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Comparative assessment of energy efficiency indicators of a multi-fuel internal combustion vehicle and an electric vehicle

Wawrzyniec Gołębiewski[1], Tomasz Osipowicz[1], Karol Franciszek Abramek[1], Wojciech Lewicki[1,*], Oleh Klyus[2]

[1] West Pomeranian University of Technology in Szczecin, Szczecin, Poland
[2] Maritime University of Szczecin, Szczecin, Poland

Abstract: In the current discussions on the future of the automotive industry, two extreme opinions clash: electromobility or vehicles with conventional drive but powered by alternative fuels. The article discusses the issue related to modeling the energy efficiency factors of a combustion engine operating on three types of fuels (Diesel 100%, Biofuel 100%, and Hemp Oil 100%) as well as an electric drive powered by energy from a coal power plant. Analytical research was conducted based on the external characteristics of the engine's performance. The external characteristic of the Fiat Panda 1.3 JTD combustion engine was obtained on the Automex dynamometer. The engine operated on three fuels: Diesel 100%, Biofuel 100% (rapeseed), and Biofuel 100% (hemp oil). The Nissan Leaf vehicle manufacturer provided the external characteristics of the electric engine. The calculation results showed that the combustion engine consumes less energy at lower speeds than the electric one. At higher speeds, the consumption rates are at a similar level. The recipients of the research are both the demand side – that is, vehicle users, as well as future manufacturers and government institutions responsible for shaping and developing future mobility in the field of individual transport.

Keywords: power unit, alternative fuels, electric vehicle, energy efficiency

1. Introduction

One of the key postulates mentioned by the supporters of the development of electromobility is the postulate regarding high efficiency of electric drives. As indicated in the literature on the subject the efficiency of an engine characterizes the amount of mechanical work it can perform per unit of energy supplied to it. In the case of motor vehicles, the mechanical work comes from both chemical and electric energy. By

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*Corresponding author
E-mail address: wojciech.lewicki@zut.edu.pl (W. Lewicki)
ORCID: 0000-0002-3691-8636 (W.Gołębiewski), 0000-0002-3321-7754 (T.Osipowicz), 0000-0001-9704-5253 (K.Abramek), 0000-0002-8959-8410 (W.Lewicki), 0000-0002-9849-5974 (O.Klyus)

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comparing the efficiencies of different energy sources, it is possible to analyze which carrier is more efficient in urban and non-urban driving cycles. The analysis of technological development presented in reference [20] showed that the majority of research and patents related to automotive development are in the area of electric and hybrid vehicles. The technology of combustion engines is mature. The authors of the article predict that its saturation will occur between 2037 and 2043. Research conducted by the authors of the paper [13] demonstrated that the higher initial cost of purchasing an electric vehicle can be recovered after just five years of use, especially for vehicles with a lower range. According to the authors, this is due to lower operating costs and higher battery efficiency compared to vehicles with a combustion engine.

The longer the period of electric vehicle usage, the more its operating costs decrease. However, the authors did not examine the operational lifespan of batteries, as they are the most expensive component of an electric vehicle. In the study [11], environmental impacts during the production, operation, and disposal of electric, hybrid, and combustion vehicles in Nepal were investigated. The analysis showed that electric and hybrid vehicles reduce overall environmental pollution by 82%. In the paper [7], the efficiency of electric and combustion propulsion systems was examined and compared in urban driving cycles. The analysis revealed that electric vehicles have higher efficiency in urban areas, especially during traffic congestion (start-stop situations). However, in the paper [15], it was described that energy systems in the Canary Islands, which consume the least energy, are not efficient for charging electric vehicles due to increased CO^2 emissions compared to combustion vehicles. The study's conclusions suggest that the environmental cost-effectiveness of using electric vehicles is more prevalent in larger urban centers with well-developed electric infrastructure.

In the study [21], the total cost of ownership (TCO) of an electric vehicle over a 15-year period was examined in Thailand, where such vehicles are promoted. The analysis revealed that the lowest ownership costs were observed for conventional gasoline vehicles, followed by hybrid vehicles, plug-in hybrid vehicles, and electric vehicles. The main factors contributing to the increased ownership costs of electric vehicles were their high acquisition cost and expensive batteries. The authors proposed efforts to reduce battery costs and introduce subsidies for the purchase of electric vehicles.

In the study [2], an analysis was conducted on the potential reduction of greenhouse gas emissions by electric and combustion vehicles in the United States from 2018 to 2030. The calculations have shown that the level of emissions from electric and combustion vehicles can be at a similar level. The decarbonization process can involve reducing fuel consumption in internal combustion engine vehicles and obtaining electric energy from renewable sources for electric vehicles by replacing natural gas power plants with nuclear ones. However, despite not emitting exhaust fumes, electric vehicles contribute to the emission of particulate matter [17]. The sources of emissions include the wear of brake pads, tire wear, road wear, and resuspended road dust. Research has indicated that due to their increased weight, electric vehicles exhibit higher non-exhaust emissions compared to combustion vehicles.

