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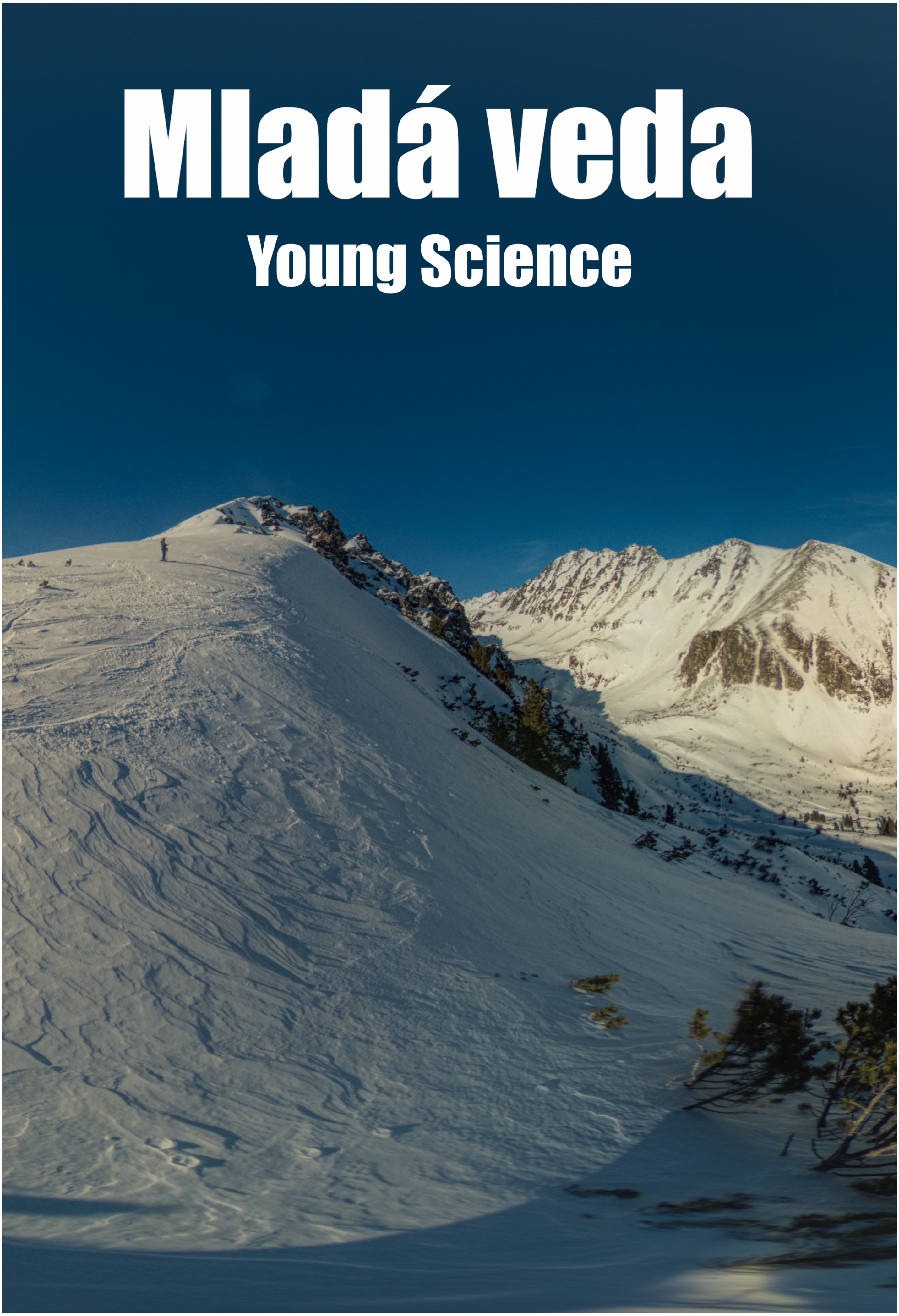

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THE POTENTIAL OF BIODIESEL AS AN ALTERNATIVE FUEL FOR THE REDUCTION OF GREENHOUSE GAS EMISSIONS

POTENCIÁL BIONAFTY AKO ALTERNATÍVNEHO PALIVA PRE ZNÍŽENIE SKLENNÍKOVÝCH PLYNOV

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Karolína Ujlacká pôsobí ako interná doktorandka na Katedre cestnej a mestskej dopravy na Fakulte prevádzky a ekonomiky dopravy a spojov Žilinskej univerzity v Žiline. Vo svojej dizertačnej práci sa venuje výskumu znižovania emisií skleníkových plynov z dopravných služieb v cestnej nákladnej doprave s akcentom na objektívne kalkulovanie, deklarovanie a internalizáciu nákladov z emisií skleníkových plynov z cestnej nákladnej dopravy.

