biodiesel is $C_K^{"} = 684.80$ eur. With a use of the permitted level of soybean oil the realized profit at the annual level is $\Delta = 1{,}496{,}700.00$ eur.

It can be concluted that it is possible to notice a significant increase in the economy of the production facility using soy crude oil thanks to the great flexibility of the applied technology.

Conflict of interests

The authors declare no conflict of interest.

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