In the paper [19], an analysis of environmental impacts from 2019 to 2050 was presented for spark-ignition engine (SI) and compression-ignition engine (CI) combustion vehicles, plug-in hybrid vehicles, and electric vehicles in Hong Kong. The study showed that by 2050, the most environmentally friendly vehicle would be the electric vehicle, followed by the plug-in hybrid vehicle with a CI engine. The least environmentally friendly vehicle in all aspects was the SI vehicle. Similar results were obtained in the study [24], where three types of vehicles-electric, hybrid, and combustion – were examined for emissions throughout their lifecycle. Electric vehicles had the lowest emissions of particulate matter and nitrogen oxides. Additionally, research results demonstrated that electric vehicles have the lowest ownership costs among the known propulsion systems [9]. However, there is uncertainty regarding future electricity and fuel prices. Nevertheless, nowadays, despite the higher purchase costs compared to conventionally powered vehicles, electric vehicles are gaining more and more popularity [23]. Plug-in hybrids can be an alternative to electric vehicles. In the study [26], a hybrid propulsion system with an SI and CI engine burning bioethanol in autoignition mode was investigated. The research showed that a mixture of bioethanol ranging from 20% to 100% can reduce CO^2 emissions by up to 78%. The authors of papers [4,13] argue that there is still potential for optimizing the operation of plug-in hybrid vehicles. Analytical research [18] indicates that electric vehicles have higher annual depreciation (13.9%) compared to combustion vehicles (10.4%) due to battery wear. The use of renewable energy sources and the modernization of electric infrastructure will impact the efficiency of fast vehicle charging stations [1,5,8, 14,22,25]. Additionally, the implementation of a system managing energy consumption in vehicles will lead to better optimization of vehicle performance [16]. In the paper [6], an innovative experiment was carried out on the feasibility of a propulsion technology consisting of a fuel cell, an internal combustion engine and an integrated electro-thermo-chemical drive on the basis of a life cycle assessment. Studies have shown that the new technology outperforms battery-powered propulsion in environmental and human health aspects. The main benefits come from the production stage of the vehicle.

Based on the literature analysis, it can be concluded that research on the optimization and implementation of alternative propulsion sources is being conducted in various directions and applied to both technical parameters and economic. However, research on comparative analyzes of drive efficiency coefficients for internal combustion engines with electric and internal combustion engines operating on conventional fuels and alternative fuels – plant fuels, is omitted.

As presented in this article, the included research has many important practical implications. At the same time, they are supplement the gap in the literature on the subject related to the aspects of comparative assessment of energy efficiency indicators of selected drive units – a conventional engine powered by alternative fuel and an electric engine. The scientific discussion is presented as follows. Section 2 contains a description of the research methods used in response to the stated aim of the work. Section 3 presents the research results. In the final part section 4, the conclusions from the author's research are presented, pointing to the current research limitations and future directions of analysis.

The aim of the conducted research was a comparative analysis of energy efficiency indicators between electric and combustion engine vehicles. The electric car was powered by energy from conventional coal-fired power plants. A car equipped with an internal combustion engine (CI) running on different fuels: (Diesel) powered by different fuels: Diesel 100%, Rapeseed oil 100% biofuel, and Hemp oil 100% biofuel. The analysis was carried out under the conditions of external characteristics of the drive units.

2. Research and Methods

2.1. Modeling the efficiency coefficients of electric and combustion engine propulsion

The analytical research was conducted based on the measurements of operating parameters of the CI engine on an engine dynamometer according to the external characteristics. Additionally, the external characteristics of the electric vehicle were generated using data provided by the manufacturer.

The cumulative fuel consumption of the vehicle was calculated using equation (1).

$$Q = \frac{100 * G_e}{\gamma^* 3.6 v} \tag{1}$$

where:
Q – cumulative fuel consumption [dm^3/100 km],
G_e – hourly fuel consumption [kg/h],
γ – fuel density [kg/dm^3],
v – vehicle speed [m/s].

The vehicle speed [m/s] was calculated using formula (2):

$$v = \frac{s}{t} = \frac{2 \cdot \pi \cdot r_d \cdot n_K}{60\, t} = \frac{\pi \cdot r_d \cdot n_k}{30} = \frac{\pi \cdot r_d \cdot n}{30\, i_{SB} \cdot i_{PG}} \tag{2}$$

where:
s – distance [m],
t – time [s],
r_d – dynamic wheel radius [m],
n_K – number of wheel revolutions,
n_k – wheel rotational speed [rpm],
n – engine rotational speed [rpm],
i_{SB} – gearbox ratio,
i_{PG} – final drive ratio.

The vehicle speed [km/h] was calculated using equation (3).

$$v_k = v \cdot 3.6 \tag{3}$$

The calorific values for the tested fuels are similar, which is why the Authors included one of them in the calculations. The energy consumption of a car with a combustion engine for 1 dm^3 of Diesel 100%, Bio Diesel RME 100%, and Bio Diesel with Hemp Oil 100% is 10 kWh of energy. For comparative purposes, the value of energy emitted during the combustion of 1 dm^3 of diesel oil was used, and this value was converted into the energy consumption of a conventionally powered vehicle. This was done in order to compare the mileage energy consumption of conventionally and electrically powered vehicles. A similar methodology was implemented for a vehicle with a conventional drive powered by vegetable fuels. The values of energy obtained from a liter of fuel were very similar, so it can be assumed with a slight error that they are the same. The road energy consumption of an electric vehicle – under steady-state conditions – was calculated using equation (4):

$$E = \frac{10^5 \cdot P_B}{3.6 \cdot v} \quad (4)$$

where:
E – road energy consumption [kWh/100 km],
P_B – traction battery power [W],
v – vehicle speed [m/s].

