Chapter 1

Environmental Aspects of the Use of CNG in Public Urban Transport

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Additional information is available at the end of the chapter

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Abstract

This chapter concerns the problem of assessing the exhaust emission from the engines of city transport buses fuelled by CNG. It presents a comparative analysis of toxic exhaust emissions of CO, HC, NO_x and PM, from urban buses powered by diesel and CNG. The measurements were carried out over the SORT standardised cycles as well as during a real drive condition on a city bus route. The research revealed that CNG bus generates significantly lower NO_x emission, whereas its CO and HC emissions are higher. Taking into account low PM emissions, CNG buses should be regarded as eco-friendly means of public transport.

Keywords: Bus, CNG, exhaust emissions, PEMS, RDE

1. Introduction

The idea of fueling engines with gaseous fuels is as old as the history of the piston engine itself. The first combustion engine in the world — the one built in 1860 by Etienne Lenoir — was fueled with light gas, similarly to the first four-stroke engine built by Nicolaus Otto in 1876. The construction of a gasoline engine by Carl Benz practically eliminated the use of gaseous fuels for almost a hundred years. The interest in gaseous fuels for spark ignition engines returned last century, in the 1970s, in the times of energy crisis and this interest has continued to date.

Gaseous fuels belong to a group of most important alternative fuels for spark ignition engines (Figure 1) while they are almost neglected for diesel engines. Of all gaseous fuels, gaseous hydrocarbons are most frequently used such as: methane (*natural gas*) and LPG (*liquefied petroleum gas*).

In Poland a very popular gaseous fuel for motor vehicles is LPG. The number of vehicles adapted for this fuel exceeded 2 million already a few years ago. In this respect Poland places in the top 3 along with South Korea and Turkey. In terms of the number of LPG filling stations, Poland places first worldwide *ex equo* with Turkey [1]. Natural gas on the other hand is not a very popular engine fuel in Poland. The filling station infrastructure is still poorly developed. The only sector of road transport where the use of natural gas as a fuel increases is municipal transit (Rzeszów, Przemyśl and Kraków city bus operators) [2].

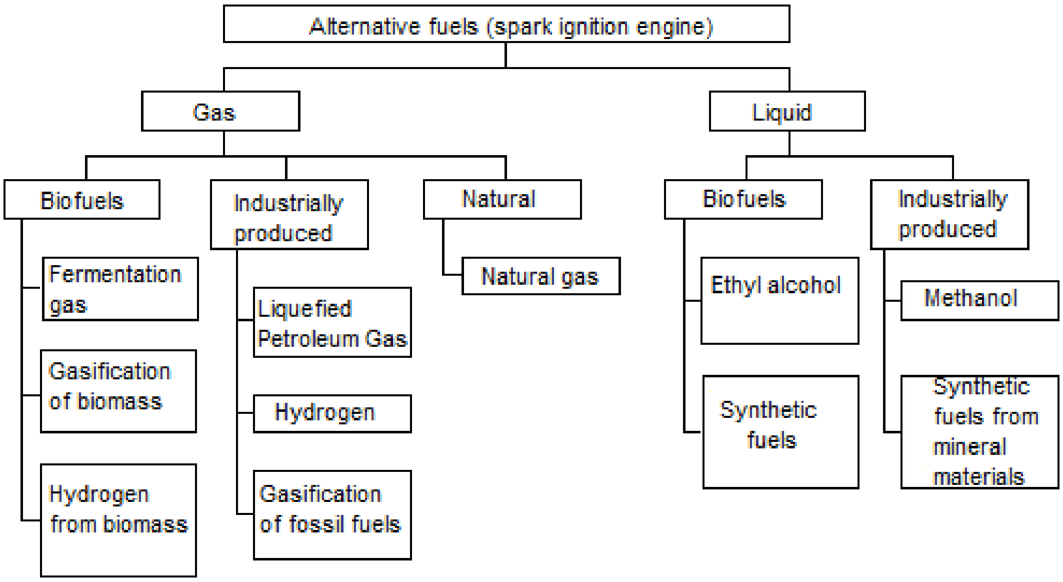

Figure 1. Gaseous fuels compared to other alternative spark ignition engine fuels.

