

## Use of certain alternative fuels in road transport in Poland

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**Abstract.** The development of biomethane and hydrogen technology in the road transport in the EU countries is recommended, among the others, in the Directive of the European Parliament and of the Council 2014/94/EU of 22 October 2014. Under the provisions of the said Directive, it is recommended to EU countries to use biomethane and progressively ensure accessibility to hydrogen cars on their territories, and above all to ensure the possibility of driving hydrogen vehicles between the member States.

The territorial accessibility for biomethane vehicles is determined by the availability of biomethane refuelling infrastructure in the first place in cities and then on the road network distances recommended in this directive. The territorial accessibility for hydrogen vehicles is determined by the availability of hydrogen refuelling infrastructure, in the first place along the TEN-T network. The article presents the possibilities of using these alternative fuels in Poland, presenting some of the results of research and analysis in this area.

### 1. Introduction

Modern alternative fuels such as biomethane and hydrogen are finding increasing use in road transport. The first action in this area in Poland is very important taking into account the existing air pollution. Biomethane is currently used mainly in urban transport. Hydrogen now allows the movement of cars with fuel cells for a distance of about 700 km. A very important activity is the construction in this field of the relevant infrastructure, which in Poland is lacking. Below are some aspects of the application of both alternative fuels.

### 2. Biomethane consumption

The road transport in Europe almost fully depends on fossil fuel. Diversification of the road transport fuels will be a key attribute for road transport in the coming years. Biogas is one of alternative renewable fuels. At present in Poland biogas is used for generating electricity and heat, but it built the first biomethane refuelling station (Figure 1). The installation is located in a landfill in Niepołomice. It is a city in the southern Polish, near Krakow, the former capital of Poland.





**Figure 1.** The view of the mobile installation for biogas upgrading, compression, storage, and distribution of biomethane in Poland.

In some countries (for example in Sweden), upgraded biogas to natural gas quality (biomethane) is used as a vehicle fuel and the European Project Baltic Biogas Bus (BBB) contributed to this. This project stimulated the use of biogas (biomethane) as fuel of city buses aiming to reduce environmental impact.

The use of biomethane to power engines of buses (vehicles) also gives significant benefits in the form of a particulate matter numbers, emissions of aldehydes, PAH (polycyclic aromatic hydrocarbons) and direct  $\text{NO}_2$  emissions. Motor vehicles powered by methane engines run quieter than vehicles powered by gasoline or diesel [1]. The above mentioned advantages of vehicles with engines supplied with methane are confirmed by the tests shown below.

The tests on the emissions of pollutants and the consumption of fuel were conducted on buses: bus I – fuelled with CNG – the tests conducted, using the bus Jelcz M121 M/4, equipped with a SI combustion engine, meeting the Euro III emission standard, with the cylinder capacity of  $11967 \text{ cm}^3$  and maximum power 180 kW. Bus II was equipped with a CI combustion engine – fuelled with diesel (bus - Jelcz M121 MB, engine's cylinder capacity  $11970 \text{ cm}^3$ , maximum power 180 kW). The tests were performed on the same driving distance and comparable road conditions (tests were performed simultaneously on two buses, which were driven directly one after the other). The Figure 2 shows tested buses. The Figure 3 shows the testing device type PEMS for the measurement of exhaust emission. Two such devices were used, one for each bus.

