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ADVANTAGES AND DISADVANTAGES OF USING METHANE FROM CNG IN MOTOR VEHICLES IN POLISH CONDITIONS

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Abstract: The current problems related to air pollution in Europe, but also in Poland, are forcing the search for solutions aimed at significantly reducing the amount of solid particles harmful to humans in the air. Road transport is responsible for almost half of the pollution, as it releases nitrogen oxides into the air. In view of the above, the authors of the article want to turn attention toward methane as a fuel alternative traditional ones, pointing to the possibility of its use by Poland and presenting its advantages and disadvantages.

Keywords: methane, CNG, alternative fuel

1. INTRODUCTION

In The 21st century began with concerns of a predicted or, in the opinion of some, already observed greenhouse effect and increasing air pollution. Unfortunately, Poland is one of the countries in Europe with the highest concentration of benzopyrene, over 1.5 ng/m^3. Road transport is responsible for approximately half of this pollution; for example in Warsaw it is responsible for 63% of it (Plan Rozwoju Elektromobilności, 2016; Górniak and Kaźmierczak, 2017).

To counteract the deterioration of air quality, the European Union is adopting increasingly stringent requirements for the purity of car exhaust fumes. Euro series standards, the last edition of which, the Euro 6 standard, came into force in 2014, assumed a reduction in the presence of NOx nitrogen oxides in exhaust fumes by more than half. Manufacturers of motor vehicles, to meet the requirements of the standard, combat the effects of the combustion process through particulate filters or exhaust fume recirculation valves. However, these are ad hoc measures, as the Euro 6 standard enforces addressing the cause of the problem, i.e. preventing the formation of solid particles (Rozporządzenie WE nr 715/2007).

The Polish government is also trying to take action to reduce pollution associated with the operation of cars. It plans to develop electromobility in transport. In 2016, the government prepared the Electromobility Development Plan, whose assumption was 1 million registered electric vehicles by 2025 (Plan Rozwoju Elektromobilności, 2016). It needs to be mentioned here that the direction of electromobility, as an alternative to the development of Polish motorisation, requires many long-term measures such as:

- mass production of cheap electric vehicles,
- construction of a network of vehicle charging stations,
- providing additional power in the Polish power grid,
- breaking the mental barriers in society.

- improvement of operating conditions of vehicles, primarily their range.

Another and, in the opinion of the authors of this study, even more promising direction for the reduction of air pollution by road transport are hydrogen-powered vehicles. Hydrogen is ecological, but its storage requires high pressures, in the order of 90 atm. and, in addition, the oxidation process is not sufficiently well-developed for general use in power units, so the application of this fuel on a larger scale requires more time.

A separate issue is the prospect of exhaustion of resources and the related increase in prices of the basic fuel of the automotive industry, i.e. oil. Poland, which does not have significant deposits of its own, is doomed to its long-term import and related economic dependence on other countries. In view of the above facts, the authors of the article want to turn attention to methane as an alternative to traditional fuels, pointing to the possibility of its use by Poland and presenting its advantages and disadvantages.

Methane in the automotive industry is used in the form of CNG (Compressed Natural Gas) or LNG (Liquid Natural Gas).

Methane as a fuel in the automotive industry has been used in England, Italy and Russia since the 1930's. In Poland, several natural gas refuelling stations were built in the 1950's, namely in Rzeszów, Tarnów, Mysłowice and Krosno. Around 4 000 so-called technical cars were driven around Poland. This type of vehicle power supply was then commonly referred to as "wood gas". The 60's and 70's were a total regression in this area. The first CNG refuelling station was reopened in 1988 at the Przemyśl Zachód natural gas mine. Since then, CNG has been used in individual cases of institutional carrier cars, such as urban bus transport (Owczarzak, 2016). Currently, the number of CNG filling stations in Poland is 25. Figure 1 shows the current map of CNG stations in Poland.