The attractiveness of gaseous fuels is mainly attributed to their low price. These fuels are cheaper than conventional liquid fuels practically in the whole world. In Europe LPG is, on average, twice cheaper than gasoline (Figure 2). This is also the case for natural gas [3]. This results not only from the lower costs of production but also from the fiscal policy of many countries.

Fuels used to power combustion engines must have specific properties. This is also the case for gaseous fuels. The most widely used gaseous engine fuels — hydrocarbon fuels (LPG, natural gas) — owing to their properties (Table 1), are suitable for application in spark ignition engines. LPG is obtained as a product of crude oil processing. Natural gas is a standalone mineral fuel but is frequently found along with crude oil. The main component of natural gas is methane. It also contains other light hydrocarbons in smaller amounts, particularly ethane, propane, butane, pentane and hexane, as well as nitrogen and helium.

Among the main features of hydrocarbon fuels one should list the following [5]:

- High octane number

- Hydrocarbon fuels easily mix with air, which makes the mixture homogenous and its composition in the micro and macro scale is level
- The combustion is usually smokeless
- Hydrocarbon fuels generate a lower mass of exhaust gas compared to liquid fuels
- The air-gas mixtures have wide ranges of ignition, which enables combustion of leaner mixtures
- Gases have high ignition temperatures and, when used in diesel engines, require positive ignition

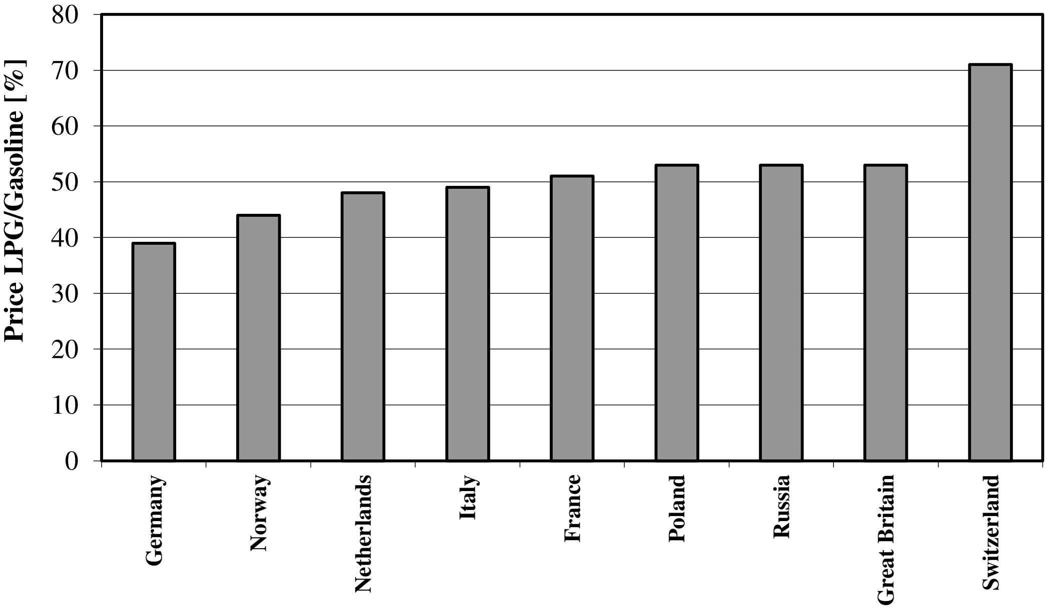

Figure 2. Price of 1 dm^3 of LPG as a percent of 95 gasoline fuel in different European states [4].

It is a common knowledge that vehicles powered with alternative fuels are environment friendly. Owing to the popularity of LPG- fueled engines, it is for these particular engines that we have most data available. These engines are usually fed with stoichiometric mixture and are fitted with three-way catalysts (TWC). The advantage of LPG in terms of low emission is high value of the H/C ratio and simple chemical composition. The exhaust emission level, however, heavily depends on the LPG system quality (the accuracy of fuel dosage, ignition timing, valve timing etc.) Accuracy that is comparable to that of gasoline fuel systems can only be achieved in the 4th and 5th generation LPG systems, particularly if the engine maps are optimized for LPG feed. In such a case, it is possible to obtain exhaust emissions of comparable or even lower values than for gasoline (Figure 3).

