Review

Characteristic of Alternative Fuels and Their Impacts on Exhaust Emissions

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Characteristic of Alternative Fuels and Their Impacts on Exhaust Emissions

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Abstract: The use of alternative fuels and electric vehicles is an opportunity to reducing exhaust emissions. We observe that the regulations on exhaust emissions from mobile sources are becoming gradually stricter on the all the world. As is widely known, using alternative fuels instead of conventional fuels helps lower vehicle emissions. The most popular alternative fuels are hydrogen, propane, biobutanol, methanol, dimethyl ether, etc. It is very important that more than a dozen alternative fuels are under development. The article contains a comparison of the operating costs of electric cars and cars with an internal combustion engine. This work shows also the characteristic of new alternative fuels and their impacts on exhaust emissions.

Keywords: alternative fuels; exhaust emissions; power electric vehicles; ethanol; hydrogen

1. Introduction

The costs of electric cars are still very high compared to cars powered by combustion engines. This is due to the costs of battery production. However, forecasts indicate that in a few years this will change and the prices of batteries for electric cars will be cheaper and the batteries themselves will be more efficient [1]. Nevertheless, the number of fully electric cars in Poland in 2023 increased by 52% compared to the previous year. At the end of 2022, there were approximately 26.5 million cars registered in Poland. There are 700 cars per 1,000 inhabitants [2]. The vast majority of them, one might even say the overwhelming majority, are traditional vehicles powered by combustion engines. However, the popularity of electric cars has recently been increasing - they are promoted through discounts and tax breaks. As widely known, electricity is used to power electric vehicles. For instance, the most popular BEV electric cars in Poland in 2023 were: Nissan, Tesla, BMW, Renault, Kia. The high price of electric cars is influenced by production costs, and above all, the production of batteries, which contain expensive and rare elements [2]. Lithium – ion batteries (LIBs) is the main element of electric vehicles (EVs) that has a significant impact on the price of the car [2–4]. Nowadays, LIBs is a main way as energy storage for the electric vehicles [5,6]. At the same time, it should be taken into account that there is a need to recycle these batteries. Their recycling could be also important from an economic viewpoint since cathodes in lithium-ion batteries contain valuable metals such as lithium, cobalt and nickel [7,8]. The environmental impacts of battery production is characterized using life cycle assessment (LCA). Understanding the energy requirements is essential, not only duo to the environmental protection, but also due to assess the implications for the power grids [9].

LCA includes the following stages:

- raw material extraction,
- manufacturing,
- use in 1st life,
- remanufacturing,
- use in 2nd life,
- material recycling and
- disposal [10].

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On the other hand, the cost of using the vehicle is very important. Recently, the prices of oil and electricity have been changing rapidly, making it difficult to compare the costs of driving vehicles. In this aspect, the way we use the car is very essential, i.e., where we drive it and how we drive it. It turns out that electric cars are more effective and useful when driving around the city than cars with an internal combustion engine. Estimated data indicate that the cost of fuel is almost three times higher than electricity for electricians. The most important conclusion are the following [2]:

- The number of electric cars in Europe is systematically growing. Nearly half of electric cars are BEVs, i.e., powered solely by battery electricity.
- The cost of purchasing a fully electric car is much higher than a combustion car.
- Using an electric car when charging from a home socket is much cheaper than refueling a combustion car at gas stations.
- Currently, an electric car is most profitable for people who live in a single-family house and have solar panels.

Electromobility allow to the reduction of CO_2 emissions. It is important taking into account the deceleration of global warming [10]. Certainly, the use of alternative fuels and electric vehicles is an opportunity to reduce exhaust emissions. Among the many available alternative fuels, the most important ones include biodisel, hydrogen, propane, biobutanol, methanol and dimethyl ether. Emerging alternative fuels may reduce emissions, improve vehicle performance, increase energy security.

2. Charakterystic of Biodisel

It's worth mentioning that biomass is one of the most important renewable energysources because it containing substances of plant or animal origin that undergo biodegradation.

They are coming from waste, and byproducts of agricultural and forest production. Biomass can exist:

- in solid form (such as briquettes and pellets),
- in liquid form (like biodiesel and bioethanol),
- gaseous form (including biogas, syngas, and hydrogen) [11–13].

Drożyner et al. [11] mentioned that biomass can be processed using the following methods by:

- thermo-chemical processing to liquid fuels or gasses (carbon oxides methane),
- pyrolysis where hydrogen is the final product.