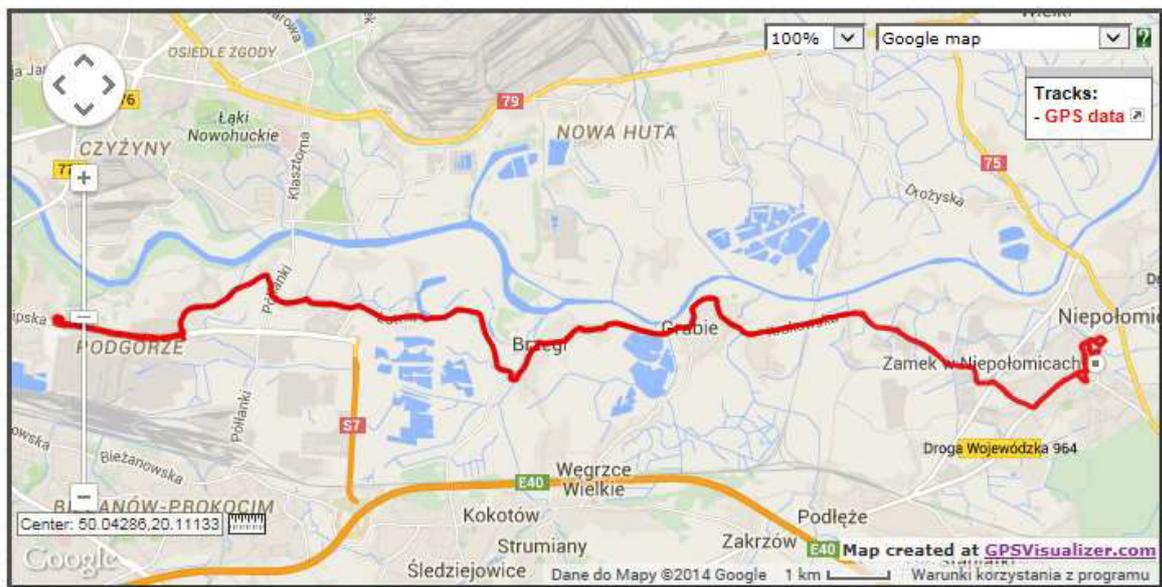


**Figure 2.** View of tested buses (bus with engine powered by CNG– left, bus with engine powered by diesel – right).

Route (between Niepołomice and Krakow outward and return) characteristics: (i) distance: 41 km, (ii) change in altitude: minimum 190 m, maximum 202 m, (iii) maximum slope: 3.1%, minimum slope: -3.1% (iv) average positive slope: 0.2%, average negative slope: -0.2% (Figure 4).

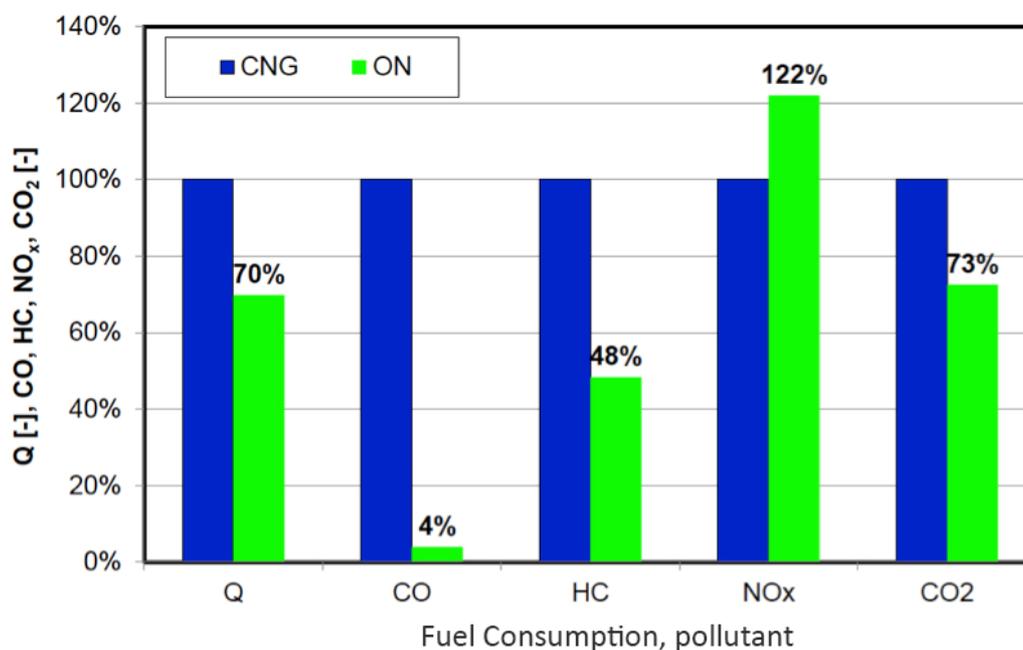


**Figure 3.** View of the testing device type PEMS.



**Figure 4.** Characteristics of the test route.

The Figure 5 shows comparison of the mileage consumption of fuel and the road emission of pollutants, obtained during testing.