There are much less exhaust emission data for natural gas-fueled vehicles, particularly heavy-duty vehicles. This is partly attributed to rather low popularity of NG -fueled heavy-duty vehicles but also to much higher costs and greater complexity of the exhaust emission testing

Fuel	Density under ordinary conditions [kg/m^3]	Fuel calorific value [MJ/kg]	Boiling temperature [°C]	Air demand [kg/kg]	Excess air coefficient λ up to the ignitability boundaries	Octane number MON (RON)
Methane	0.72	50	−161	17.2	0.7 – 2.1	110 (140)
Liquefied petroleum gas Propane-butane 50%/50%	2.35	46	−30	15.5	0.4 – 1.7	95 (100)
Natural gas 1)	0.74	48	−161	17.0	0.7 – 2.1	100–110
Generator gas 1)	1.02	5.5	− 253 – −192	1.20	–	105
Fermentation gas 1) (biogas)	1.20	20	–	6.6	0.7 – 2.3	110
Hydrogen	0.089	120	−253	34	0.5 – 10.5	70
Gasoline 95	720 – 775	42.6	40 – 210	14.7	0.4 – 1.4	85 (95)
Methanol	797	19.9	64.4	6.5	0.3 – 2.0	95 (115)
Ethanol	793	26.7	78.3	9.0	0.3 – 2.1	94 (111)

1) Typical values have been given; gas composition and its parameters may vary widely.

Table 1. Properties of gaseous fuels compared to other spark ignition engine fuels [6]

in this group of vehicles. In general, we can state that NG -fueled heavy-duty vehicles are predominantly single fuel units based on either stoichiometric or lean mixture strategy.

Engines fed with a stoichiometric mixture ($\lambda = 1$) are fitted with three-way catalysts (TWC). Compared to conventional HDD engines, they are characterized by much lower emission of NO_x and PM but also by 15-20% higher energy consumption (under the conditions of the ESC test). The conversion rate of CO, HC and NO_x depends on the capability of keeping $\lambda = 1$. Due to a high temperature of the exhaust gas, premature process of deactivation of the catalytic converter and the oxygen sensor may occur leading to an increase in the exhaust emissions [8].

Engines fed with homogenous lean mixtures operate with the excess air coefficient in the range from $\lambda = 1.6$ (full load) to $\lambda = 1.2$ (idle) i.e. in the range ensuring low emission of CO and NO_x. The elimination of CO and HC is done with the oxicat converters, which, however, have a low conversion rate of methane. For this reason, the emission of THC from gas- fueled engines remains on a level similar to diesel- fueled engines, while the emission of the outstanding exhaust components is much lower. The consumption of gas is lower than in the earlier described stoichiometric scenario [8].

As mentioned in the beginning, in Poland the only sector of transport where the number o natural gas-fueled vehicles is growing dynamically is public transport. These are usually new CNG- fueled vehicles of very high emission categories (Euro V, EEV). The aim of this paper is to experimentally determine the exhaust emission parameters of this type of vehicles.

