Methanisation of road transport in Poland in the light of the law on electromobility and alternative fuels

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Abstract. The act on electromobility and alternative fuels is directed, as the name suggests, on the development of electromobility in Poland, i.e. the development of primarily BEV (Battery Electric Vehicle) as well as public transport buses with such drive. However, it also applies to methane fuels, i.e. mainly CNG or LNG. The article discusses the advantages and disadvantages of the abovementioned fuels, the number of vehicles with engines fuelled with these fuels in the country in the context of the situation in other European countries, and the refuelling infrastructure for the vehicles in question in the country was also changed in the context of existing in other European countries. The examples present emission advantages and disadvantages in the aforesaid vehicles, also taking into account the results of own tests in real traffic conditions.

1. Introduction
With the number of vehicles on the increase globally, exhaust emissions are becoming a growing problem.

In the atmosphere greenhouse gases result from natural processes (volcanos, biological activity of fauna and flora) and also due to human activity or human presence (anthropogenic emissions), such as combustion of fossil fuels or deforestation [7], [8], [10], [18]. The burning of fossil fuels also involves transportation. It is the road emission that accounts for the greatest portion of emissions generated by transport. In 2011 it came to approx. 98% [6], [12]. The share of transport in total emission of carbon dioxide (CO₂) in 2011 in the country accounted for roughly 12-14% [4], [6].
Figure 1. Carbon dioxide emission (without LULUCF – (land use, land use-change and forestry)) in 2011 in Poland in a breakdown into respective categories of emission sources [6].

For this reason, both the European Union as well as automobile companies are making efforts to put greater emphasis on ecology. More and more environmental friendly solutions are implemented, which are to eliminate the issue of harmful emissions produced by vehicles. This approach is best exemplified by electric vehicles and FCEV. At present the problem does not concern vehicles only but also the most effective production of electric energy.

2. Transport gasification
Methane is the main component of natural gas. Flammable components of natural gas include methane and its homologues series, non-flammable components comprise nitrogen or carbon dioxide. The use of natural gas for fuelling combustion engines has direct impact on vehicle exhaust emissions. Emission levels depend on many factors such as engine construction, technical condition of the engine, shape and size of the combustion chamber, characteristics of the fuel system and setting options [2], [11].

Table no. 1 presents the parameters of methane fuel compared with fuels used in conventional internal combustion engines [2], [14], [15].

Table 1. Comparison of methane fuel parameters and parameters of commonly used conventional fuels [2]

| Parameter                                      | Methane | LPG   | Petrol | ON          |
|------------------------------------------------|---------|-------|--------|-------------|
| Calorific value in normal conditions [MJ/kg]  | 50      | 46,1  | 42,5 – 44 | 40,6 – 44,4 |
| Calorific value in normal conditions [MJ/Nm³] | 36      | 94,9  | 31080 – 32560 | –          |
| Calorific value of stochiometric mixture [MJ/m³] | 3,37   | 3,66  | 3,70 | –          |
| Air demand [kg/kg]                             | 17,2    | 15,7  | 14,7 – 15,0 | 14,5        |
| Octane number                                  | 130     | 115   | 95 – 98 | 3           |
| Density [kg/m³]                                | 0,717   | 536   | 720 – 760 | 800 – 850   |
| (0°C 0,1MPa)                                   | (15°C 1,5MPa) | (15°C 0,1MPa) | (15°C 0,1MPa) |
| Flammability limit (% fuel content in air)      | 5 – 15  | 1,8 – 9,0 | 1,3 – 7,6 | 0,6 – 6,5   |
| Laminar flame speed [m/s]                      | 0,34    | 0,83  | 0,3 – 0,6 | –           |
| Autoignition temperature [°C]                  | 645     | 500   | 230 – 550 | 230         |
| Boiling point [°C]                             | -162    | -47   | 35 – 210 | 160 – 380   |
The use of gas fuel such as CNG for fuelling internal combustion engines in vehicles proves reasonable not only because of lower emissions of certain toxic components of exhaust gases but also due to lower noise emissions in such vehicles.

### Table 2. Change in annual air pollution emissions relating to the transition from petrol/diesel fuelled vehicles to methane-fuelled vehicles [9]

| Type of vehicle                                      | Change in annual air pollution emissions (grams per vehicle annually) |
|------------------------------------------------------|-----------------------------------------------------------------------|
|                                                       | Average mileage (km) | SO₂  | PM  |
| Passenger vehicle (CNG vs petrol)                    | 13 000                | -7    | -15  |
| Passenger vehicle (CNG vs diesel)                    | 13 000                | -12   | -16  |
| Light commercial vehicles (CNG)                      | 16 000                | -15   | -12  |
| Small heavy vehicles (CNG dedicated)                 | 35 000                | -67   | -225 |
| Large heavy vehicles (LNG dedicated)                 | 60 000                | -179  | -574 |
| Buses (CNG dedicated)                                | 50 000                | -215  | -924 |

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### 3. CNG and the Act on Electromobility

The use of alternative fuels such as CNG is difficult in Poland. This situation stems – among others - from the absence of adequate refilling infrastructure. At present there are only about 25 stations in Poland (Gas Vehicle Report 2011: Germany – 900 stations, Czech Republic – 50 stations, Italy – 858 stations). Most city transport companies that use CNG-fuelled buses have CNG refilling stations in their own depots.