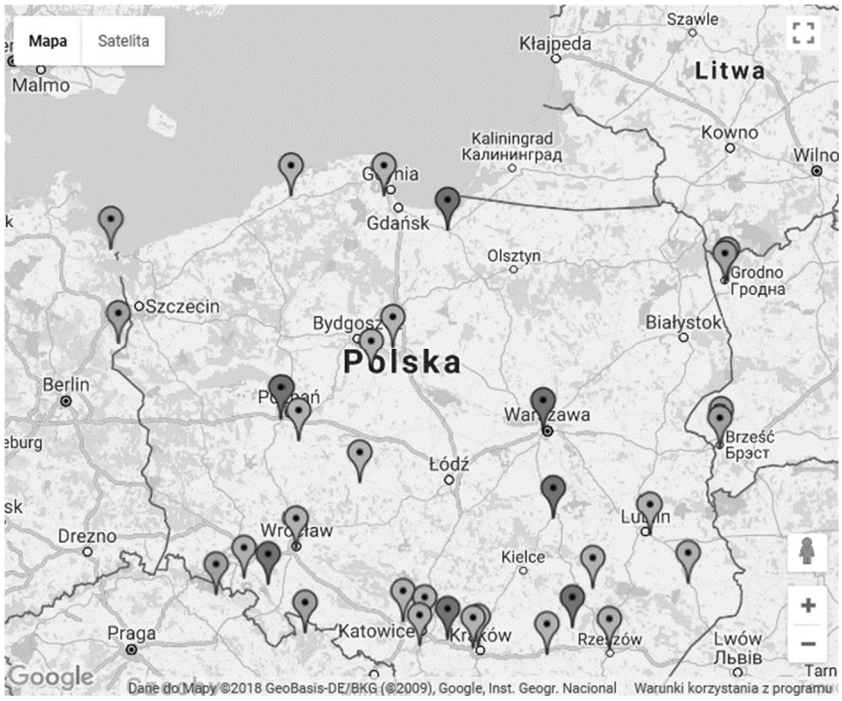

Fig. 1. Current map of CNG stations in Poland

Source: (CNG.Auto, 2017).

2. METHANE AS AN ALTERNATIVE TO PETROLEUM-DERIVED FUELS

Internal combustion engines powered by petroleum-derived fuels have dominated the automotive world for nearly 150 years. There are many indications that further streamlining of engines to more efficiently burn fuel and increase exhaust purity will be increasingly difficult and costly. This is related to the increasingly complex equipment of the engine such as increasing the pressure of fuel injection (about for spark-ignition engines and 200 MPa for compression-ignition engines), the amount of air fed, exhaust fume catalytic filter systems, and all this together connected with more and more complex computer control. The falsification of exhaust fume quality analysis in cars of one of the known brands discovered in the US might point to the fact that the possible improvements to the internal combustion engine have reached their limit.

There is much in favour of the thesis that traditional combustion engines are at the end of their development, and electric cars are facing more than a decade of increase in popularity and mass production, so the question should be asked: what about the transitioning period? The answer may be methane. When analysing the possibility of using methane as a transitional fuel between internal combustion engines and electric engines, one should take into account, among others, the advantages and disadvantages of this fuel. Table 1 presents a comparison of petroleum-derived fuels such as gasoline, diesel oil and LPG with CNG methane.

Table 1
The switch-on time and the time lag of the leg sliding down function depending on the different power source

Aspect	Petroleum-derived fuels (gasoline, diesel oil, lpg)	CNG (methane)
Ecology	Carbon dioxide CO_2.	20% less CO_2 (Stelmasiak, 2006).
Exhaust fume purity	Complex hydrocarbons (THC).	Lack of complex hydrocarbons (THC).
	Carbon monoxide CO.	Significantly less CO.
	Nitrogen oxides NO_x.	40% less NO_x for CI engines.
	Particulate matter PM.	None.
Production	Derivatives of petroleum.	Natural resource subjected only to dehydration and filtration
Noise		Engine working more quietly by about 10dB – reduced knocking.
Engine efficiency	Gasoline octane number 95-98 Diesel oil octane number 85.	CNG octane number 110-120.
Engine complexity		Engine with a simpler structure. Particulate matter filter is also not required.
Future fuels		It can be an adaptive bridge for the distribution, storage and power supply before the use of hydrogen fuel.
Availability of deposits	Occur in Poland in very limited quantity, 90% imported from abroad.	Access to methane from domestic deposits is documented at 145 billion m^3. From conventional land and marine deposits. The new Baltic Pipe pipeline under construction from Norwegian fields through Denmark. From shale gas, billions of m^3 – undocumented. In the future from deposits in the form of clathrate (methane hydrate). Methane from hard coal deposits - 1 to 2 billion m^3 per year. Documented reserves of 90 billion m^3 in 60 deposits (from 10.5 to 11.1 m^3 of methane excreted during the extraction of 1 ton of coal) (Przegląd Gazowniczy, 2017). The use of methane from biomass composting, the so-called Biogases. Through the gas terminal, 5 billion m^3 currently, 7.5 billion m^3 per year after expansion.