The traction battery power was calculated using equation (5):

$$P_B = \frac{P_E}{\varepsilon_E} = \frac{P_K}{\varepsilon_E \varepsilon_{PG}} = \frac{P_K}{\varepsilon_E \varepsilon_{PG}} = \frac{F_N \cdot v}{\varepsilon_E \varepsilon_{PG}} \quad (5)$$

where:
P_E – electric motor power [W],
ε_E – electric motor and inverter efficiency,
ε_{PG} – main gearbox efficiency,
F_N – driving force [N].

The driving force is determined by the following relation (6):

$$F_N = \frac{T_{tqmax} \cdot i_{UN} \cdot \varepsilon_{UN}}{r_d} \quad (6)$$

where:
T_{tqmax} – maximum torque of the engine [Nm],
i_{UN} – drivetrain ratio,
ε_{UN} – drivetrain efficiency.

The mass-specific energy consumption of the vehicle is represented by the following relation (7):

$$E_m = \frac{E}{m_p} \quad (7)$$

where:
E – road energy consumption [kWh/(100 km kg)],
m_p – maximum total vehicle mass [kg].

The cost of driving 100 km was calculated using equation (8):

$$C = C_p \cdot E \quad (8)$$

where:
C – cost of driving 100 km [PLN],
C_p – cost of 1 dm^3 of fuel [PLN].

The actual energy consumption of the electric vehicle – under steady-state conditions (including energy generation) is represented by formula (9):

$$Eelek = \frac{E}{\varepsilon_{Elek} \cdot \varepsilon_{prz} \cdot \varepsilon_{lad}} \quad (9)$$

where:
ε_{Elek}– power station efficiency,
ε_{prz} – transfer efficiency (between power and charging stations),
ε_{lad} – charging efficiency.

3. Result and Discussion

The energy consumption calculation for the combustion engine vehicle utilized an external characteristic obtained from the engine dynamometer (Fig. 1–3). The engine was fueled with Diesel 100%, Rapeseed oil biofuel 100%, and Hemp oil biofuel 100%. The external characteristics of the electric drive were obtained from the manufacturer's data and presented in Fig. 4.

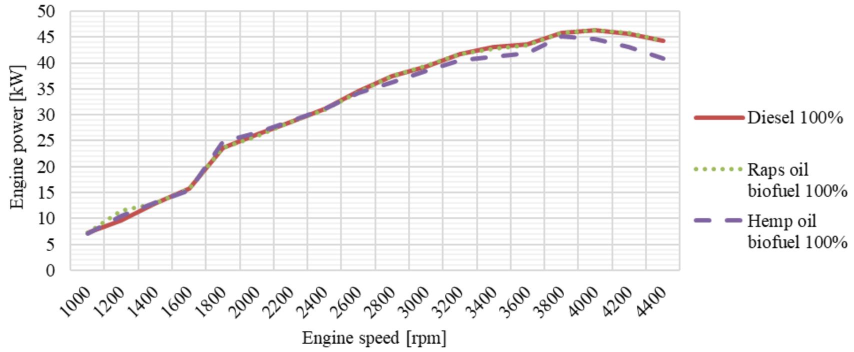

Fig. 1. Engine power for various fuel (source: own study)

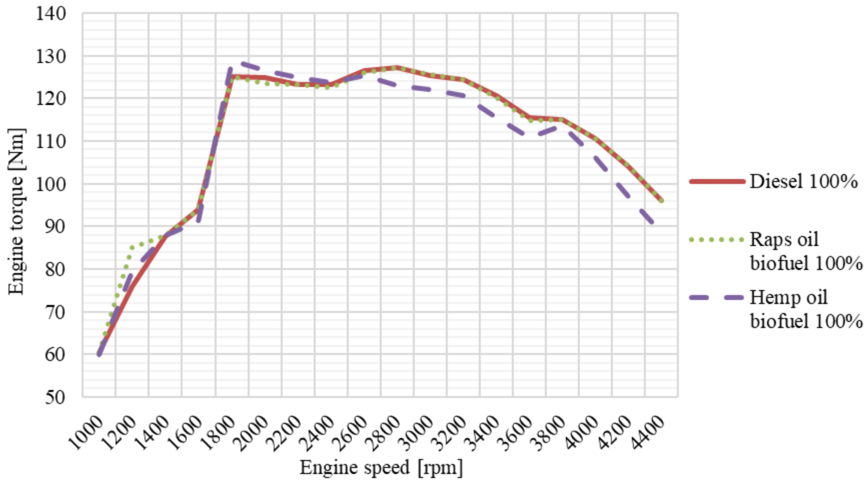

Fig. 2. Engine torque for various fuel (source: own study)

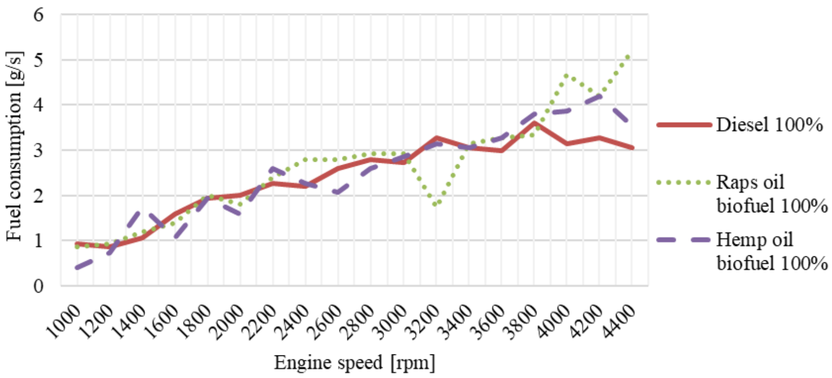

Fig. 3. Engine fuel consumption (source: own study)