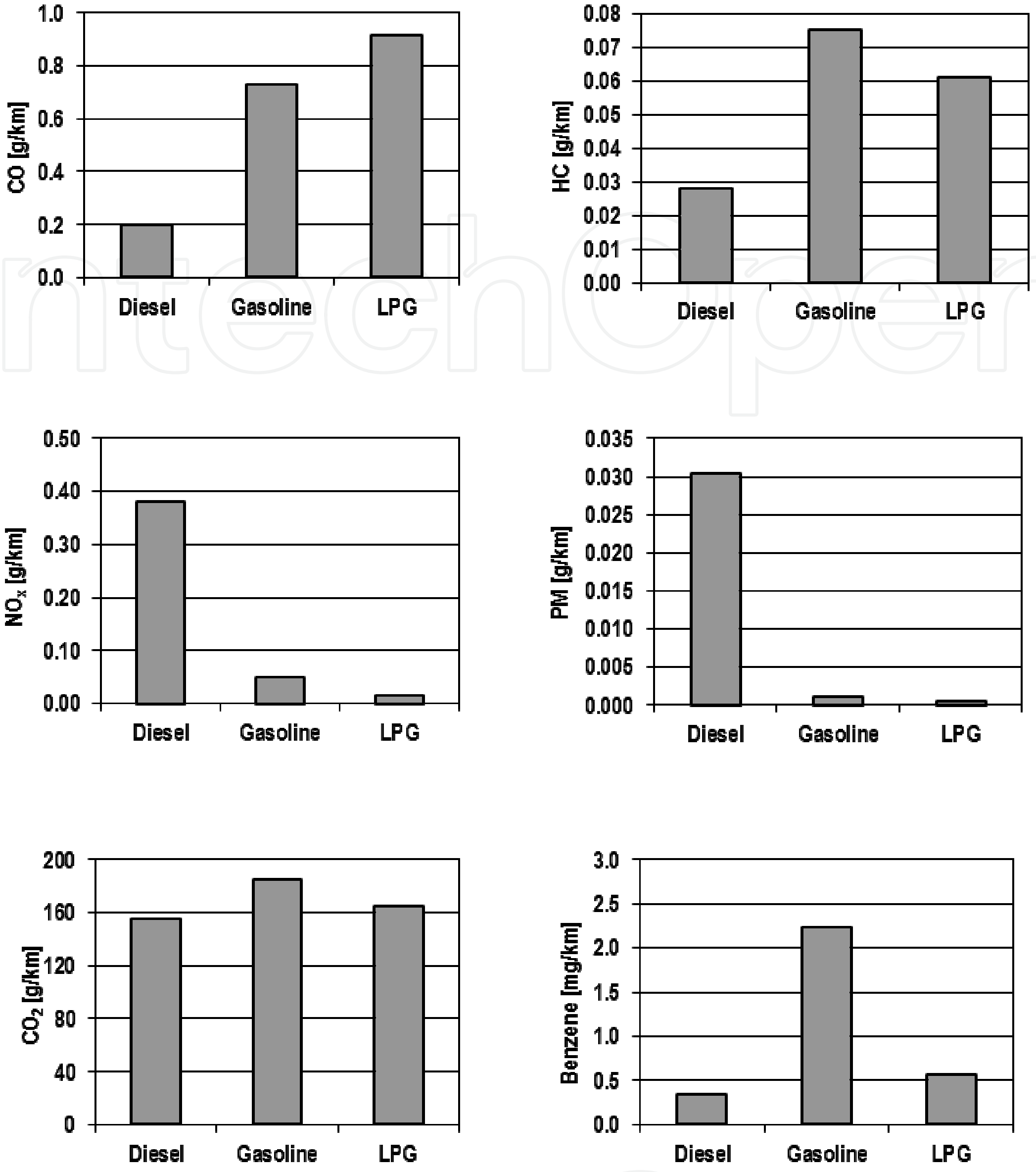

Figure 3. Average exhaust emissions in the NEDC test from modern passenger vehicles fueled with conventional fuels and LPG [7].

2. Overview of CNG vehicles

Given the availability of significant amounts of natural gas in the world, high level of operational safety and low emissions, CNG has the greatest share in the three mentioned alternative fuels. The CNG feed is realized from gas cylinders in which the gas is compressed to the pressure of approx. 20–25 MPa. The most frequently modified engines are spark ignition and diesel engines including their (single or dual) fuel systems. Dual fuel systems are most frequently used in passenger vehicles. Buses and other transport vehicles are usually fitted with single, gas fuel systems. Currently, an increasing number of carmakers have serially manufactured CNG-fueled vehicles in their portfolio. Natural gas is mainly used as bus fuel in short distance carriage of passengers. This results mainly from the economic factors. The cost of CNG in transport is much lower than that of diesel fuel. This chiefly results from the lack of sufficiently developed fueling stations. This is one of the most important issues blocking rapid development of CNG vehicles for carriage of goods and passengers. This problem extends across all European states. The number of CNG vehicles operated in Europe is growing, but it is still relatively low. Table 2 presents the data related to the number of CNG vehicles in selected European states.

Currently, most of the manufacturers of light duty vehicles (LDV) and buses have CNG-fueled vehicles in their portfolio. Works are continuing on the improvement of the designs of these vehicles and their engines. One of the most significant problems is fitting large CNG tanks in the vehicle. Despite the fact that the tanks must operate under high pressure, they must also be of high volume. For larger vehicles (buses, light duty trucks, heavy duty trucks) there is usually enough space to fit the tanks, but for light duty vehicles this remains a serious problem. The fitting of the tanks must not compromise the vehicle safety and its functionality. Examples of vehicle designs with the CNG tanks visible have been shown in Figure 4.

