ALTERNATIVE FUELS IN URBAN TRANSPORT

[1]Marek ŠAFRÁNEK, [2]Iveta VOZŇÁKOVÁ

VSB - Technical University of Ostrava, Ostrava, Czech Republic, EU
[1]marek.safranek.st@vsb.cz, [2]iveta.voznakova@vsb.cz

Abstract

Due to an ever-increasing population, urban transport is becoming one of the main factors negatively impacting the quality of the environment. Road transport plays a fundamental role in contributing to the creation of greenhouse gas emissions and air pollution to the greatest possible extent. At the same time, noise and dependence on oil resources are also increasing.

Worldwide, the inventories of conventional fuels such as oil, natural gas and coal are decreasing, and their rapid depletion is realistic threat. Therefore, more attention must be paid to alternative means of running our means of transport. One way to reduce the environmental burden while simultaneously making transport more environmentally friendly, is the use of alternative fuels or alternative modes of transport.

Subsidizing alternative fuels is one of the possible solutions for creating sustainable transport and leading not only to economic savings, but also to conservation of the environment.

At present, the use of alternative fuels is not very widespread in the Czech Republic, but some cities are already using alternative fuel vehicles and testing the economic aspects of these transport variants.

The aim of the article is to analyze the use of alternative fuels in urban transport and to recommend the best alternatives for urban transport.

Keywords: Alternative fuels, economy, ecology, urban transport

1. INTRODUCTION

The article aims to carry out economic and environmental analyses on the possible use of alternative fuels for urban transport in the Moravian-Silesian Region.

The idea of sustainable development is based on meeting the needs of today's generations while avoiding the risk of failing to be able to meet these needs for future generations. The comprehensive approach that sustainable development requires brings economic, social and environmental aspects into synergy. [1]

The UN's Sustainable Development Agenda 2030, adopted by world leaders, sets 17 sustainable development goals. One of these goals is to address the problems associated with urbanization, part of which is an increasing share of the population living in cities. Cities must provide employment, suitable housing and basic services without burdening land and resources. Additionally, emphasis must be placed on expanding infrastructure and reducing air pollution, safe removal and handling of solid waste in a way that correlates with prosperity and the continuous growth of cities. [2]

The way to meet the main ideas of sustainable transport development is based on the use of suitable alternative fuels. The introduction of these alternative fuels will lead to a more cost-effective solution that will be in line with reducing the environmental burden within the context of operating transport fleets of municipal transport companies.

Most cars today use gasoline or diesel engines to propel them. These fuels are made from petroleum and their combustion generates a wide variety of pollutants. One of the possible ways to achieve environmentally-friendly transport and a lesser environmental burden is to use alternative fuels. [3]

Applied alternative fuels in transport without direct ties to crude oil [4]:

- Gas fuels - CNG (Compressed Natural Gas), Hydrogen (H),
- Liquid fuels:
  - I. generation biofuels - clean biofuels (FAME, vegetable oils),
  - II. generation biofuels - in the near future, producing fuel from non-food biomass is being considered (for example, cellulose from wood pulp or other plants),
- Electricity - electric vehicles and hybrid motor vehicles.

Figure 1 shows the individual alternative fuels and standard fuels from the perspective of local burden on the air (vertical axis) and the global burden on the climate system (horizontal axis). [5]

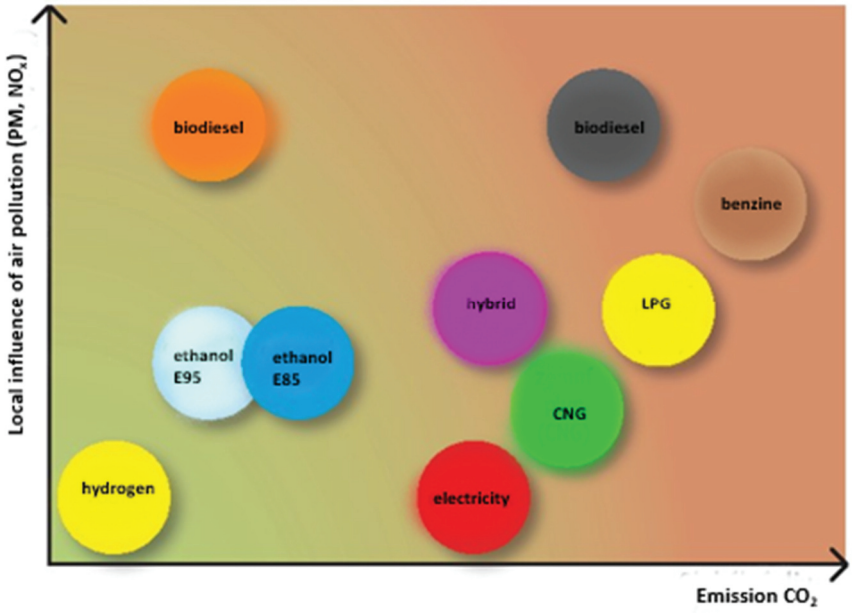

Figure 1 Alternative and standard fuels from the perspective of their burden on air quality and global burden on the climate system [5]