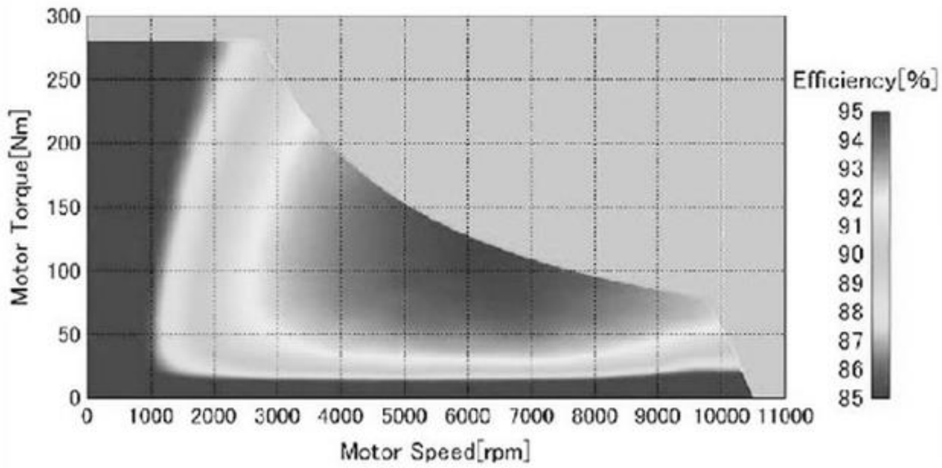

Fig. 4. Electric vehicle external characteristic (Nissan Leaf) [10]

3.1 Presentation of modeling result

The external characteristics of the combustion engine (Fig. 1–3) and the electric vehicle Nissan Leaf (Fig. 4) were utilized for the study. Fig. 5 presents the cumulative fuel consumption relative to vehicle speed. The fuel consumption was calculated based on the external characteristics of the engine operating on three types of fuels for five gears. Fig. 6 describes the torque magnitude relative to rotational speed for the electric and combustion engine vehicles fueled by different fuels.

At the next stage of research, maximum energy consumption relative to speed was calculated for the examined combustion engine vehicle at different gear ratios and various fuels in comparison to the electric vehicle and the electric vehicle powered by a coal power plant based on formula 4. It was presented in Fig. 7. The costs of driving 100 km for the combustion engine vehicle fueled by different fuels and the electric vehicle are presented in Fig. 8 (based on formula 8).

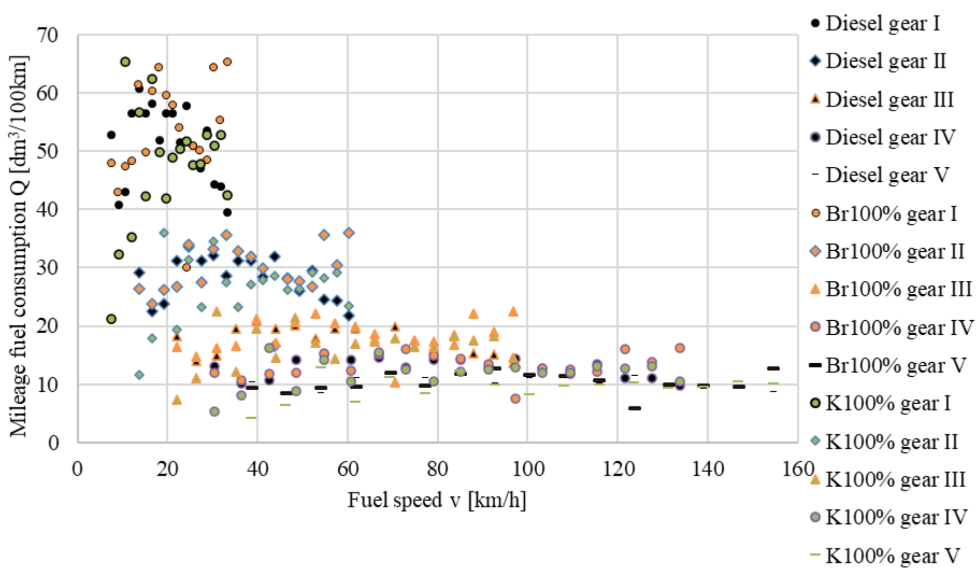

Fig. 5. Fuel consumption according to external engine characteristics (source: own study)