Biomass can be processed using biotechnological methods, i.e., through fermentation of oily plants biodiesel. Then, it can be obtain fuel, which is used in standard diesel and gas engines [11]. Biodiesel is a renewable fuel that can be produced from vegetable oils, animal fats as well as from recycled cooking grease. This fuel can be used in diesel vehicles [3]. It should be noted that biodiesel and conventional diesel vehicles are a very similar. It can be even said that they are one and the same [1]. Moreover, biodiesel blends can be capable of running many various vehicles, because biodiesel fuel raises the cetane number of the fuel. The cetane number is a measure of the fuel's ability to spontaneously ignite the compressed fuel-air mixture. The cetane number affects the ease of starting a cold engine, exhaust gas emissions and the 'noisy' fuel combustion in the cylinder.

Biodiesel improves also fuel lubricity at blend levels as low as 1% which reduces friction within the moving parts, avoiding additional wear. It is worth noting that, a higher cetane number causes that the engine is easier to start. Additional, a higher cetane number reduces ignition delay. The advantageous feature of biodiesel is that, life cycle analysis (LCA) shows that emissions for biodiesel are 74% lower than those from petroleum diesel [1]. Roschat et al. [14] showed a highly efficient and cost-effective liquid biofuel for diesel engines. It was blended fuel containing waste cooking oil (WCO) biodiesel, distilled Yang-Na oil, and petroleum diesel oil. The prepared liquid biofuels met standards and closely resembled petroleum diesel (i.e., the viscosity of 3.86 cSt, the density value of 876 kg/m^3, the heating values of 9991 kcal/kg) [14]. The performance testing of the blended fuels in a small diesel engine showed the efficiency levels matched with a commercial petroleum diesel oil with

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low emissions of CO_2, CO, HC, and NOx. Therefore, the obtained blended fuel is a future option. It can be recognizes as an alternative energy source in the coming years [14].

3. Ethanol

Ethanol is a renewable fuel made from plants. This obtained alcohol is blended with gasoline. Similar to conventional fuels, the using of ethanol can result in emissions of greenhouse gases (GHGs) and toxic various chemicals. Ethanol/gasoline-capable flexible fuel vehicles (FFVs) must to meet the same emissions standards as conventional vehicles [3]. Bioethanol is defined as ethanol produced from biomass and/or biodegradable adherents for use as fuel [15]. This is an alternative to conventional fuel. One of the main source odf biomas is starchy plants (wheat, barley, rye, corn, oats, and starchy potato crops) or plants rich in sucrose (sugars), i.e., suger beet or sugar cane and sugar sorghum [15]. In order to obtain a review of the future prospects for renewable energy, it can be using the SWOT analysis. Then we can see strengths and weaknesses. Table 1 shows the results of the SWOT analysis for bioethanol [15].

Table 1. the SWOT analysis for bioethanol. Author compilation, based on [15].

Strengths	Weaknesses
Bioethanol can be produced from various raw materials 1.	High raw material costs for crops with high sucrose and starch content, due to th use of large quantities of fertilizers.
The use of bioethanol 2. Reduces air pollution and global climate change caused by the greenhouse effect. 3.	High raw material costs for crops with high sucrose and starch content, due to th use of large quantities of fertilizers.
Bioethanol can be mixed with gasoline in any proportion. 4.	The use of bioethanol on a larger scale can cause the replacement of agricultural crops for human and animal consumption with agricultural crops for biofuels.
Some plant residues resulting from the process of obtaining bioethanol can be reused for heating.	Production of bioethanol is connect with large financial investments and has high costs.
Bioethanol used as a fuel has a higher octane number than gasoline, with an effect on reducing fuel consumption and increasing electricity. In small amounts, ethanol is not toxic to humans and the environment.	Bioethanol used as a fuel cannot be used in a large amount for old cars, in aviation, motor boats, etc.
Ethanol combustion results in low CO2 emissions.	At low temperatures, cars that use pure bioethanol E100 start much harder.
Compared to fossil fuels, bioethanol is biodegradable.	

3. Hydrogen

Hydrogen is recognized as a clean energy, because is a potentially emissions-free alternative fuel that can be produced from renewable resources and can be used as fuel in cell electric vehicles [16]. The hydrogen is most widespread component on the Earth and it can be obtained from a number of sources, both renewable and nonrenewable [16]. It is important that we can produce the hydrogen by various processes, such as:

- electrolysis of water,
- the reforming of hydrocarbons,
- pyrolysis,
- co-pyrolysis [17].

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Hydrogen can be produced from primary energy sources and hydrogen-rich compounds (i.e., water, methane, etc.) [16]. The new technologies are investigated in the range of production of hydrogen production from waste materials and biomass [16,18,19]. Now, hydrogen is produced mainly by steam reforming of natural gas and from refinery streams. Each production process requires thermal or electrical energy [20].

4. Emerging Alternative Fuels

Emerging alternative fuels influence on the reduction of greenhouse gas emissions and increase energy security. Some of these emerging fuels: biobutanol, dimethyl ether, methanol and renewable gasoline. Araújo dos Santos et al. [21] reported that biobutanol as biofuel has gasoline-likeproperties but energy efficiency of biobutanol is 25% higher than ethanol. Biobutanol is defined as the butanol produced from the natural or organic or biodegradable or renewable biomass [21] At present, biobutanol is considered the gasoline of the future due to good physical properties such as high boiling point, low cost of production and safety of application.