2. ANALYSIS OF ALTERNATIVE FUELS

Regulation and across-the-board bans on operation of older diesel cars in some cities boost the case for the use of alternative fuels, which are backed by both state authorities and the European Union. Every transport company must consider several factors when deciding on the use of alternative fuels. [6]

One of the main factors is the composition and number of vehicles in the fleet, their amortization and possible investments in purchasing new vehicles. Another factor is the daily action radius of individual vehicles as well as the availability of alternative fuels.

The differences in technical and design solutions of alternative propulsion vehicles are so great that it is almost impossible to make their overall comparisons and to say unequivocally which of the alternative engines is best. It will be more appropriate to carry out economic and environmental comparisons of the factors providing the main reasons for the creation and introduction of these new engines in the real world.

2.1 Economic Comparisons

The economy plays a key role in the proliferation of alternative engines in urban transport. In particular, return on investment, vehicle operating costs, economy and availability of filling stations.

The price of oil, which is a strategic raw material and a determinant for other fuel and energy prices, can rise and fall depending on a large number of factors. From a short-term perspective, the price of oil can be influenced primarily by a supply that is very inflexible and unable to respond quickly to higher demand, but also by the US dollar exchange rate, unfavorable weather conditions and seasonal fluctuations (summer holidays). Another possible factor is unpredictable war conflicts and political instability in the countries (most commonly in the Middle East), where this raw material is extracted. [7]

Table 1 shows the development of the average prices of CNG, gasoline and diesel in the years 2010 - 2017. [8] From the perspective of price, CNG appears to be an advantageous alternative fuel, whereas 1 liter of gas or diesel corresponds to consumption of 1 m^3 CNG, because the price of natural gas in the individual years is up to one half the price.

Table 1 Yearly Average Prices of CNG - Gasoline - Diesel in the Czech Republic [8]

	2010	2011	2012	2013	2014	2015	2016	2017
CNG (CZK/m³)	16.46	16.7	16.95	17.19	18.1	18.39	17.69	17.25
Gasoline (CZL/l)	31.74	31.57	33.65	36.21	36.5	31.42	28.75	30.39
Diesel (CZK/l)	30.57	34.25	36.53	35.91	36.15	30.75	27.08	29.57

Another fact that impacts the return on future investments is the acquisition cost of a vehicle, or, the difference between the price for a vehicle using a classic motor and the price of a vehicle using an alternative motor design.

2.2. Environmental Comparisons

Environmental reasons are one of the main arguments supporting the idea of using alternative fuels in urban transport. Gas and diesel fuels, to a large extent, contribute to environmental pollution, and substances that are part of exhaust gases can cause a host of serious illnesses. [9]

The impact of alternative fuels on the environment will be clearly lower or completely zero, for example, with fuel cells. Inside the fuel cells, hydrogen and atmospheric oxygen are stored in the pressure tank. This reaction produces energy that is transformed into electric current and water vapor. Vehicles with exhaust fuel cells do not discharge any harmful substances. This solution would therefore make a significant contribution to reducing CO2 emissions while increasing the energy independence of public transport. Hydrogen production technology using natural gas generates half the CO2 emissions compared to conventional gasoline production and combustion. If hydrogen was produced through water electrolysis, this would result in lower emissions of this greenhouse gas. When renewable energy is used, emissions may theoretically approach zero. [5,10,11,]

Electric cars may seem to be an appropriate solution, because their advantage is entirely clean operation, but we also need to take into consideration the large amount of energy required to extract minerals for the production of photovoltaic cells. The question is also the subsequent method of eco-friendly disposal of these cells. An environmental problem in the Czech Republic may also be the fact that electricity is produced largely in thermal power stations that are detrimental to the environment even if they do not pollute the atmosphere in the given city. [12]

Life Cycle Assessment (LCA) is a tool that enables us to identify and quantify the environmental impacts of a product in terms of its entire lifecycle; that is, resource generation, fuel production, distribution to the consumer and final consumption of the vehicle. [13]