Karolína Ujlacká works as an internal doctoral student at the Department of Road and Urban Transport at the Faculty of Operation and Economics of Transport and Communications of the University of Žilina. In her dissertation thesis she is researching reduction of greenhouse gas emissions from road transport services freight transport with an emphasis on objective calculation, declaration, and internalisation of costs of greenhouse gas emissions from road freight transport.

Abstract

The negative impact of road transport on the environment is one of the most important challenges of the present time. One of the main goals in the field of transport is the minimization of environmental impacts, while it is essential to maintain its efficiency and ability to ensure high quality. To achieve this goal, it is necessary to implement measures that will enable a significant reduction of emissions and environmental burden, while at the same time supporting the transition to sustainable transport technologies. One of the promising alternatives in this area is the use of biodiesel B100, which represents an ecologically friendly drive with a low environmental impact throughout its entire life cycle. This cycle, known as "well-to-wheel", includes the process of obtaining raw materials, distribution and consumption itself, while the waste generated during production is further used. The production of biodiesel uses renewable resources such as different types of biomass, which

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ensures its availability on a global level and sustainability compared to fossil fuels, whose reserves are rapidly decreasing.
Keywords: chi-square, IBM SPSS statistics, analysis, methods

Abstrakt

Negatívny vplyv cestnej dopravy na životné prostredie patrí medzi najvýznamnejšie výzvy súčasnej doby. Jedným z hlavných cieľov v oblasti dopravy je minimalizácia environmentálnych dopadov, pričom je nevyhnutné zachovať jej efektívnosť a schopnosť zabezpečiť vysokú kvalitu. Na dosiahnutie tohto cieľa je potrebné implementovať opatrenia, ktoré umožnia výrazné zníženie emisií a environmentálnej záťaže, a zároveň podporiť prechod na udržateľné dopravné technológie. Jednou z perspektívnych alternatív v tejto oblasti je využitie bionafty B100, ktorá predstavuje ekologicky priaznivý pohon s nízkym environmentálnym dopadom počas celého svojho životného cyklu. Tento cyklus, známy ako „well-to-wheel“, zahŕňa proces získavania surovín, distribúciu a samotnú spotrebu, pričom odpad vznikajúci pri výrobe je ďalej využívaný. Výroba bionafty využíva obnoviteľné zdroje, ako sú rôzne druhy biomasy, čo zabezpečuje jej dostupnosť na globálnej úrovni a udržateľnosť v porovnaní s fosílnymi palivami, ktorých zásoby sa rýchlo znižujú.
Kľúčové slová: emisie z dopravy, životné prostredie, alternatívne pohony, bionafta

Introduction

As the population grows and standards of living increase, transport requirements naturally increase. This puts a negative strain on the environment. Therefore, emissions of harmful air pollutants should be prevented, or prevent them, or they should be reduced [1,2].

Oil is expected to become increasingly scarce and its resources increasingly uncertain in the coming decades. As the International Energy Agency (IEA) recently stated, the less the world succeeds in reducing carbon emissions, the more the price of oil will rise [3].

Road trucks are currently among the main consumers of oil on a global level. The industry's daily oil consumption is about 17 million barrels, which is about one fifth of global oil demand. Only passenger cars account for a larger share of this demand, accounting for around a quarter of the total. Freight transport is primarily dependent on diesel, which accounts for more than 80% of its consumption of petroleum products. While the use of petroleum in passenger cars has started to decline due to the easier introduction of alternative fuels, petroleum consumption from on-road trucks is still growing and now accounts for almost half of diesel demand [4].

The European Union has started implementing steps aimed at mitigating the negative effects of industries on the environment and the health of the population. The aim of these measures is to ensure that further deterioration of the ecological situation is avoided and that negative environmental impacts are gradually eliminated. An important part of this strategy is the definition of specific targets for the reduction of environmental burdens [5].

It is important to realize that greenhouse gases are not produced exclusively during the operation of motor vehicles, but also within the wider life cycle of the vehicle. Indirect environmental burden includes processes associated with the production of cars and their components, as well as disposal after the end of their useful life. This complexity of the environmental burden emphasizes innovations that can contribute to improving living standards and a greener future for road transport, especially in the truck segment. At the same time, it is important to focus on a more ecological future of road transport, especially in the truck sector, which has a significant share in the emission balance.