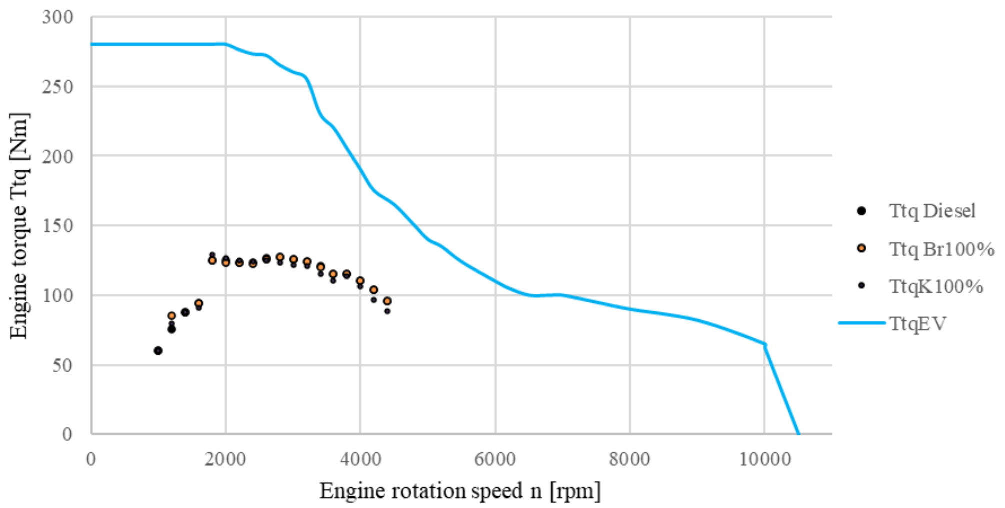

Fig. 6. Engine external for Fiat Panda powered by various fuels and Nissan Leaf electric vehicle (source: own study)

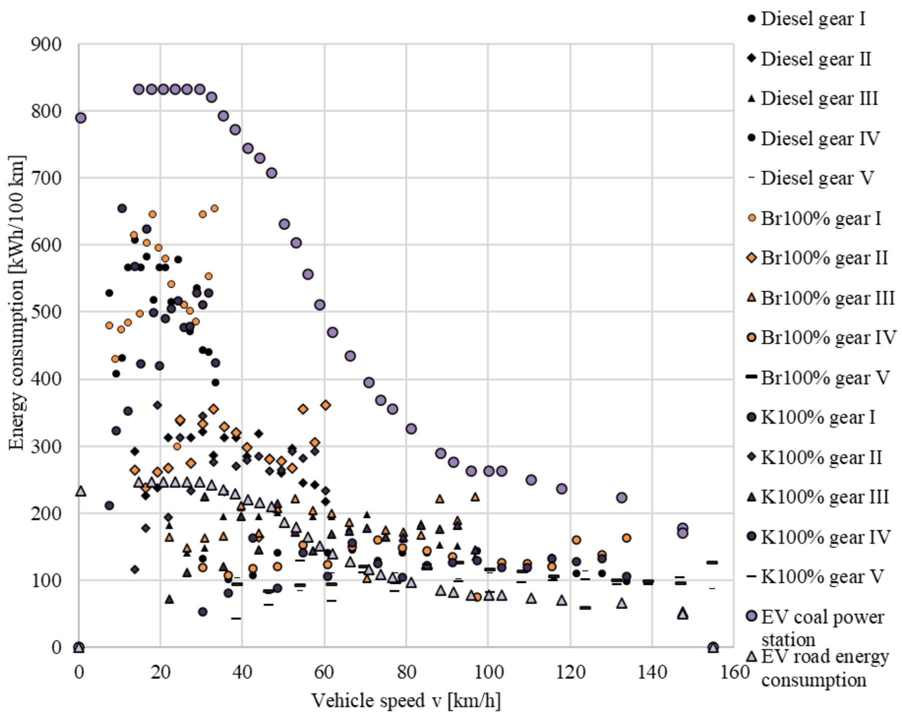

Fig. 7. Energy consumption – maximum propulsion parameters(source: own study): Br100% – rapeseed biofuel ester, K100% – hemp biofuel ester, EV – electric vehicle

Fig. 9 shows the energy consumption relative to the vehicle`s mass based on the external characteristic obtained from the engine dynamometer for the combustion engine vehicle fueled by different fuels and from the manufacturer for the electric vehicle. Fig. 10 illustrates the modeled maximum torque relative to the total maximum vehicle mass for the combustion engine powered by three types of fuels and the electric vehicle. Fig. 11 presents the calculated maximum energy consumption for the electric vehicle and the electric vehicle considering the power source as a coal power plant (source: own study).

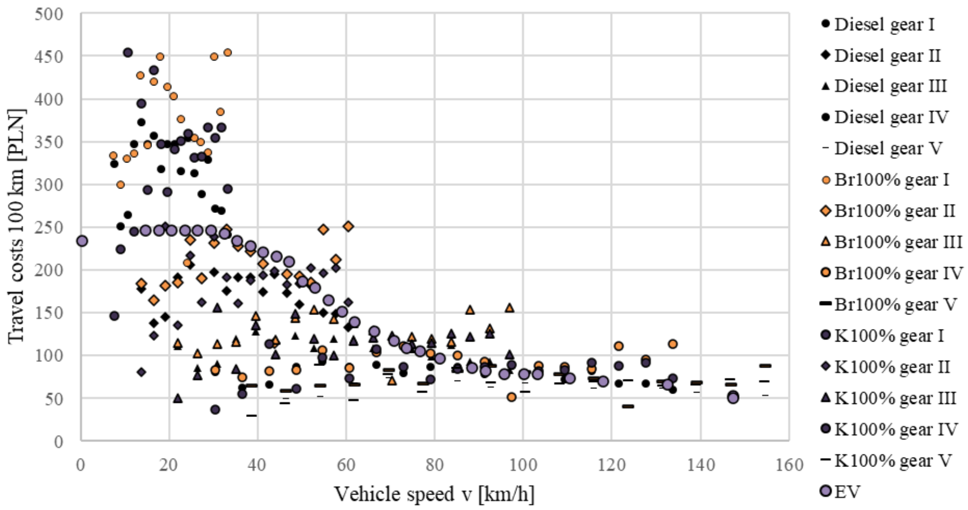

Fig. 8. The cost of driving 100 km – maximum propulsion parameters (source: own study)