On the other hand, dimethyl ether (DME) can be recognized as environmental friendly fuel which and can be used as a clean high-efficiency compression ignition fuel [22]. This is a liquefied gas with properties similar to of LPG. DME is classified as synthetic fuel, which can be produce with using the biomass or waste products. Moreover, emission of NOx from blends of DME and diesel are much lower than those of diesel [22]. Therefore, DME is recognized as a fuel ecological.

Next alternative fuel is methanol. This alcohol can be produced from coal, CO_2, natural gas, biomass. This substances has many advantages such as low production costs, high octane number, low combustion temperature, etc. [23]. Moreover, methanol can be used directly and with blending with conventional fuel [24]. In turn, the next alternative fuel is renewable gasoline. It is worth to mention, Renewable gasoline is a fuel produced from biomass by means biological, thermal, and chemical processes. Renewable gasoline can be used in conventional engines.

5. Summary and Outlook

Without a doubt, buying a new electric car is more expensive than a combustion car. An electric car from the same segment as a combustion car can cost up to twice as much. Nevertheless, the popularity of electric cars is growing and this trend will certainly continue in the coming years. Currently, an electric car is available to people who have a single-family house with photovoltaic panels. Additionally, they will use electric cars to travel near their home. In such a situation, the cost of maintaining it will be lower and its purchase makes sense. It is expected that the cost of batteries will most likely decrease in the near future. There are plans to build many battery factories for electric cars in Europe. Therefore, we can conclude that electric cars are the future of the automotive industry. We will find out soon, although hydrogen cell technology may change everything again. On the other hand, the application of biofuels can stimulate the production of raw materials for obtaining bioethanol which is considered a renewable energy sources and has many advantages such as this fuel reduces dependence on fossil fuels, which can be replaced with fuels from renewable plant sources [15]. The second the gasoline of the future is biobutanol due to a numerous advantages such as a low cost of production and safety during application [21].

To sum up, it is worth noting that currently alternative fuels include: methanol, ethanol, hydrogen, compressed natural gas, liquefied petroleum gas (LPG), vegetable oils and fatty acid methyl esters, and dimethyl ether (DME) and blends of these with gasoline or diesel [22] and each of them has similar properties usually and a number of advantages such as high efficiency and environmental friendliness.