One of the prospective solutions to the negative impact of transport on the environment is the use of biodiesel. Biodiesel does not contain sulphur, which significantly contributes to the elimination of the formation of acid rain and contributes to the reduction of the greenhouse effect. It produces less carbon dioxide compared to fossil fuels, reduces smoke emissions and contributes to improved air quality. Thanks to these environmental benefits, biodiesel is gaining increasing importance as an attractive alternative to traditional fossil fuels. Its use can contribute not only to the protection of the environment, but also to support the health of current and future generations. The expected shortage of fossil fuels has stimulated the search for substitutes for oil derivatives. The result of this search was an alternative fuel called "biodiesel". The concept of biodiesel is still being debated. Some definitions consider biodiesel to be any mixture of vegetable oil and fossil diesel, while others consider only mixtures of alkyl esters of vegetable oils or animal fats and diesel [6,7].

Biodiesel, also known as FAME (Fatty Acid Methyl Ester), is an alternative fuel produced primarily by the chemical processing of vegetable oils. It is commonly added to conventional fuel labelled B7, which is required to contain 6.9% bio-based components. This renewable energy source represents a promising solution for the future as it is inexhaustible when properly set up. Biodiesel is produced from pure rapeseed oil or other available oils such as sunflower, palm, corn oil, cooking oils and animal fats [7,8].

The importance of biodiesel for reducing greenhouse gas emissions

The emission footprint of classic (fossil) diesel is 91.1 g CO2/MJ, in contrast, biofuel from vegetable oil has an emission footprint of 33 g CO2/MJ and biofuel made from waste raw materials (used cooking oil) even only around 9 g CO2/MJ. he difference is therefore huge, with up to 90% CO2 emission reductions in the case of B100 from waste oil [9].

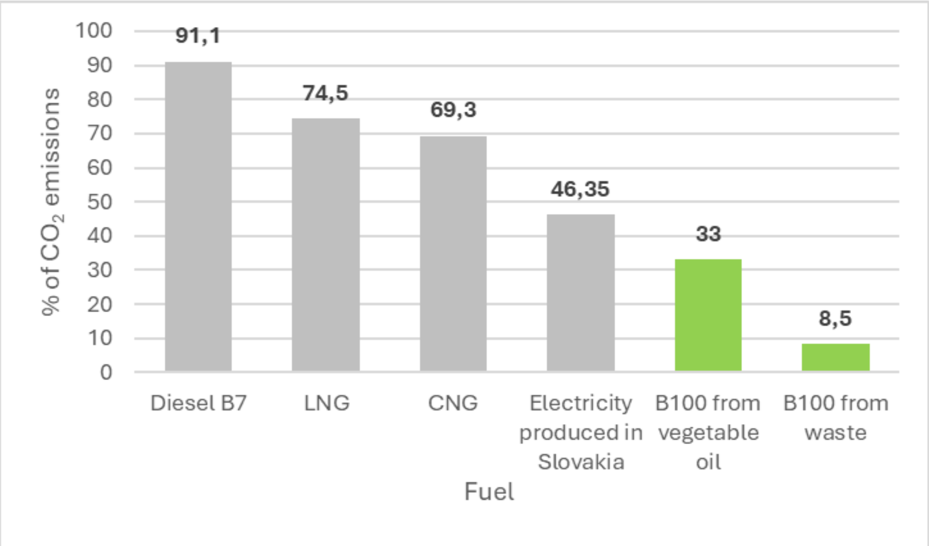

Fig. 1 – CO2 emissions from fuel (g/MJ)
Resource: Author's own processing according to [9]

Biofuel made from vegetable oil such as rapeseed or sunflower oil can reduce greenhouse gas emissions by 62% compared to conventional fossil diesel B7. Even more efficient are biofuels made from waste materials, such as used cooking oils or animal fats, which achieve emission savings of 88%. This significant decrease in greenhouse gas production could have a major impact on stabilizing the rising global temperature. Reducing emissions of carbon dioxide and other gases that contribute to the greenhouse effect would contribute to slowing down climate change, which would have a positive impact on the environment.