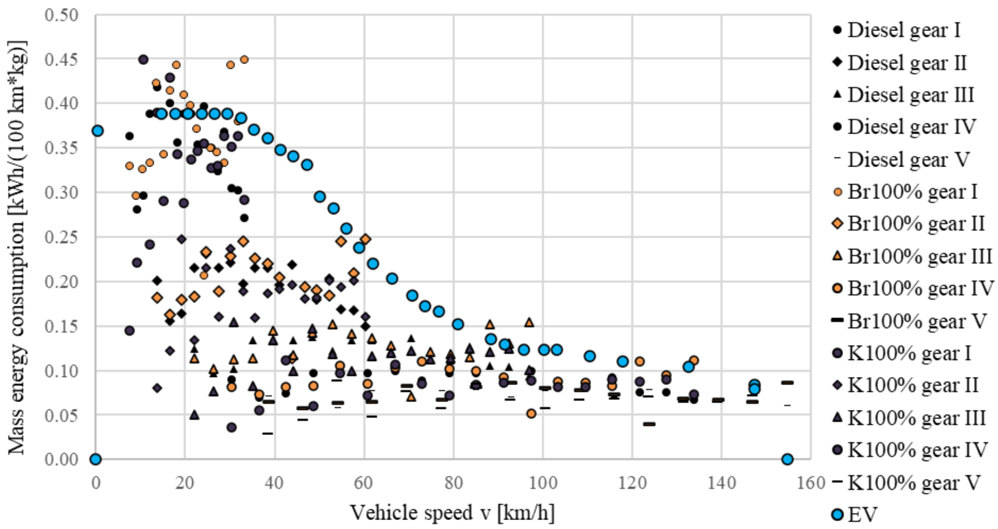

Fig. 9. Mass energy consumption – maximum propulsion parameters (source: own study)

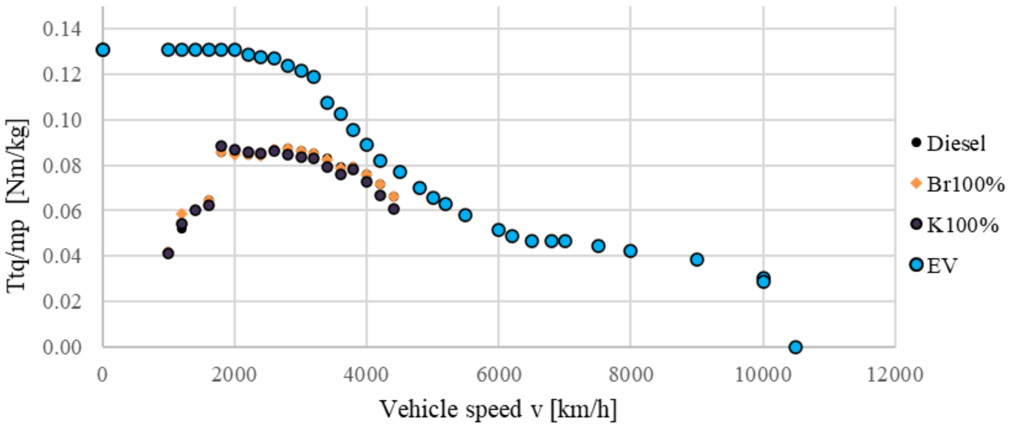

Fig. 10. Ratio of maximum torque to maximum gross vehicle mass (source: own study)

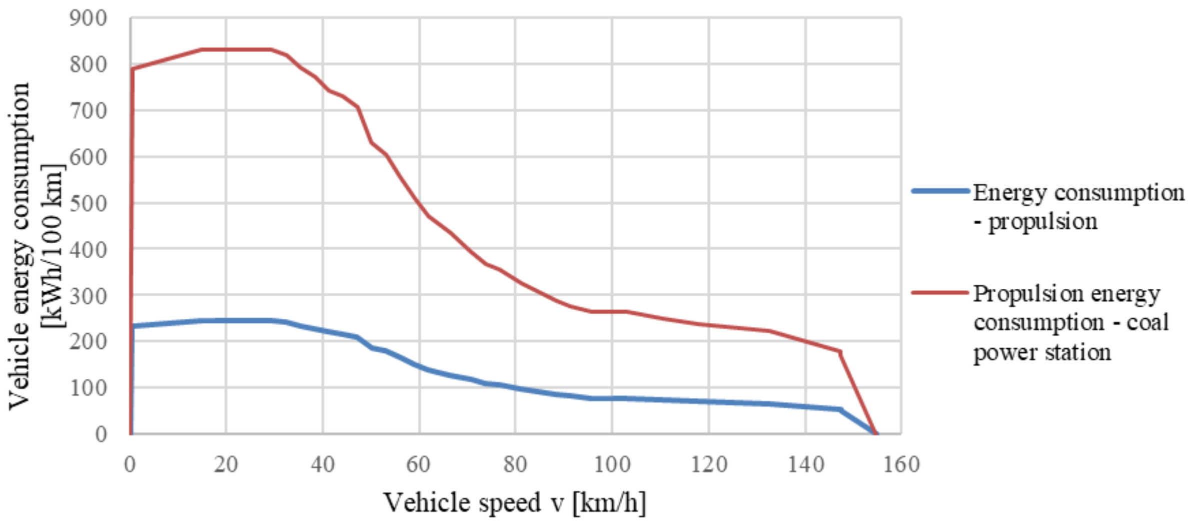

Fig. 11. Electric vehicle maximum energy consumption (source: own study)

Observations of the market reality indicate that the vast majority of passenger car manufacturers are already preparing to withdraw conventionally powered vehicles from their offer. In particular, those based on self-ignition technology. Some will do it before January 2035. At this stage of consideration, however, it should be remembered that changes in the automotive market will not happen overnight. It is a series of processes and certainly, analyzing the age of the Polish car park, conventionally powered vehicles will still be used for a long time [12]. In the authors` opinion, research on alternative fuels, including plant fuels, may be a solution to this problem.