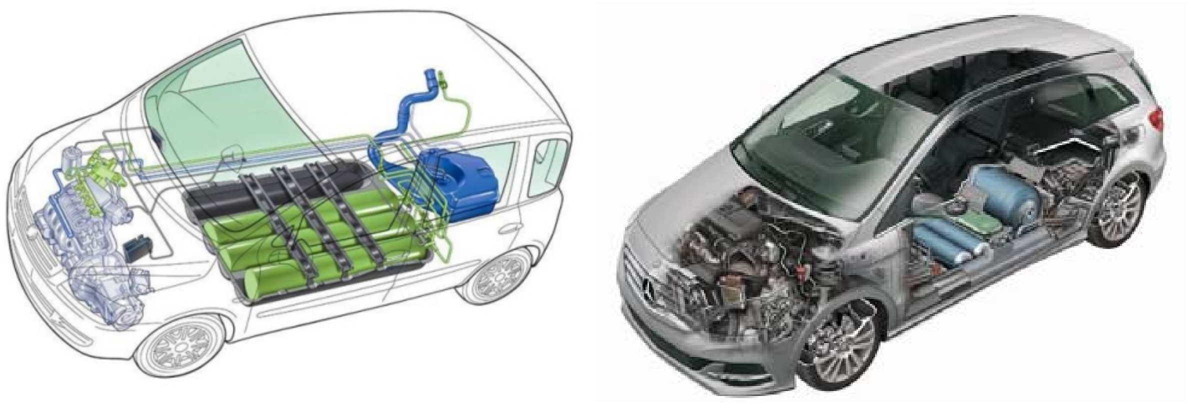

Figure 4. Examples of CNG -fueled vehicles.

Another factor influencing the common use of CNG as fuel is the possibility of quick refueling. Two types of refueling can be distinguished: quick (vehicle is fueled in 3–7 minutes) and slow (usually lasts up to several minutes for a passenger car). In order to quickly charge natural gas into the gas tank without high efficiency compressor, cascade storage is applied. Cascade storage is a tri-segment (low-, mid- and high pressure) system. The system includes 10–50 tanks of the capacity of 80–150 dm3 each for each segment. Between fuelings, the compressor charges the cascade system (to the pressure of 25–30 MPa) and during the refueling process, the gas is fed from the cascade storage and the compressor only maintains the required pressure. Slow refueling systems do not require cascade storage. The gas is charged directly to the tanks with the pressure slightly exceeding nominal. Tanks fitted in vehicles are filled within 6–8 h, which is a much cheaper solution for vehicle fleets or private users.

UE countries	LDV	Buses	Trucks
Austria	8 100	167	54
Belgium	1015	3	15
Bulgaria	61 000	280	40
Croatia	219	78	3
Cyprus	0	0	0
Czech	6650	512	81
Denmark	61	26	17
Estonia	300	30	10
Finland	1 600	45	20
France	10 050	2 400	1 100
Germany	95 708	1 735	176
Greece	280	618	102
Hungary	5 000	86	32
Ireland	3	0	0
Italy	880 000	2 300	3 000
Latvia	29	0	0
Lithuania	80	300	0
Luxembourg	230	39	1
Malta	0	0	0
Holland	6 498	686	386
Poland	3 050	400	50
Portuguese	45	354	86
Romania	0	0	0
Slovakia	1 100	261	65
Slovenia	29	24	5
Spain	905	1 609	1 322
Sweden	43 795	755	2 163
Great Britain	20	37	621
Summary	1 125 768	12 745	9 349

Table 2. Number of CNG -fueled vehicles in the EU member states divided into types of vehicles

3. Testing methods and equipment

The investigations were performed on two 18m city buses fitted with a CNG and a diesel engine respectively. The bus fitted with the CNG engine (8.9 dm^3) produced 238 kW of power. The vehicle was fitted with a three- way catalyst (TWC). The composite CNG cylinders of the capacity of 214 dm^3 each were mounted on the roof. The cylinders fitted on the roof increased the vehicle's height to 3 400 mm, which may constitute a serious downside in terms of road infrastructure. Basic technical data of the engines of the tested buses have been presented in Table 3. The view of the buses with the measurement equipment has been shown in Figure 4.