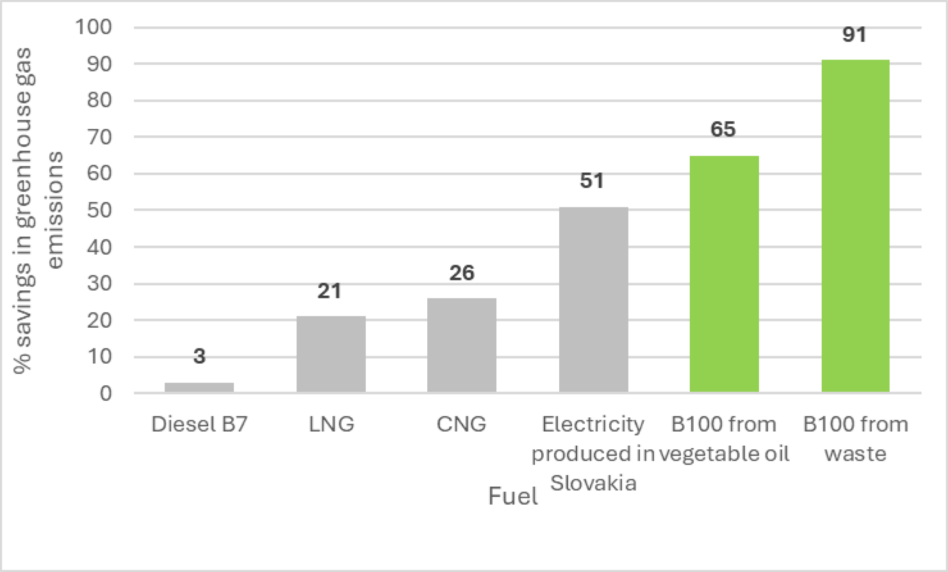

Fig. 2 – Percentage saving of greenhouse gas emissions
Resource: Author's own processing according to [9]

Achieving the renewable energy target can be achieved through biofuels that offer 100% renewable energy. This significantly reduces the need to use fossil fuels and also contributes significantly to the development and implementation of new, greener technologies. The production of biofuels from sources such as vegetable oils or waste materials reduces dependence on non-renewable raw materials and contributes to a more sustainable economic model. Such an approach promotes responsibility towards nature, as biofuels are produced from renewable raw materials that can be used again and again. This reduces waste, improves the circular process and at the same time reduces the carbon footprint compared to fossil fuels.

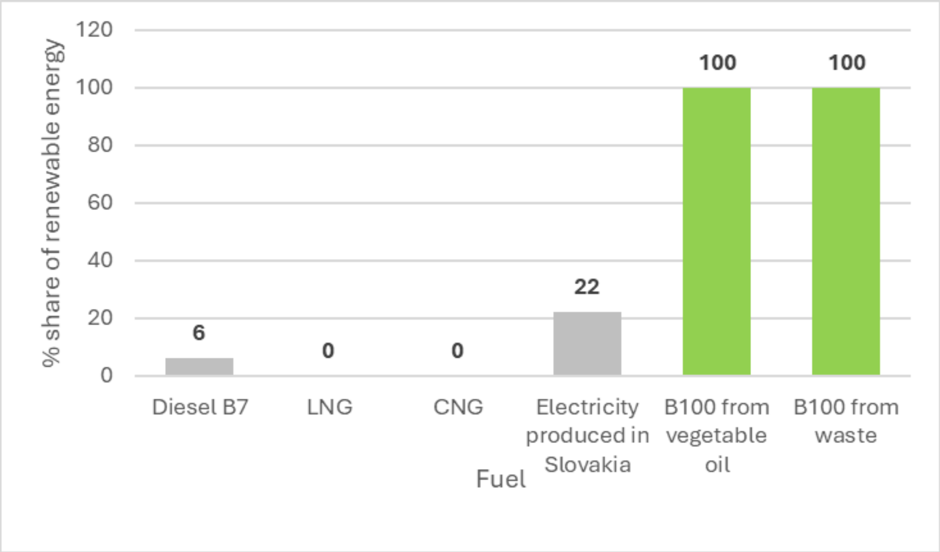

Fig. 3 – The percentage of renewable energy in the fuel
Resource: Author's own processing according to [9]

Analysis and Evaluation of Energy Consumption and CO2 Emissions of Vehicles Powered by B7 and B100 Fuels

This is a model comparison conducted on two identical tractor units of the same specification, Scania R450, equipped with Wielton tipping semi-trailers with a volume of 49 m³. Both vehicle combinations performed real cargo transport under identical operating conditions, ensuring maximum objectivity in the comparison.