In this paper developed efficiency coefficients for the combustion engine powered by different fuels (Diesel 100%, Bio Diesel 100%, Hemp oil 100%) and the electric propulsion. Modeling was conducted based on the external characteristics of the engines. Based on the measurement results and manufacturer's data, the following were calculated: fuel consumption converted to the electric vehicle, energy consumption, and the cost of driving 100 km for the combustion engine vehicle fueled by different fuels and the electric vehicle, taking into account the energy source from the coal power plant thus indicate:

1. The road energy consumption of the electric vehicle (considering the use of electricity derived from coal combustion) is higher than that of the combustion engine vehicle powered by diesel or biofuels. However, it should be noted that the electric vehicle exhibits a higher mass-specific torque index.
2. Driving the conventional propulsion vehicle is most cost-effective above the second gear (Fig. 8) for all fuel types.
3. The modeling showed that at low speeds, the combustion engine vehicle is more economical than the electric one.
4. As the speed increases, the costs become similar. However, it is essential to highlight that the electric vehicle emits zero emissions during driving. At this stage, it should be noted that, additionally, by utilizing renewable energy sources, the operational costs can be reduced, and the carbon dioxide emission generated by the coal power plant can be decreased [3].

4. Conclusions

Despite the results obtained, which prove better energy efficiency parameters of cars equipped with internal combustion engines, it is important to remember about the continuous development of renewable energy infrastructure. The dynamic development of unconventional power plants will contribute to the increasing energy efficiency of electric vehicles and their lower equivalent carbon dioxide emissions.

The authors support the thesis promoted by other researchers that the future of individual motoring seems to be in favor of electric vehicles. However, the pace of these changes seems to be important both for the demand side, i.e. vehicle users, and for the supply side of manufacturers. It is still an unanswered question whether any alternatives will emerge during this process to extend the life of conventional fossil fuel powered power units. In the opinion of the authors, a certain solution to this problem seems to be synthetic fuels, min. plant-based ones. Although the presented research indicated such an eventuality, it should be remembered that they concerned one drive unit with specific parameters and which certainly does not allow for full conclusions.

To sum up, the presented studies on the comparative assessment of the energy efficiency indicators of a multi-fuel combustion vehicle and an electric vehicle do not fully exhaust the essence of the research issues, but are an attempt to signal the complexity of the presented research problem. Certainly, this issue will require further analyzes and research on min. the service life of the propulsion unit itself and engine accessories in the case of using this category of fuels to power it.

References

1. Brandstätter, G., Kahr, M., Leitner, M. (2017). Determining optimal locations for charging stations of electric car – sharing systems under stochastic demand. Transportation Research Part B 104. 17–35.
2. Challa, R., Kamath, D., Anctil, A. (2022). Well-to-wheel greenhouse gas emissions of electric versus combustion vehicles from 2018 to 2030 in the US. Journal of Environmental Management 308. 114592.
3. Coban, H.H., Lewicki, W., Miśkiewicz, R., Drożdż, W. (2022). The Economic Dimension of Using the Integration of Highway Sound Screens with Solar Panels in the Process of Generating Green Energy. Energies, 16(1), 178.
4. Cui, W., Cui, N., Li, T., Cui, Z., Du, Y., Zhang, C. (2022). An efficient multi-objective hierarchical energy management strategy for plug-in hybrid electric vehicle in connected scenario. Energy 257. 124690.
5. Deza, A., Huang, K., Metel, M.R. (2022). Charging station optimization for balanced electric car sharing. Discrete Applied Mathematics 308. 187–197.
6. Diskin, D., Kuhr, Y., Ben–Hamo, I.Y., Spatari, S., Tartakovsky, L. (2023). Environmental benefits of combined electro – thermos – chemical technology over battery – electric powertrains. Applied Energy 351. 121833.
7. Dong, H., Zhuang, W., Chen, B., Wang, Y., Lu, Y., Liu, Y., Xu, L., Yin, G. (2022). A comparative study of energy-efficient driving strategy for connected internal combustion engine and electric vehicles at signalized intersections. Applied Energy 310. 118524.
8. Falbo, P., Pelizzari, C., Rizzini, G. (2022). Optimal incentive for electric vehicle adoption. Energy Economics 114. 106270.
9. Franzo, S., Nasca, A., Chiesa, V. (2022). Factors affecting cost competitiveness of electric vehicles against alternative powertrains: A total cost of ownership-based assessment in the Italian market. Journal of Cleaner Production 363. 132559.
10. Gołębiewski, W., Lisowski, M. (2018). Theoretical analysis of electric vehicle energy consumption according to different driving cycles. IOP Conf. Series: Materials Science and Engineering 421. 022010.