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References

1. Giza, K.; Pospiech, B.; Gęga, J. Future technologies for recycling spent lithium-ion batteries(LiBs) from electric vehicles—overview of latest trends and challenges, *Energies,* **2023,** 16, 5777. DOI: https://doi.org/10.3390/en16155777.
2. Internet: https://mubi.pl/poradniki/samochod-elektryczny-czy-spalinowy/ (23.05.2024).
3. Internet: https://afdc.energy.gov/fuels (3.05.2024).
4. Gonzales-Calienes, G.; Kannangara, M.; Bensebaa, F. Economic and environmental viability of lithium-ion battery recycling — case study in two Canadian regions with different energy mixes, *Batteries*, **2023**, 9, 375. DOI: https://doi.org/10.3390/batteries9070375.
5. Chagnes, A.; Pospiech B. A brief review on hydrometallurgical technologies for recycling spent lithium-ion batteries, *Journal of Chemical Technology and Biotechnology,* **2013,** 88, 1191–1199. DOI: 10.1002/jctb.4053.
6. Yao, Y.; Zhu, M.; Zhao, Z., Tong, B.; Fan, Y., Hua, Z. Hydrometallurgical processes for recycling spent lithium-ion batteries: A critical review, *ACS Sustainable Chem. Eng.* **2018,** *6*, 13611-13627. DOI:10.1021/acssuschemeng.8b03545.
7. Sun, X.; Luo, X.; Zhang, Z.;Meng, F.; Yang, J. Life cycle assessment of lithium nickel, cobalt, manganese oxide (NCM) batteries for electric passenger vehicles, *J. Clean. Prod*. **2020**, 273, 123006. DOI: 10.1016/j.jclepro.2020.123006.
8. Mohr, M.; Peters, J.F.; Baumann, M.; Weil, M.; Toward a cell-chemistry specific life cycle assessment of lithium-ion battery recycling processes, *J. Ind. Ecol.* **2020**, 24, 1310-1322. DOI: 10.1111/jiec.13021.
9. Kurland, S.D. Energy use for GWh-scale lithium-ion battery production, *Environ. Res. Commun.* **2020**, 2, 012001. DOI: https://doi.org/10.1088/2515-7620/ab5e1e.
10. Wewer, A.; Bilge, P.; Dietrich, F. Advances of 2nd life applications for lithium ion batteries from electric vehicles based on energy demand, *Sustainability* **2021**, 13, 5726. DOI: https://doi.org/10.3390/su13105726.
11. Drozyner, P.; Rejmer, W.; Starowicz, P.; Klasa, A.; Skibniewska, K.A. Biomass as a renewable source of energy, *Tech. Sci.* **2013**, 16 (3), 211–220.
12. Dufresne, A.; Nanocellulose: a new ageless bionanomaterial, *Mater. Today* 2013, 16 (6) 220–227. DOI: https://doi.org/10.1016/j.mattod.2013.06.004.
13. Afzal, a.; Soudagar, M.E.M.; Belhocine, A.; Kareemullah, M.; Hossain, N.; Alshahrani, S.; Saleel,A.C.; Subbiah, R.; Qureshi, F.; Mujtaba, M.A. Thermal performance of compression ignition engine using high content biodiesels: a comparative study with diesel fuel, *Sustainability* **2021**, 13 (7688) 1–20. DOI: https://doi.org/10.3390/su13147688.
14. Roschat, W.; Phewphong, s.; Inthachai, S.; Donpamee, K.; Phudeetip, N.; Leelatam, t.; Moonsine, P.; Katekaew, S.; Namwongsa, K.; Yoosuk, B.; Janetaisong, P.; Promarak, V. A highly efficient and cost-effective liquid biofuel for agricultural diesel engines from ternary blending of distilled Yang-Na (*Dipterocarpus alatus*) oil, waste cooking oil biodiesel, and petroleum diesel oil, *Renew. Energy Focus* **2024**, 48, 100540, DOI: https://doi.org/10.1016/j.ref.2024.100540
15. Berevoianu, R.L. Bioethanol – renewable energy source, In: *Agrarian Economy and Rural Development – Realities and Perspectives for Romania. International Symposium.* 12th Edition, The Research Institute for Agricultural Economy and Rural Development (ICEADR), Bucharest, **2021**, 129-134.
16. Hassan, Q.; Algburi, S.; Sameen, A.Z.; Salman, H.M.; Khudhair Al-Jiboory A. A review of green hydrogen production by renewable resources, *Energy Harvesting and Systems* **2024**; 11(1): 20220127. DOI: *https://doi.org/10.1515/ehs-2022-0127.*
17. Bicakova, O.; Straka, P. Production of hydrogen from renewable resources and its effectiveness, *Int. J. Hydrogen Energy* **2012**, 37, 11563-11578. DOI: http://dx.doi.org/10.1016/j.ijhydene.2012.05.047.
18. Jaszczur, M.; Rosen, M.A.; Śliwa, T.; Dudek, M.; Pieńkowski, L., Hydrogen production using high temperature nuclear reactors: efficiency analysis of a combined cycle, *Int. J. Hydrog*. Energy. **2016**, 41 (19) 7861–7871. DOI: 10.1016/j.ijhydene.2015.11.190.
19. Ceran, B., Q. Hassan, M. Jaszczur, Sroka, K. An Analysis of Hybrid Power Generation Systems for a Residential Load. *In E3S Web of Conferences* **2017**, Vol. 14, 01020. EDP Sciences.
20. Jaszczur, M.; Rosen, M.A.; Sliwa, T.; Dudek, M.; Pieńkowski, L. Hydrogen production using high temperature nuclear reactors: Efficiency analysis of a combined cycle. *6th International Conference on Hydrogen Production*, **2015**, UOIT—Oshawa, Ontario, Canada.
21. Araújo dos Santos, A.C.; Sobral Loureiro, A.C.; Barbosa de Souza, A.L.; Barbosa da Silva,N.D.; Mirre, R.C.; Pessoa, F.L.P. Biobutanol as an alternative and sustainable fuel: an integrative review, VII International

 doi:10.20944/preprints202406.1395.v1

Symposium On Innovation And Technology – *One planet, one ocean and one health SINTEC* **2021.** https://pdf.blucher.com.br/engineeringproceedings/siintec2021/208672.pdf

22. Makoś, P.; Słupek, E.; Sobczak, J.; Zabrocki, D.; Hupka, J.; Rogal, R. Dimethyl ether (DME) as potential environmental friendly fuel, E3S Web of Conferences 116, 00048, **2019**, ASEE19, https://doi.org/10.1051/e3sconf/201911600048.
23. Bansal, P.; Meena, R. Methanol as an Alternative Fuel in Internal Combustion Engine: Scope, Production, and Limitations, *Chapter in book: Methanol*, **2021**, DOI: 10.1007/978-981-16-1224-4_2.
24. Semelsberger, T.A. Borup, R.L. Greene,H.L. Dimethyl ether (DME) as an alternative fuel, *J. Power Sources*, **2006**,156, 497-511