The key conditions maintained included:

- Identical route and distance traveled.
- Approximately equal cargo weight for both vehicle combinations.
- Identical weather conditions during the transport.
- Sequential driving, where the second vehicle followed the first closely, experiencing the same inclines and declines along the route.

Below is a table summarizing the technical specifications of the compared Scania R450 vehicles:

Model	**Scania R450**	**Scania R450**
Vehicle Type	Tractor Unit	Tractor Unit
Model	13-liter, 6-cylinder engine	13-liter, 6-cylinder engine
Engine Power	331 kW	331 KW
Emission Standard	Euro 6	Euro 6
Tires	315/70R22.5	315/70R22.5
Fuel	**Diesel B7**	**Diesel B100**
Fuel Tank Capacity	400 liters	800 liters
Empty Vehicle Weight	14 740 kg	15 140 kg

Table 1 – Comparison of technical specifications of Scania R450 trucks
Resource: Author's own processing according to internal data of the transport company

In addition to the different propulsion, these outwardly identical kits have a different total weight due to a modified biodiesel tank for longer range. The tank capacity is increased by 400 l.

Comparison of fuel prices

The price difference between B7 and B100 is €0.284/l without VAT, while biodiesel has a higher price. This price difference represents a significant barrier that discourages carriers from purchasing biodiesel vehicles.

	Price (€/l)	
	Price with VAT	Price without VAT
B100	1,801	1,501
B7	1,463	1,217

Table 2 – Comparison of fuel prices

Resource: Author's own processing according to current diesel prices for the month of November

To reach its 2050 climate neutrality target, the EU is taking action to reduce car emissions. The EU plans to reduce car emissions by 55% by 2030 compared to 2021 levels, with the aim of achieving zero emissions from new cars and vans by 2035. To achieve a smooth transition to climate neutrality, biodiesel is a great solution because of the low acquisition cost of biodiesel-powered vehicles, as well as the relative ease of connecting infrastructure to existing infrastructure. Measures such as biofuel tax credits would need to be introduced to encourage the use of biodiesel. These steps could help bridge the price gap and make biodiesel a more attractive option for the transport sector.

Comparison of performance and environmental parameters of identical vehicles with B7 and B100 drives

Monitored period: 11.8.-13.8.2021							
Fuel	Distance traveled (km)	Fuel consumed (l)	Average consumption (l/100km)	Loaded km	Empty km	Transported cargo (t)	β (%)
Biodiesel	1059	313	29,56	772,00	287,00	100,10	72,90
Diesel	1073	290	27,03	785,00	288,00	101,20	73,16
Monitored period: 17.8.-20.8.2021							
Fuel	Distance traveled (km	Fuel consumed (l)	Average consumption (l/100km)	Loaded km	Empty km	Transported cargo (t)	β (%)
Biodiesel	1487	468	31,47	1254,00	233,00	101,70	84,33
Diesel	1502	445	29,63	1269,00	233,00	102,10	84,49

Monitored period: 23.8.-27.8.2021							
Fuel	Distance traveled (km)	Fuel consumed (l)	Average consumption (l/100km)	Loaded km	Empty km	Transported cargo (t)	β (%)
Biodiesel	2586	752	29,08	2212,00	374,00	75,60	85,54
Diesel	2618	700	26,74	2261,07	356,93	76,20	86,37

Table 3 – Comparison of operating characteristics of vehicles
Resource: Author's own processing according to real data from the transport company

To increase the clarity of the data, the information on the individual vehicles has been compiled into a summary report that allows a clear comparison of the differences in performance parameters. Table 4 shows the values where we can see when the B7 fuelled vehicle performed better and when the B100 fuelled vehicle performed better. The cells are underlined in green where the B100 fuelled vehicle performed better and the B7 fuelled vehicle performed better in red.

Fuel	**Weight of transported cargo(t)**	**Distance traveled (km)**	**Fuel consumed (l)**	**Average consumption (l/100km)**	**Energy Consumption (MJ/km)**
Nafta B7	279,5	5 193	1435	27,8	9,95
Nafta B100	277,4	5 132	1533	30,0	9,86
The difference	2,1	61	- 98	- 2,2	0,09

Table 4 – Summary comparison of operating characteristics of vehicles
Resource: Author's own processing according to real data from the transport company

Based on the data obtained, graphical representations were created that llowed visualization of the individual parameters. Graph 1 shows that the differences in the weight of cargo transported and the distance travelled during the period under consideration were essentially insignificant. These minimal variations ensured high comparability of the data between the tested vehicles, which allowed subsequent calculations of other relevant values with sufficient accuracy and reliability.