LCA analysis is further separated into several additional analyses, where to find the answer to the question of the impact of fuels on the environment, the most appropriate tool is called Well-to-Wheels (WTW), which is most commonly used to assess the effects of fuels depending on vehicle types and engines. This analysis is

further divided into two parts. The first one is WTT (Well-to-Tank) - assessing the energy intensity and production of greenhouse gas emissions during the various phases of fuel production. The second is the Tank-to-Wheels (TTW) - assessing the energy intensity and greenhouse gas emissions of burning the fuel in the vehicle. [14]

When evaluating the most suitable fuel in terms of environmental impact, it is not possible to focus only on the final production of pollutants arising from fuel combustion in a vehicle, but it is necessary to consider the entire fuel life cycle, which includes the initial phase of fuel production, through its actual production and final combustion in the vehicle.

According to the WTW analysis, we can state that almost all alternative fuels, except for CNG and LPG, the initial stages of production preceding their final consumption are very demanding. Based on the WTW analysis, greenhouse gas emissions from the use of CNG as a fuel in vehicles relative to usable energy content are generally lower than the corresponding emissions for petrol and diesel. The riskiest factor in this type of alternative fuel is the distance of the deposits and the possibility of limiting / interrupting gas supply, where all market participants must comply with the limitation of gas consumption. [15,16]

Generally speaking, CNG vehicles produce significantly less pollutants than conventional petrol or diesel vehicles. From the environmental point of view, this involves, above all, a significant reduction in Particulate Matters (PM), smoke, as well as a reduction in other NOx emissions and carbon monoxide (CO) emissions. Another advantage is noise reduction, both within the vehicle and outside the vehicle, because natural gas engines are quieter than petrol or diesel engines. [17]

Based on the assessment, it can be said that CNG is one of the possible, suitable alternative fuel variants.

3. CONCLUSION - CNG AND HYDROGEN AS THE MOST SUITABLE FUELS

In the near future, we can expect a wide range of alternative fuels to be combined with a variety of production technologies. The use of synthetic fuels or hydrogen is effective in reducing GHG emissions in the end-use phase only if it is possible to capture and store the CO2 generated in the production process. Synthetic motor fuels and hydrogen have a higher potential for replacing fossil fuels than conventional biofuels, bioethanol and biodiesel. The development of large-scale production of these fuels is currently hindered in particular by the high cost and complexity of production. [18]

CNG - compressed natural gas (98 % methane) appears to be the most suitable fuel because, from the ecological point of view, CNG vehicles do not produce particulate matter (PM10), their emissions of nitrogen, sulfur and carbon oxides are significantly lower, and contamination of soil, roads and garages cannot occur. Significant reduction of exhaust emissions leads to air protection. The economic view is that in the case of natural gas consumption, there are significant savings in the operation of vehicles, by up to 50 % when converted to cost per 1 km. Another advantage is sufficient supply of natural gas deposits as well as the possibility of biogas production. From a safety point of view, CNG is the safest fuel, which is stored in thick-walled pressurized gas bottles with a protection valve against gas leakage, there is no contamination of the soil and its ignition temperature is many times higher than for other fuels.

From an environmental perspective, Hydrogen (H) - is among the very promising alternative fuels. During combustion, only water vapor or water is generated, potentially along with small amounts of nitrogen oxides. Hydrogen is an almost inexhaustible source, but its acquisition is energy-intensive and hydrogen technology would not solve the problem of resource exhaustion. The solution is to use energy from the core, renewable sources, or to develop new technologies to produce hydrogen. [19,20]

The barrier to greater proliferation of CNG and hydrogen in transport means is the filling station infrastructure compared to a dense network of petrol stations for vehicles using conventional fossil fuels to drive. Another possible obstacle is significantly higher acquisition costs for CNG or hydrogen vehicles. In the future, however,

placement of greater emphasis on protecting the health of the population may be anticipated, with which the negative impact of transport pollution is associated, and therefore these alternative fuels will be preferred despite the abovementioned obstacles.

Today, big cities are striving to make urban transport as environmentally friendly as possible, in particular by changing the fleet of transport companies, integrating the transport system, and increasing the comfort and safety of passengers.