**Figure 5.** Comparison of the mileage consumption of fuel and the road emission of pollutants, obtained during testing.

The conducted tests indicate, that the road emission of nitric oxides ( $\text{NO}_x$ ) of the bus with an engine refuelled with CNG is lower than the road emission of  $\text{NO}_x$  of the bus with the compression ignition engine (CI). Considering the fact, that excess emission of nitric oxides from CI engines is a serious problem, especially in urban traffic, the benefit of utilizing buses with engines refuelled with CNG is obvious here.

The emission of particulate matter, the second most significant component of the exhaust gases in the CI engines (in the presented tests it was not measured due to lack of such possibility, using the PEMS type measuring devices), in the case of using engines refuelled with CNG is lower than the one occurring in the CI engines (without utilizing expensive purifying systems).

In the case of emission of the carbon dioxide ( $\text{CO}_2$ ) by the bus with the engine fuelled with CNG, therefore with the spark-ignition engine (SI), it is greater than the one occurring in the bus with the engine fuelled with diesel. When using biomethane, though, which is nearly entirely renewable, during life cycle (from well to wheel), the bus with the engine fuelled with biomethane will be a better solution than utilizing a bus with the CI engine for the reason of the  $\text{CO}_2$  emission, which is lower during the life cycle of the CNG engine, comparing to the CI engine.

There is an advantage in the bus with the CI engine over the one with the SI engine, fuelled with CNG (biomethane) in relation to the emission of carbon monoxide (CO), and in the case of the emission of the hydrocarbons (HC). The measurements, performed with the PEMS devices, allowed to define their total value (non-methane hydrocarbons and methane), and indicate the higher values for the bus with the SI engine. It needs to be emphasized, that methane is not toxic, although it is a greenhouse gas. The utilization of the more efficient catalytic systems will allow the reduction of the road emission of CO and HC.

## 2. Hydrogen consumption

The development of hydrogen technology in the road transport brings a lot of hope for the operation of zero emission vehicles (Fuel Cell Electric Vehicle (FCEV)).

This technology is supported primarily by [2]:

- no pollutants emissions,
- reduction in noise emissions,
- reduction in fossil fuel imports,

- increasing the export and services potential and new jobs.

However, there are some disadvantages of using this technology e.g. among the others [2]:

- difficult shift from paradigm - fossil fuels to the paradigm - renewable fuels (hydrogen),
- investments related to the construction of hydrogen refuelling stations network,
- limited, in most countries of the world, political support to hydrogen technology with the envisaged foreground development of the road transport methanization and focusing on EVs,
- lack of up-to-date knowledge on modern hydrogen technology.

The pre-commercial phase (2020 – 2030), involves construction in Europe, of about 200 - 300 hydrogen refuelling stations located primarily in large urban agglomerations and along the TEN-T network. It is to handle about 5,000 passenger cars and 500 buses equipped with fuel cells. The early commercial phase of hydrogen propulsion technology should appear in Europe around 2020 and ensure the creation of hydrogen infrastructure including approximately 2,000 hydrogen filling stations / min 1000 / along the strategic transport routes, serving 500 thousand passenger cars and 1,000 buses equipped with fuel cells. The commercial development phase (2040 – 2050) of the hydrogen power technology should begin at the end of the third decade of the twenty-first century. These forecasts are burdened however with a relatively high degree of uncertainty, particularly with regard to the numbers of fleet of hydrogen-powered FCEVs [3].

The current global fleet of such cars can be estimated at 2-3 thousand, while yet recently it was assumed that only in Europe it will reached a level of 5,000 passenger cars and 1,000 buses [3].

In Europe, the most advanced program of the transport hydrogenization, with a budget of 1.4 billion Euro has Germany. The program entitled -"National Innovation Programme Hydrogen and Fuel Cell Technology" is coordinated by the Nationale Organisation Wasserstoff – und Brennstoffzellentechnologie (NOW GmbH) [3].