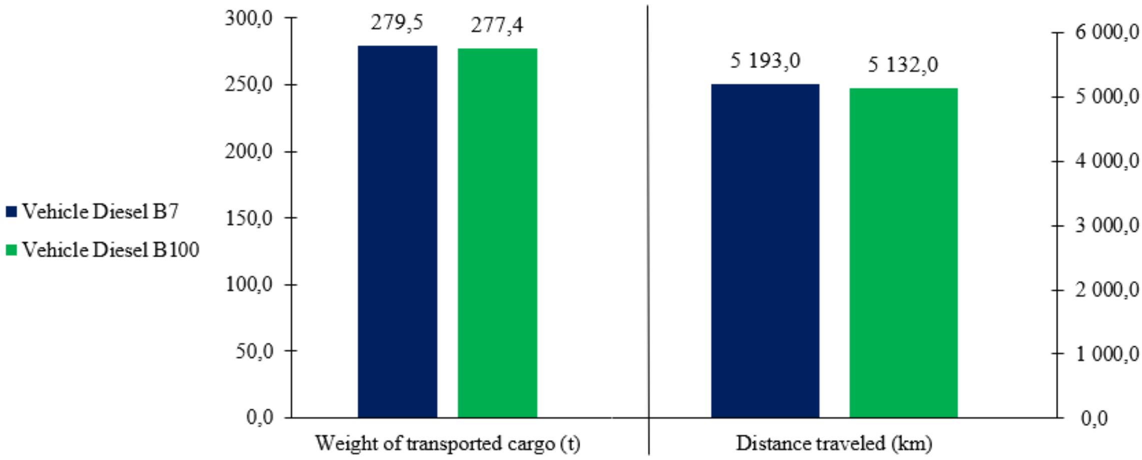

Fig. 1 – Comparison of transported goods weight and distance traveled by individual vehicles.
Resource: Author's own processing according to real data from the transport company

A higher consumption in l/100 km was recorded for a vehicle powered by biodiesel compared to conventional diesel. This result indicates that the use of biodiesel, although more environmentally friendly, may lead to higher fuel consumption under certain operating conditions, which may be a consequence of different energy properties of the fuel. Factors such as the lower energy density of biodiesel, its chemical composition, as well as engine optimization for conventional diesel, may contribute to this increased consumption.

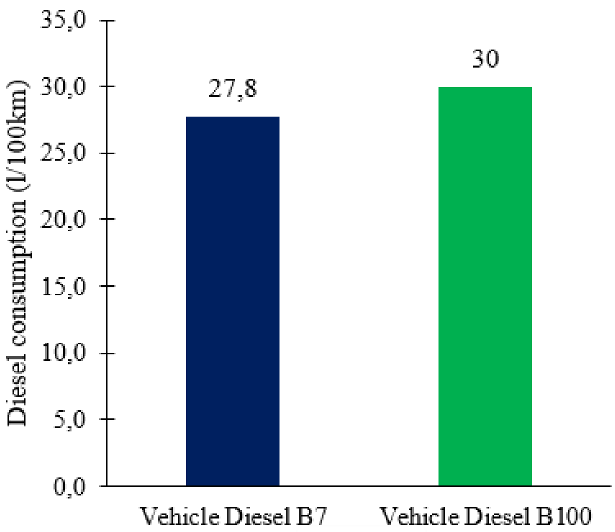

Fig. 2 – Comparison of the consumption of individual vehicles
Resource: Author's own processing according to real data from the transport company

When comparing energy consumption, the biodiesel-powered vehicle performed better. To calculate the energy consumed in MJ/km for each vehicle, it was first necessary to calculate the total energy consumption. The total energy consumption was calculated by multiplying the fuel consumed in litres by the energy factor from STN EN 16258 - Methodology for calculating and declaring energy consumption and greenhouse gas emissions from transport services (freight and passenger transport).

$$Total\ energy\ consumption\ =\ fuel\ consumed * energy\ factor\ coefficient \quad (1)$$

$$Total\ energy\ consumption\ \ B7 = 1435 * 36 = 51\ 660\ MJ$$

$$Total\ energy\ consumption\ \ B100 = 1533 * 33 = 50\ 589\ MJ$$

The next step for the calculation of the energy consumed in MJ/km was the ratio of the total energy consumption to the distance travelled.

$$Energy\ consumption\ = \frac{total\ energy\ consumption}{distance\ travelled}$$
(2)

$$Energy\ consumption\ B7 = \frac{51\ 660}{5193} = 9{,}95\ MJ/km$$

$$Energy\ consumption\ B100 = \frac{50\ 589}{5132} = 9{,}86\ MJ/km$$

A significant and very environmentally beneficial difference can be observed in the production of CO_2. A biodiesel-powered vehicle has significantly lower CO_2 emissions, which contributes to achieving the targets for reducing emissions in transport.