Parameter	CNG -fueled vehicle A	Diesel- fueled vehicle B
Engine type	Spark ignition	Compression ignition
Engine displacement	8.9 dm^3	9.2 dm^3
Number of cylinders	6	6
Compression ratio	12:1	17.5±0.5
Maximum power	239 kW @2000 rpm	231 kW @1900 rpm
Maximum torque	1356 Nm @1300 rpm	1275 Nm @1100–1710 rpm
Emission Technology	EEV	EEV
Aftertreatment	TWC	SCR/DPF
Length	18 000 mm	18 000 mm
Height	3 400 mm	3 050 mm
Vehicle weight	24 000 kg	24 000 kg

Table 3. Technical specifications of the tested city buses

In the on-road exhaust emissions tests of the city buses a PEMS portable exhaust emissions analyzer was used (Semtech DS by Sensors Inc.) capable of measuring and recording the following parameters (Figure 5):

- Concentration of CO and CO_2 (NDIR analyzer – Non-Dispersive Infrared), $NO_x = NO + NO_2$ (NDUV — Non-Dispersive Ultraviolet), HC (FID analyzer — Flame Ionization Detector), O_2 (electrochemical sensor);
- Thermodynamic parameters of the exhaust gas (mass flow, temperature, pressure) — a flow meter utilizing the Pitot tube;
- Ambient conditions — pressure, temperature, humidity;
- Position and speed of the vehicle — GPS system;
- Data pulled from the vehicle on-board diagnostic system (data transmission protocol — CAN SAE J1939/J2284.)

The diagram showing the location of the analyzer in the bus has been shown in Figure 6.

Figure 5. City buses prepared for the tests (left - CNG -fueled vehicle).

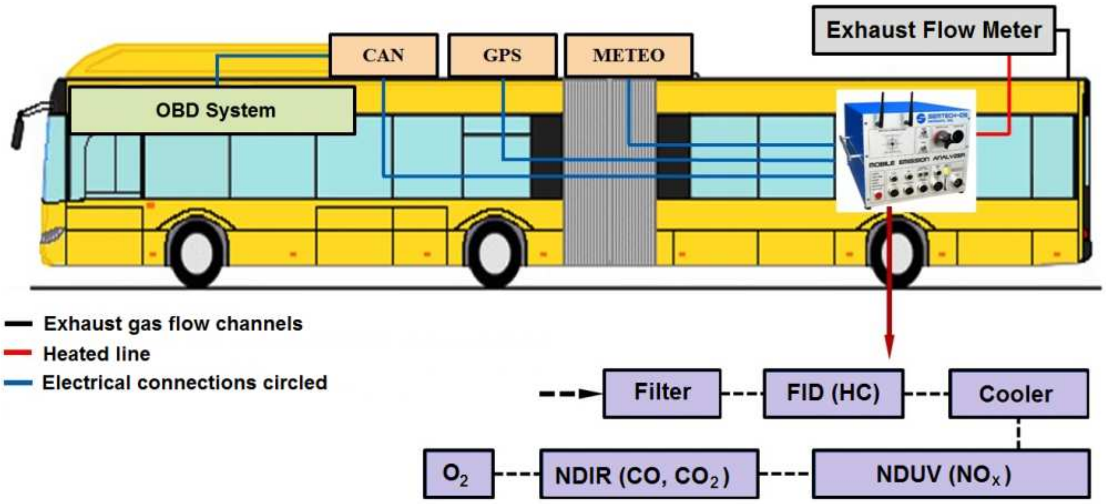

Figure 6. Diagram showing the location of the portable analyzer (Semtech DS) in the tested city buses.

The exhaust gas sample is taken from the flow meter and is then transported through a heated line (red line) maintaining the temperature of ~190°C. The temperature prevents possible HC condensation on the walls. Upon passing the filter, the sample reaches the FID analyzer, where the HC concentration is measured. When the sample is chilled to the temperature of 4°C it reaches the NDUV and NDIR analyzers respectively. These analyzers measure the concentrations of $NO_x = (NO + NO_2)$, CO and CO_2. Finally, a measurement of the O_2 concentration is performed with an electrochemical sensor. The control and monitoring of the Semtech DS device is realized with a portable computer connected to the main unit through a wireless connection. The device can communicate with a local area network; however, in the performed tests this method of communication was not applied.

The measurements were performed in the SORT tests and under actual conditions of operation (Figure 7), when the buses operated on regular city routes in Poznań. The selected test route reflected typical city bus operating conditions in large agglomerations. The selected city route has been classified by the bus operator as one of the most heavily loaded in terms of number of passengers and length (16.2 km). The test route had 43 bus stops. A varied configuration of the test route (main city road, residential area roads and downtown roads) ensures high variability of accelerations and share of road congestions, which enables the analysis of the exhaust emissions in a wide range of vehicle operating parameters.