The situation across the country is expected to change shortly due to the Act on Electromobility and Alternative Fuels. In accordance with the said act the minimal number of CNG refilling stations located in local communities (gmina) by 31 December 2020 should be at least [1]:

- 6 – in communities with a population of more than 1 000 000, where at least 60 000 motor vehicles are registered and with at least 700 motor vehicles per 1000 inhabitants,
- 2 – in communities with a population of more than 100 000, where at least 60 000 motor vehicles are registered and with at least 400 motor vehicles per 1000 inhabitants.

The number of CNG refilling stations referred to in section 2 includes also recharging stations and CNG refilling stations, accordingly, located along TEN-T [1].

If the assumptions envisaged in the Act on Electromobility are implemented by year 2020, then the use of vehicles, including CNG-fuelled buses will be much easier. The growing use of such buses in city transport is becoming more and more noticeable across the country.

In Poland there are approx. 420 CNG-fuelled buses in use (Gas Vehicles Report 2011: Germany – 1590, Czech Republic 336, Italy 2300), which account for c.a. 3.5% of all registered city transport...
buses. This group also includes older generation buses that are slowly withdrawn from the market. However, if we consider only city transport buses produced after year 2010, it will turn out that such buses have a considerable share only in some Polish cities. The leader in this area is the city of Tychy, where such buses account for 55% of the entire fleet. In Radom, Mysłowice, Słupsk and Zamość – those buses account for just 30%. One of the biggest orders for CNG-fuelled buses (21 vehicles) has been placed by a city transport company - MPK Tarnów [3]. Fig. 2 below presents the fleet of CNG-fuelled buses as at the end of February 2018 and the planned deliveries of such buses.

![Figure 2](image.png)

**Figure 2.** Used and planned urban transport buses with CNG-fuelled engines in Poland (condition as in February 2018) [3], [5]

4. **Own studies**

To verify the rationality of using CNG for fuelling city transport buses, own studies were conducted in real traffic conditions. The tests were performed in one of the Polish cities. The test route was selected because of its traffic load and length. The tested vehicles are used on a daily basis for transporting passengers via that route. The route is 26 km long and has a maximum slope of 4.7%. The chosen test section combines both typical urban and suburban conditions.

![Figure 3](image.png)

**Figure 3.** Test route

The tests involved two city transport buses with a length of 12 metres each. One of the buses was equipped with a diesel-fuelled engine, the other with a CNG-fuelled spark-ignition engine. Both buses
had a similar maximum output (diesel – 213 kW, CNG – 200 kW), similar torque (diesel – 1100 Nm, CNG – 1050 Nm) and the same emission levels – Euro VI.

The tests were conducted with the use of PEMS produced by Sensors Inc. PEMS allowed for recording levels of THC, NO\(_X\), CO and CO\(_2\). Its use also allowed for recording the flow levels. For the system to operate properly it was necessary to connect the buses to flow-meters, a GPS receiver, a weather station and CAN.

![Figure 4. Testing equipment – PEMS – used in the study](image)

To ensure comparability of the tests both vehicles moved one after another so as to avoid excessive variances in the characteristics of the route, and also differences in traffic and weather conditions. Table no. 3 below presents a comparison of the respective route phases of the tested buses. As noticeable, there are great similarities, which allowed for an appraisal of the results.

| Value         | Bus powered by CNG fuel | Bus powered by diesel fuel |
|---------------|-------------------------|---------------------------|
| Acceleration  | % 38                     | 40                        |
| Fixed velocity| % 19                     | 13                        |
| Braking       | % 28                     | 30                        |
| Stopover      | % 15                     | 17                        |

The tests provided basis for two-dimensional histograms of emission intensity of respective substances in the velocity – acceleration relation. Fig. 5 – 7 below present emission intensity for CO\(_2\), NO\(_X\) and HC. Noticeable is the fact that both as regards NO\(_X\) and HC, emission levels are lower for the CNG-fuelled bus. However, there is a moderately lower emission level of CO\(_2\) in the diesel-fuelled bus.
The test results also allowed for a comparison of road emissions between diesel-fuelled buses and CNG-fuelled buses (fig. 8). Road emissions of hydrocarbons and nitrogen oxides are lower than that generated by the diesel-fuelled bus.

However, attention should be given to the fact that the CNG-fuelled bus generated a higher levels of carbon oxide and greater fuel consumption. Nevertheless, considering the advantages of CNG as a fuel, i.e. practically zero emission of PM, non-toxicity of methane and the easy adaptability of vehicles for being fuelled with CNG, its application as a fuel is feasible.
5. Conclusions
The use of an alternative fuel such as compressed natural gas for fuelling engines in buses can be reasonable due to lower emissions of certain hazardous substances and also in the light of the Act on Electromobility and Alternative Fuels.

Own studies of buses in real traffic conditions proved that the use of CNG for fuelling urban transport buses in terms of – among others – NOX, CO2 and HC emissions was advantageous in the current technical conditions. Road emissions of those substances were lower by respectively 41%, 1.6% and 61% for a CNG-fuelled bus compared to a diesel-fuelled bus.

Differences in the emission of harmful substances such as NOX or THC result from design differences between SI and CI engines. In the case of carbon dioxide, smaller and smaller differences in this emission are noticed. This is due to the development of the SI engine. According to [19], CO2 emissions can be up to 6% lower compared to those emissions from the CI engine. The research carried out confirms this trend.

The studied CNG-fuelled engine characterised with slightly higher emissions of CO and fuel consumption. Road emission of CO was greater by 6.3% compared to the studied bus with self-ignition engine. The same applies to fuel consumption which was greater by 43.5% (calculated m3/100 km and dm3/100 km into MJ/100 km) for a CNG-fuelled bus. Further comparative studies within the said scope are continued.

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