Other automotive and technologically advanced countries, began at the end of the first decade of the twenty-first century to create long-term programs of work on the use of hydrogen in road transport [3-9].

At present, there are over 60 models of cars powered by fuel cells in various stages of technical and market development, prepared by practically all major automotive companies [2-3].

In practice, so far, on the relatively mass scale, Toyota launched the production of fuel cell cars in the autumn of 2014. In 2014 of the Mirai model produced in 700 units, and the plan for 2015 envisages production of 3500 cars. Cars with fuel cells are also manufactured by Hyundai [3]. In Poland, there are practically no vehicles with fuel cell. There is also lack refuelling stations for hydrogen vehicles equipped with these cells.

### *2.1. The future network of hydrogen refuelling stations on the Polish territory*

Development of hydrogen stations infrastructure is a key factor in the development of hydrogen technology in the road transport by the year 2050. In March 2015 there were 184 hydrogen refuelling stations operating in the world (in this e.g. 82 in Europe, 63 in North America). Unfortunately only 40% hydrogen refuelling stations (74 stations) were of a public character. The remaining ones frequently functioned within various types of research centres, industrial facilities and energy units, or as private use stations [3].

Despite the strategic importance of developing hydrogen filling stations infrastructure, in the available materials, including various national programs for the hydrogen propulsion technology developments, the explicitly formulated programming methodology for the development of these stations, has not been encountered [2].

An attempt to formulate the methodology has been made in the framework of the European HIT-to-Corridors project within the work: Circumstances of the national plan for hydrogenization of road transport in Poland [3].

The methodology developed is of multi-stage character. Individual steps leading to the designation of the location of hydrogen refuelling stations in Poland (as the methodology alone seems to be of universal character) are as follows [3]:

Stage I: Method allowing to identify regions in which the hydrogen refuelling stations should be located in the first place.

Stage II: Method allowing to identify urban centres, in which should be located the said stations.

Stage III: Method for determining the area of the station location.

Stage IV: Method used to indicate a specific location of hydrogen refuelling station.

Stage V: Method indicating the preferred order of building investments in creating future network of hydrogen filling stations on the Polish territory. In any of the said stages, the group of 3-5 basic characteristics was adopted that determines, according to the experts, the potential future demand for hydrogen fuel, whose likely impact strength was determined by giving them the appropriate rank on a scale of 1 to 5.

In stage I, were taken into account : the average value of GDP / capita, the average population density (inhab./km<sup>2</sup>) or the average traffic flow of cars on the roads of international importance running through the province (cars/day). With the criteria adopted in the II stage, the cities predisposed for the location on their territory of the refuelling hydrogen stations, are in the order of ranking: Warsaw, Katowice (group of towns – Górnośląskie conurbation), Kraków, Tri-City (Gdańsk, Gdynia, Sopot), Łódź, Wrocław, Poznań. The indication in the III stage of the hydrogen refuelling station locations in the selected cities or in groups of cities (Warsaw, Katowice (group of towns - Górnośląskie conurbation), Krakow, Tri-City (Gdańsk, Gdynia, Sopot), Łódź, Wrocław, Poznań and Szczecin) was based on the measurement results of the average passenger cars traffic intensity on the roads leading to these cities or on selected road junctions located in the vicinity of these cities and also takes into account the possibility of refuelling hydrogen vehicles transiting through Poland through the trans-European transport (TEN-T) network, including the direction between Germany and the Baltic countries[3].

The location criteria for the hydrogen refuelling stations specified in stages I - III are of course general in nature. It is necessary to consider by the experts the issues of specific site location, such as the existing or planned service station, nearby existing petrol stations, or the plot, on which in accordance with applicable local development plan the said location is possible and there is an interest of potential investor of such a project (stage IV). Pointing to the proposed order of the investments in the construction of hydrogen refuelling stations in Poland (Stage V) and taking into account the above-mentioned reasons, the preliminary aspect of locations in the cities or urban areas selected according to the rankings stages I to III, was considered.