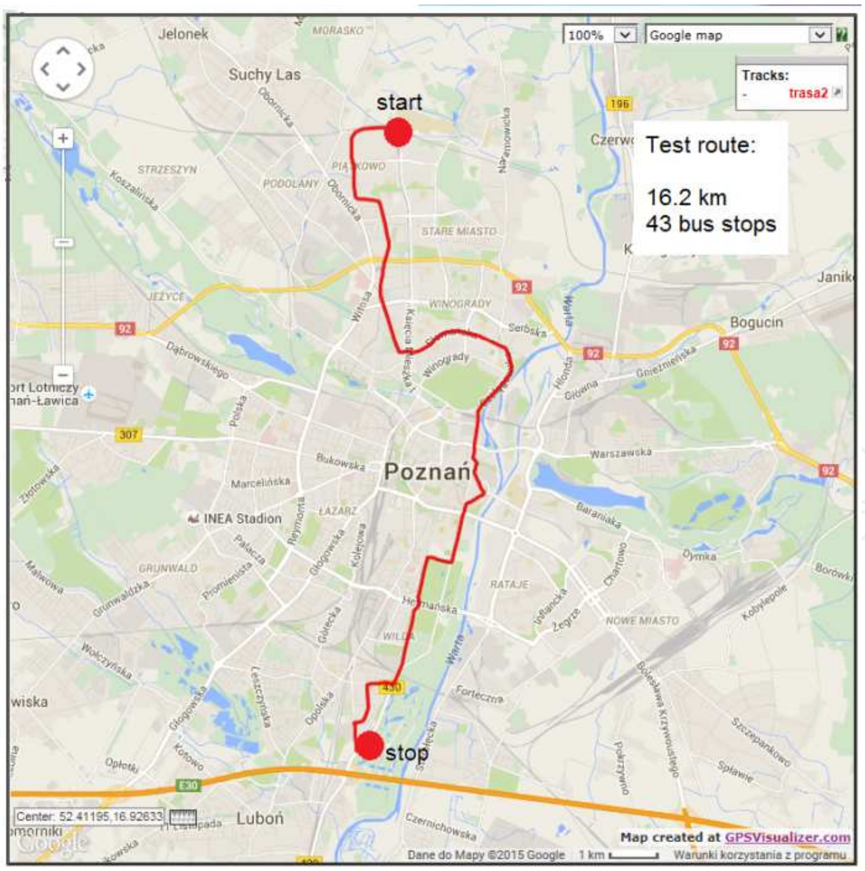

Figure 7. The RDE test route (created at gpsvisualizer.com).

The second stage of the investigations covered the SORT test measurements that are a universal and commonly recognized method of assessment of gas mileage as well as exhaust emissions. These tests are made of modules and reflect three types of traffic conditions – downtown roads, urban roads and extra urban roads (Figure 8; Table 4). The basic module of the SORT cycle is described with vehicle speed, route length and time. These parameters build the velocity profile characteristics of a given route, allowing for the bus stops, stops at intersections, driving off and cruise.