A significant contribution to improving the environment in Ostrava and, at the same time, reducing the cost of operating public transport buses is to invest in low-floor CNG-compressed natural gas buses that will replace diesel buses by 2020. The city has also built terminals to allow the direct connection of suburban public transport to the city transport system, thereby increasing its attractiveness and efficiency. At the same time, this results in a decrease of the impact of transport on the environment. [21]

A possible comparison can be made with the City of Birmingham, located in the UK, which aims to reduce the level of NO2 on key bus routes by investing in the acquisition of 20 new hydrogen-powered vehicles. [22]

ACKNOWLEDGEMENTS

The work was supported by the specific university research of the Ministry of Education, Youth and Sports of the Czech Republic No. SP2018/109

REFERENCES

[1] The European Unions Approach to Sustainable Development [online]. [cit. 2018-10-27]. Available at: https://ec.europa.eu/info/strategy/international-strategies/global-topics/sustainable-development-goals/eu-approach-sustainable-development_cs

[2] OSN: *Sustainable Development Ggoals* [online]. [cit. 2018-10-27]. Available at: https://www.un.org/sustainabledevelopment/cities/

[3] RAMADHAS, A. S. *Alternative Fuels for Transportation*. Florida: CRC Press Taylor & Francis Group, 2011. p. 6 - 19

[4] Ministry of the Environment - Alternative Fuels in Transport [online]. [cit. 2018-10-30]. Available at: https://www.mzp.cz/cz/alternativni_paliva_doprave

[5] Hydrogen Fuel Cells [online]. [cit. 2018-10-30]. Available at: https://www.eve.eus/La-energia/Infografias/Pilas-de-combustible-de-hidrogeno/Pilas-de-combustible-de-hidregeno.aspx

[6] Mobility and Transport [online]. [cit. 2018-10-30]. Available at: https://ec.europa.eu/transport/home_en

[7] Prices of Oil on World Markets [online]. [cit. 2018-10-31]. Available at: http://optionone.cz/co-ovlivnuje-cenu-ropy/

[8] Price Development of CNG and Other Fuels [online]. [cit. 2018-10-31]. Available at: http://www.cng4you.cz/kolik-to-stoji/vyvoj-cen-cng-v-cr-a-dalsich-paliv.html

[9] Impact of the Car [online]. [cit. 2018-11-01]. Available at: http://autopust.cz/dopady-automobilismu/

[10] Hydrogen powered car [online]. [cit. 2018-10-30]. Available at: https://www.honda.com/search?s=hydrogen&c=HondaCars

[11] LENS, P. N. *Biofuels For Fuel Cells*. London: IWA Publishing, 2005. p. 35 - 72.

[12] Elecric Drives [online]. [cit. 2018-11-01]. Available at: http://www.vitejtenazemi.cz/cenia/index.php?p=elektricke_pohony&site=doprava

[13] HAUSCHILD, M., ROSENBAUM, R. K., OLSEN, S. *Life Cycle Assessment*. Springer International Publishing, 2018. p. 9-16.

[14] HUSS, A., MAAS, H., HASS, H. *Tank-To-Wheels Report Version 4.0.* [cit. 2018-11-02]. Luxembourg, 2013.

[15] LARIVÉ, J-f, BEZIAT. J-c. *Well to Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context*. [cit. 2018-11-02]. Luxembourg, 2011. Available at: https://iet.jrc.ec.europa.eu/about-jec/sites/iet.jrc.ec.europa.eu.about-jec/files/documents/wtw3_wtw_report_eurformat.pdf

[16] My energy - The Gas Industry [online]. [cit. 2018-11-02]. Available at: http://www.mojeenergie.cz/cz/plynarenstvi-dodavka-energie

[17] CNG fuel and ecology [online]. [cit. 2018-11-02]. Available at: https://www.cng.cz/uzitecne-informace/ekologie

[18] ŠEBOR, G., POSPÍŠIL, M., MAXA, D., ŽÁKOVEC, J. *Alternative Gaseous Fuels in Transport*. VŠCHT in Prague. Chemical Sheets 100, p. 25 - 29, 2006. Available at: https://docplayer.cz/6038773-Alternativni-plynna-paliva-v-doprave-milan-pospisil-a-gustav-sebor-a-daniel-maxa-a-a-jan-zakovec-b-lpg.html

[19] Hydrogen in Transport [online]. [cit. 2018-11-02]. Available at: http://vitejtenazemi.cz/cenia/index.php?p=vodik&site=doprava

[20] EVERS, A. *The Hydrogen Society*. Berlin: Adame Advertising and media GmbH, 2010. p. 90 - 111.

[21] Healthy Ostrava [online]. [cit. 2018-11-05]. Available at: http://zdravaova.cz/category/udrzitelna-mestska-doprava/podkategorie-udrzitelna-mestska-doprava/verejna-doprava/

[22] Hydrogen Buses to be Given Green Light [online]. [cit. 2018-11-05]. Available at: https://www.birmingham.gov.uk/news/article/178/cleaner_hydrogen_buses_to_be_given_green_light