Safety	Gasoline – 340℃ Diesel oil – 260℃	High temperature of self-ignition of CNG – 595℃. Gas lighter than air does not accumulate near the ground and in cavities. Requires additional control during inspections, air-tightness of the system, cylinder condition.
Storage, transport, distribution		Requires storage under a pressure of 22 MPa A small number of CNG filling stations in Poland – 25. It does not require a car transport to the refuelling station, distribution can rely on a gas pipeline available locally. The possibility of self-refuelling of a vehicle using natural gas for domestic use. Longer charging time. For fast refuelling requires additional compression to 30 MPa.
Weight and volume consumption		Traditional steel cylinders are heavy Composite cylinders are available which are many times lighter and more expensive Cylindrical shape of the canister.
Range		The range of vehicles is about 50% smaller compared to the same models powered by diesel.
Price per unit of power	ES95 – 4.70 PLN/0.735 kg * 44.3 MJ/kg = 0.1413 PLN/MJ ON – 4.61 PLN/0.830 kg * 43 MJ/kg = 0.1261 PLN/MJ LPG – 2.12 PLN/0.52 kg * 47.3 MJ/kg = 0.0874 PLN/MJ	CNG – 3.29 PLN/0.714 kg * 48.0 MJ/kg = 0.0957 PLN/MJ
Price per unit of volume	ES95 – 4.70 PLN/l ON – 4.61 PLN/l LPG – 2.12 PLN/l	CNG – 3.29 PLN/m^3
Net Caloric Value (NCV) according to KOBIZE for 2017	E95 – 44.3 MJ/kg ON – 43.0 MJ/kg LPG – 47.3 MJ/kg	CNG – 48.0 MJ/kg
Government projects		The draft bill on electromobility and alternative fuels of 27 April 2017 implementing EP and Council Directive 2014/94/EU on the development of alternative fuels infrastructure (Górnictwo wobec ustawy, 2017). Part of the requirements of the directive: 1. By 2020, the creation of an appropriate number of CNG refuelling points within urban agglomerations 2. By 2025, the creation of an appropriate number of refuelling points to move across the EU within the TEN-T trans-European transport network (Part of the draft bill: • Construction of generally accessible refuelling points by OSDg (gas network operator). Natural gas will be obtained by means of compressors installed on the gas distribution pipeline • Mandatory for municipalities: a) over 100 000 residents, b) 60 thousand vehicles, c) 400 vehicles per 1000 inhabitants • Number of refuelling points for a municipality at least from 2 to 6, depending on the number of inhabitants • Abolition of excise tax.

The comparison of methane with petroleum-based fuels shows that methane is a much cleaner fuel, but it requires much greater safety precautions during operation, such as a suitable fuel cylinder and more frequent technical inspections of the fuel system. Nevertheless, assuming that safety requirements are met, methane looks good when compared with traditional car fuels. Table 2 presents a detailed summary of the advantages and

disadvantages of using methane gas as car fuel in Polish conditions, and Table 3 presents the synthetic results of the analysis (Stelmasiak, 2006, Materiały przedsiębiorstwa Dual Fuel Systems LTD, 2013, Gazownictwo wobec ustawy o elektromobilności i paliwach alternatywnych, 2017, PAP/PSZ, 2017).