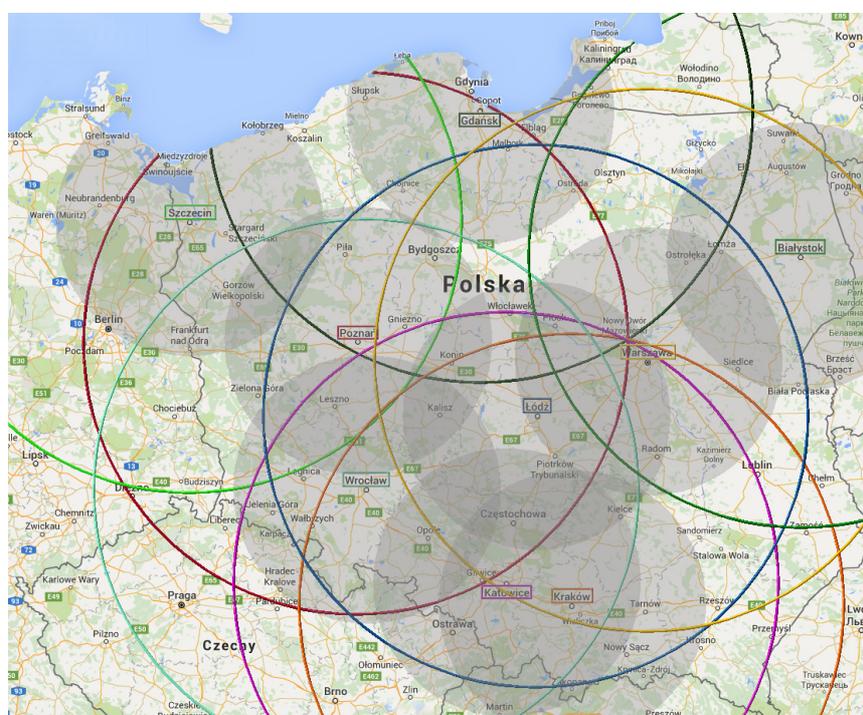
In the first place taken into account were [3]:

- already existing refuelling opportunities in the neighbouring countries,
- the expected future hydrogen refuelling station locations in the Baltic countries,
- gradually increasing the area available for hydrogen-powered cars as a result of the subsequent location of new stations at distances up to 300 km from the existing or sequentially from the newly-opened ones.

With the above criteria, the order of preliminary proposals to build hydrogen refuelling stations in Poland are as follows: 1 - **Poznań** 2 - **Warsaw**, 3 - **Białystok**, 4 - **Szczecin**, 5 – **Łódź area**, 6 - **Tri-City area**, 7 - **Wrocław**, 8 - **Katowice region**, 9 - **Kraków** (Figure 6-7).



**Figure 6.** Map of Poland with marked sites of the proposed public hydrogen refuelling station locations. Source: ITS own compilation.



**Figure 7.** Penetration areas of cars with fuel cells (within 300 km of areas of hydrogen refuelling stations), of the stations proposed to be built by 2030.

### 3. Summary

The advantages of biomethane as an automotive fuel is primarily lower emissions of nitrogen oxides, particulate matter, and carbon dioxide in (life-cycle) as compared to the emissions of these components emitted from a diesel engines. The use of biomethane in the road transport brings about independence from the import of crude oil and crude oil derived fuels, as is it in case of hydrogen.

The advantages of hydrogen as an automotive fuel is the lack of pollutants emission from motor vehicles' engines, which is especially important in crowded city centres and with the possibilities of its local production.

As a result of verification, under Polish conditions, of the original method developed for determining the initial location of the hydrogen refuelling station in Poland, in the pre-commercial phase, the said location has been indicated along with the order of investment, taking into account above all the freedom to move around Poland of cars powered by hydrogen visiting Poland and transiting our country between other EU countries.

The places where it is proposed to be built hydrogen refuelling stations should be (in order of their creation): **1 - Poznań 2 - Warsaw, 3 - Białystok, 4 - Szczecin, 5 –Łódź region, 6 - Tri-City area, 7 - Wrocław, 8 - Katowice region, 9 - Kraków.**

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