For the calculation in formula 3, the coefficient reported by the transporter was used, which refers to the EU Directive 2018/2001 on the promotion of the use of energy from renewable sources. This was then compared with the calculation according to STN EN 16258 - Methodology for calculating and declaring energy consumption and GHG emissions from transport services (freight and passenger transport) in formula 5, as the data is obtained for the year 2021, when this standard was in force. A comparison was also made with the new standard STN EN ISO 14083 - Greenhouse gases. Quantification and reporting of greenhouse gas emissions from transport chain activities, in formula 6, which was issued on 1 June 2024.

Calculation of CO_2 emissions declared by the carrier according to EU Directive 2018/2001:

$$Total\ CO_2\ produced = total\ energy\ consumption * emission\ factor\ coefficient \quad (3)$$

$$Total\ CO_2\ produced\ B7 = 51\ 660 * 90{,}8 = 4\ 690\ 728\ g$$

$$Total\ CO_2\ produced\ B100 = 50\ 589 * 33 = 1\ 669\ 437\ g$$

$$CO_2\ produced\ = \frac{Total\ CO_2\ produced}{distance\ travelled} \quad (4)$$

$$CO_2\ produced\ \mathrm{B7} = \frac{4\ 690\ 728}{5193} = 903\ \mathrm{g/km}$$

$$CO_2\ produced\ \mathrm{B100} = \frac{1\ 669\ 437}{5132} = 325\ \mathrm{g/km}$$

Calculation of CO_2 emissions according to STN EN 16258:

$$Total\ CO_2\ produced\ = fuel\ consumed * emission\ factor\ coefficient \quad (5)$$

$$Total\ CO_2\ produced\ \ B7 = 1435 * 2{,}48 * 1000 = 3\,558\ 800\ g$$

$$Total\ CO_2\ produced\ \ B100 = 1532 * 0{,}4 * 1000 = 612\,800\ g$$

$$CO_2\ produced\ B7 = \frac{3\,558\ 800}{5193} = 685\ g/km$$

$$CO_2\ produced\ B100 = \frac{612\ 800}{5132} = 119{,}41\ g/km$$

Calculation of CO_2 emissions according to STN EN ISO 14083:

$$Total\ CO_2\ produced\ = fuel\ consumed * fuel\ density * emission\ factor\ coefficient \quad (6)$$

$$Total\ CO_2\ produced\ \ B7 = 1435 * 0{,}836 * 3{,}17 * 1000 = 3\,802\,922{,}2\ g$$

$$Total\ CO_2\ produced\ \ B100 = 1532 * 0{,}892 * 0{,}15 * 1000 = 205\,115{,}4\ g$$

$$CO_2\ produced\ = \frac{3\,802\,922{,}2}{5193} = 732{,}32\ g/km$$

$$CO_2\ produced\ = \frac{205\,115{,}4}{5132} = 39{,}97\ g/km$$

The results have been summarized in a table for a better overview.

Fuel	**CO2 Emissions (g/km) - carrier**	**CO2 Emissions (g/km) - STN 16258**	**CO2 Emissions (g/km) -STN EN ISO 14083**
Nafta B7	903	685	732,32
Nafta B100	325	119	39,97
The difference	578	566	692,35

The results have been recalculated according to the coefficients for a better understanding. These are not the values measured by the exhaust gas analyser. Measurement with an analyser would be very costly, so the haulier has chosen to determine the values according to the above calculations.

The calculation of CO_2 emissions from fuels varies depending on the methodology and standard used, which affects the resulting values and interpretations of the environmental impact. The key difference lies in the approach to taking into account fuel consumed, energy and fuel density.

Under EU Directive 2018/2001, CO_2 emissions are recalculated based on fuel and energy consumed. On the other hand, STN EN 16258 calculates emissions based solely on the fuel consumed. The latest standard, STN EN ISO 14083, integrates fuel density as an additional factor, thus increasing the accuracy of the calculation, especially for different types of biofuels.