Table 2
Summary of the advantages and disadvantages of methane-powered cars

Aspect	Advantages	Disadvantages
Ecology		
Lower exhaust fume pollution	20% lower emission of CO_2	
	0 emission of complex hydrocarbons (THC)	
	Reduced emission of CO	
	40% emission of NO_x for CI engines	
	0 emission of particulate matter (PM)	
Mitigation of the greenhouse effect	Utilisation of methane which leaks into the atmosphere (mines, fermentation)	
	Bridge to high-pressure (hydrogen) technologies	
	Natural resource subjected to filtration, does not require refining	
Availability of natural gas - methane		
Good availability and great diversification of sources in comparison with crude oil	Domestic methane deposits is documented at 145 billion m^3.	
	Planned Baltic Pipe pipeline from Norwegian fields through Denmark.	
	From coal deposits 1-2 billion m^3/year, 90 billion m^3 available.	
	From biomass composting plants	
	Through the gas terminal, 5 billion m^3 currently, 7.5 billion m^3 per year after expansion.	
	from the Yamal pipeline 10 billion m^3/year (total flow 33 billion/year)	
Safety		
		Requires storage under high pressure of 22 MPa
	Lighter than air, does not accumulate in crevices	
	Self-ignition temperature 595℃ (Diesel oil – 240℃)	
Use		
		Requires additional installation inspections
		Cylindrical containers take up additional space
		Weight of the steel containers
		High price of composite containers
		Number of CNG refuelling stations – 25; 70 by 2025
		Range of the car (50% less than on diesel oil)
	It does not require transport to the petrol station, only a connection to the pipeline	
	The possibility of self-refuelling from the home gas network	
Operation		
	Engine quieter by approx. 10 dB	
	Less knocking, octane number 110-120	
	Simpler engine design	
	Highest energy efficiency 48 MJ/kg	
	Suitable for SI and CI engines without big adjustments	

Table 3
Synthetic summary of the advantages and disadvantages of methane-based fuel

Category	Ecology	Availability of resources	Safety	Use	Operation
Rating	✓	✓	✓	✗	✓
Key aspect	pure exhaust fumes	own deposits, diversification of sources	less explosive	small number of refuelling stations, high price of installation in a car	better engine efficiency

An analysis of data contained in Tables 2 and 3 allows us to conclude that currently a significant problem when using methane as a fuel for car vehicles on a large scale is the small number of refuelling stations and, at the moment, the high price of installing a gas system in a car, which can greatly discourage potential new customers from using this fuel. However, given the experience of introducing LPG fuel into the market on a large scale, these problems can also be solved quickly. An important issue is the availability of methane in Poland. Table 4 shows the main and potential directions for methane supply for Poland. An analysis of the data in the table shows that the possibilities of obtaining this fuel are prospective and give the chance to meet the demand for fuel in Poland in the near future (Gazownictwo wobec ustawy o elektromobilności i paliwach alternatywnych 2017, PAP/PSZ, 2017, Mazowiecka Agencja Energetyczna, 2009).

Table 4
Main existing and potential sources of methane supply for vehicles

Poland's needs in 2016	Yearly availability [billion m^3]	Source of gas
natural gas – 16 billion m^3 per year	4.5	Domestic deposits – 145 documented
LPG – 4.6 million m^3	11	From overseas networks – Russia, Germany, the Czech Republic
	10	New pipeline under construction from Norwegian fields through Denmark
	?	From shale deposits – billions of undocumented m^3
	?	In the future from deposits in the form of clathrate (methane hydrate)
	1 - 2	Methane from coal deposits. Documented resources of 90 billion m^3 over 60 deposits (from 10.5 to 11.1 m^3 of methane excreted during the extraction of 1 ton of coal)
	6	Use of methane from composting biomass, the so-called biogases
	5, after expansion 7.5	Gas terminal

3. CONCLUSION

Looking at the advantages and disadvantages of using CNG as a carrier of methane to power cars, we see that in addition to the obvious advantages such as low price, low pollution and the availability of natural resources in line with forecasted customer needs, there are also disadvantages. They include a poorly developed network of CNG stations and high costs of gas installations in cars. These are issues to be solved with the gradual spread of the use of CNG, for example, there are already Polish manufacturers producing light composite compressed gas tanks.

On the horizon there is already a few-million-strong group of potential customers, owners of cars and trucks equipped with over-a-dozen-year-old diesel engines. These cars do not meet

Euro 4 standards and are less and less welcome in large cities. The only chance for their continued use is to change the fuel to a more ecological alternative. It can be 50/50, i.e. diesel cars, adapted to a two-fuel system, such as diesel and natural gas, in a 50%/50% ratio. This solution does not completely eliminate impurities from the exhaust fumes, but significantly reduces them and, consequently, will allow the use of existing vehicles for several more years. It can be assumed that just as the network of LPG stations was developing in the 90's of the last century resulting in 5 390 stations with autogas operating in 2016, so too the network of CNG power stations can develop.

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