11. Joshi, A., Sharma, R., Baral, B. (2022). Comparative life cycle assessment of conventional combustion engine vehicle, battery electric vehicle and fuel cell electric vehicle in Nepal. Journal of Cleaner Production 375. 134407.
12. Lewicki, W. (2018). Ekonomiczne bariery rozwoju rynku elektromobilności w Polsce. Autobusy–Technika, Eksploatacja, Systemy Transportowe, 226.12: 1099–1102.
13. Liu, Z., Song, J., Kubal, J., Susarla, N., Knehr, K.W., Islam, E., Nelson, P., Ahmed, S. (2021). Comparing total cost of ownership of battery electric vehicles and internal combustion engine vehicles. Energy Policy 158. 112564.
14. Mastoi, M.Sh., Zhuang, Sh., Munir, H., Haris, M., Hassan, M., Usman, M., Bukhari, S.S.H., Ro, J–S. (2022). An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends. Energy Reports 8. 11504–11529.
15. Nuez, I., Ruiz–Garcia, A., Osorio, J.(2022). A comparative evaluation of CO2 emissions between internal combustion and electric vehicles in small isolated electrical power systems – Case study of the Canary Islands. Journal of Cleaner Production 369. 133252.
16. Pozzi, A., Raimondo, D.M. (2022). Stochastic model predictive control for optimal charging of electric vehicles battery packs. Journal of Energy Storage 55. 105532.
17. Sang–Hee, W., Hyungjoon, J., Seung-Bok, L., Seokhwan, L. (2022). Comparison of total PM emissions emitted from electric and internal combustion engine vehicles: An experimental analysis. Science of The Total Environment 842. 156961.
18. Schloter, L. (2022) Empirical analysis of the depreciation of electric vehicles compared to gasoline vehicles. Transport Policy 126. 268–279.
19. Shafique, M., Azam, A., Rafiq, M., Luo, X. (2022). Life cycle assessment of electric vehicles and internal combustion engine vehicles: A case study of Hong Kong. Research in Transportation Economics 91. 101112.
20. Sinigaglia, T., Martins, M.E.S., Siluk, J.C.M. (2022). Technological forecasting for fuel cell electric vehicle: A comparison with electric vehicles and internal combustion engine vehicles. World Patent Information 71. 102152.
21. Suttakul, P., Wongsapai, W., Fongsamootr, T., Mona, Y., Poolsawat, K. (2022). Total cost of ownership of internal combustion engine and electric vehicles: A real-world comparison for the case of Thailand. Energy Reports 8(10). 545–553.
22. Teng, X., Zhuang, W., Liu, F–P., Chiu, Y–H. (2022). China's energy efficiency improvement on account of the development of wind and solar power: Applying a dynamic non-radial directional distance function. International Journal of Hydrogen Energy 47(84), 35914-35927.
23. Verma, Sh., Dwivedi, G., Verma, P. (2022). Life cycle assessment of electric vehicles in comparison to combustion engine vehicles: A review. Materials today: Proceedings 49(2). 217–222.
24. Yang, L., Yu, B., Yang, B., Chen, H., Malima, G., Yi-Ming, W. (2021). Life cycle environmental assessment of electric and internal combustion engine vehicles in China. Journal of Cleaner Production 285. 124899.
25. Yap, K.H., Chin, H.H., Klemes, J.J. (2022). Solar Energy-Powered Battery Electric Vehicle charging stations: Current development and future prospect review. Renewable and Sustainable Energy Reviews 160. 112862.
26. Zhang, H., Liu, Sh., Lei, N., Fan, Q., Wang, Z. (2022). Leveraging the benefits of ethanol-fueled advanced combustion and supervisory control optimization in hybrid biofuel-electric vehicles. Applied Energy 326. 120033.

Ocena porównawcza wskaźników efektywności energetycznej wielopaliwowego pojazdu spalinowego i pojazdu elektrycznego

Streszczenie: W toczących się obecnie dyskusjach na temat przyszłości motoryzacji ścierają się dwie skrajne opinie: elektromobilność lub pojazdy z konwencjonalnym napędem, ale zasilane paliwami alternatywnymi. W artykule omówiono zagadnienie związane z modelowaniem współczynników efektywności energetycznej silnika spalinowego zasilanego trzema rodzajami paliw (olej napędowy 100%, biopaliwo 100% i olej konopny 100%) oraz napędu elektrycznego zasilanego energią z elektrowni węglowej. Badania analityczne przeprowadzono w oparciu o zewnętrzną charakterystykę pracy silnika. Charakterystykę zewnętrzną silnika spalinowego Fiat Panda 1.3 JTD uzyskano na hamowni Automex. Silnik pracował na trzech paliwach: olej napędowy 100%, biopaliwo 100% (rzepak) oraz biopaliwo 100% (olej konopny). Zewnętrzna charakterystyka silnika elektrycznego została dostarczona przez producenta pojazdu Nissan Leaf. Wyniki obliczeń wykazały, że przy niższych prędkościach silnik spalinowy zużywa mniej energii niż silnik elektryczny. Przy wyższych prędkościach wskaźniki zużycia są na podobnym poziomie. Odbiorcami badań jest zarówno strona popytowa - czyli użytkownicy pojazdów, jak i przyszli producenci oraz instytucje rządowe odpowiedzialne za kształtowanie i rozwój przyszłej mobilności w zakresie transportu indywidualnego.

Słowa kluczowe: jednostka napędowa, paliwa alternatywne, pojazd elektryczny, efektywność energetyczna