From Figure 3, it is possible to observe the differences in CO_2 production expressed in grams per kilometre (g/km) for the different types of fuel. Standard EN 16258 and standard

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EN ISO 14083 give the emission factor for B7 diesel as relatively the same, namely 2,48 and 2,65 kilograms of emissions per kilogram of fuel for B7 and B100 respectively. STN EN 16258 provides an emission factor for biodiesel with a bio content of 85 % (B85), which limits the accuracy for pure biodiesel fuels. In contrast, STN EN ISO 14083 already includes emission factors for 100% biodiesel (B100), allowing a more accurate assessment of its carbon footprint. These differences highlight the need to update older standards and harmonise calculations at both European and global level.

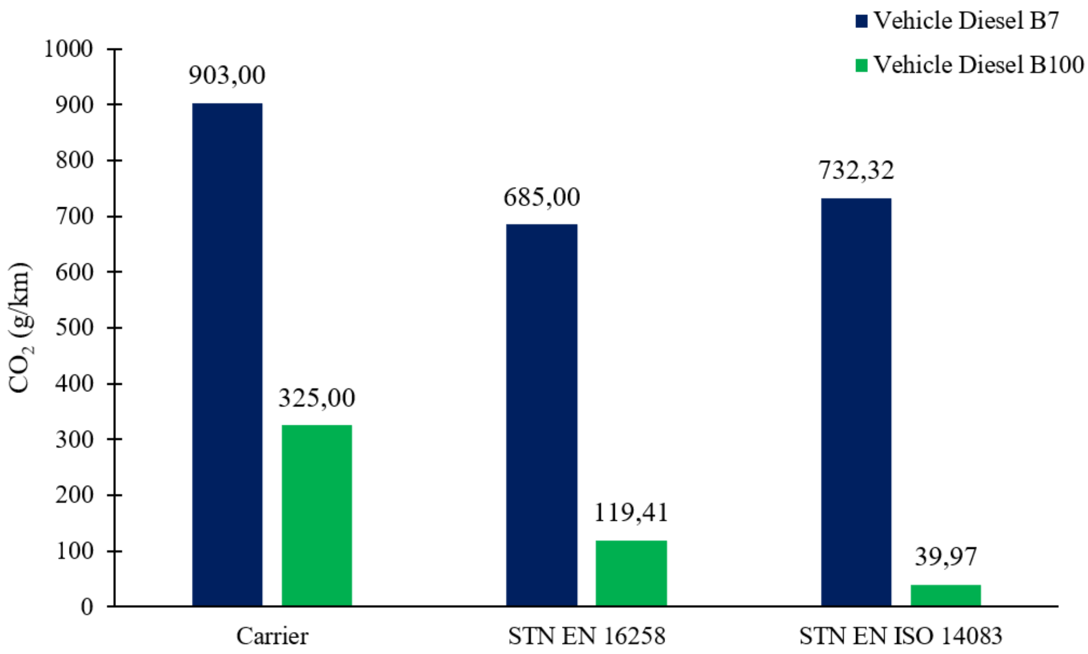

Fig. 3 – Comparison of CO2 production by individual vehicles according to established standards. Resource: Author's own

Thanks to the knowledge and the results achieved, we can see that biodiesel is one of the alternative fuels that can make a significant contribution to meeting the targets set, precisely because of its almost zero-waste production and lower CO2 production, the introduction of alternative fuel vehicles - biodiesel - can bring positive results in terms of the impact of transport on the environment.

Conclusion

Biodiesel as an alternative fuel is an important tool for achieving the targets for the share of renewable energy in transport, while contributing to the reduction of CO2 in the transport sector. In the test and comparison carried out between diesel and biodiesel powered vehicles, a lower CO2 production of 578 g/km was recorded according to the EU Directive 2018/2001, which is used by the haulier. According to STN EN 16258, the difference is 565.59 g/km and according to the latest STN EN ISO 14083, biodiesel shows an improvement in CO2 production of up to 692.35 g/km.

However, there are a number of factors that may deter customers from purchasing alternative fuels when implementing them into fleets of hauliers. Key barriers include high investment costs. Therefore, in an effort to reduce emissions from the vehicle fleet of the

Slovak Republic, or the EU as a whole, support from the states will certainly be needed in various ways through subsidies, grants, taxes and levies in order to increase the share of environmentally friendly vehicles in road freight transport at a faster pace in the short term and to achieve a better quality of the environment for the population and to facilitate the process of a smooth transition to alternative fuels.

This article was recommended for publication in the scientific journal Young Science:
doc. Ing. Vladimír Konečný, PhD.

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