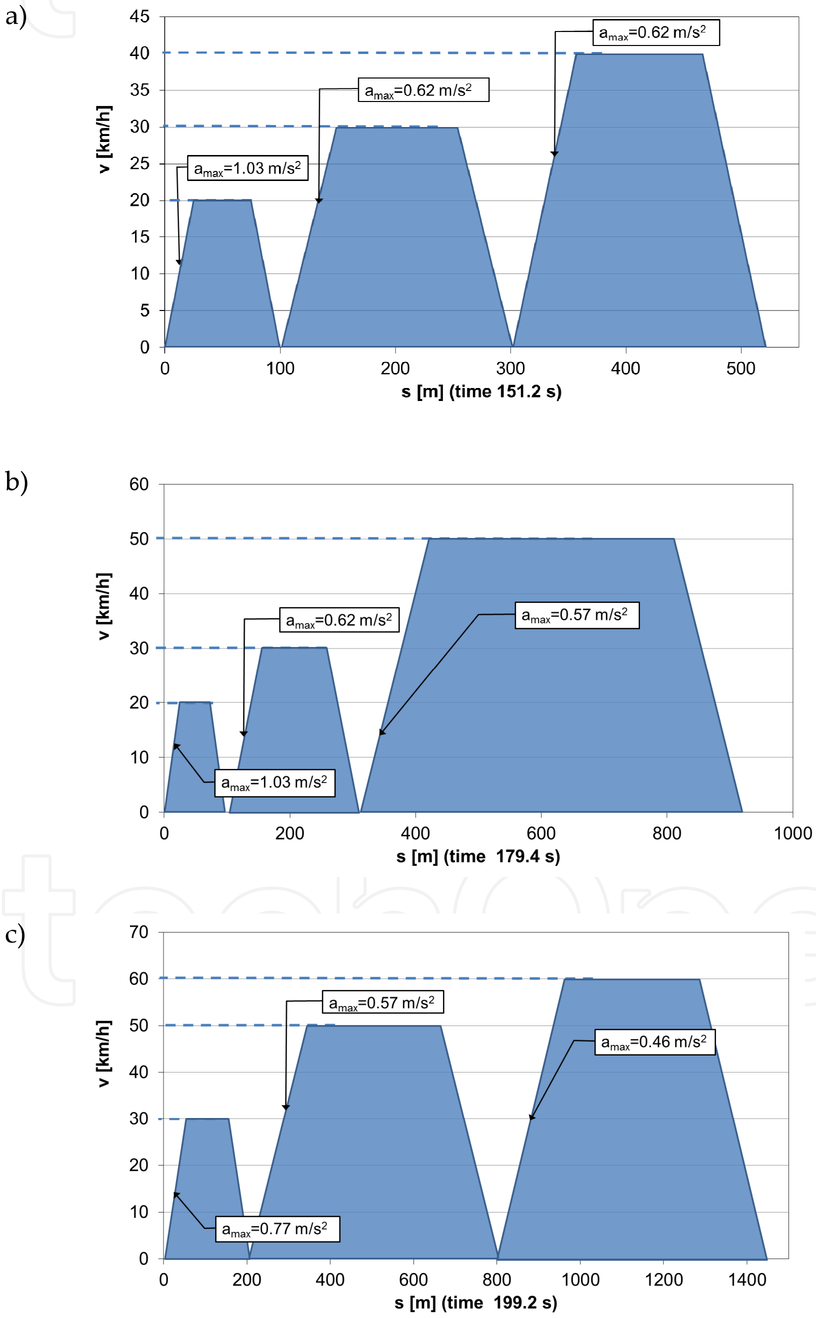

Figure 8. Velocity profiles of the SORT driving tests: a) SORT 1, b) SORT 2, c) SORT 3 [9].

	SORT 1	SORT 2	SORT 3
Average speed [km/h]	12.6	18.6	26.3
Share of stationary vehicle in the test [%]	39.7	33.4	20.1
Constant speed in profile 1 [km/h]/[m]	20/100	20/100	30/200
Acceleration in profile 1 [m/s^2]	1.03	1.03	0.77
Constant speed in profile 2[km/h]/[m]	20/200	40/220	50/600
Acceleration in profile 2 [m/s^2]	0.77	0.62	0.57
Constant speed in profile 3 [km/h]/[m]	40/220	50/600	60/650
Acceleration in profile 3 [m/s^2]	0.62	0.57	0.46
Time of stoppage in each profile [s]	20/20/20	20/20/20	20/10/10
Distance covered in the tests [m]	520	920	1450
Delay in velocity profiles [m/s^2]	0.8	0.8	0.8

Table 4. Characteristics of the SORT driving tests [9]

4. Results and Analysis

4.1. SORT driving cycles

SORT 1, 2 and 3 driving tests were performed for city buses fueled with diesel and CNG fuels. Since the tests were of comparative nature, the driving conditions of the tested buses were analyzed. In Figures 9–11 a comparison of the speeds of the vehicles in individual tests has been presented along with the coefficients of determinacy that are a measure of reproducibility of the driving parameters. The values of the obtained coefficients fall in the range between R^2=0.994 and 0.999. It is commonly accepted that coefficient R^2>0.95 indicates a significant correlation between the tested parameters. This condition was fulfilled for all driving tests in the presented investigations, the driving parameters were comparable, which renders the comparison of the results of the trials fully justified.

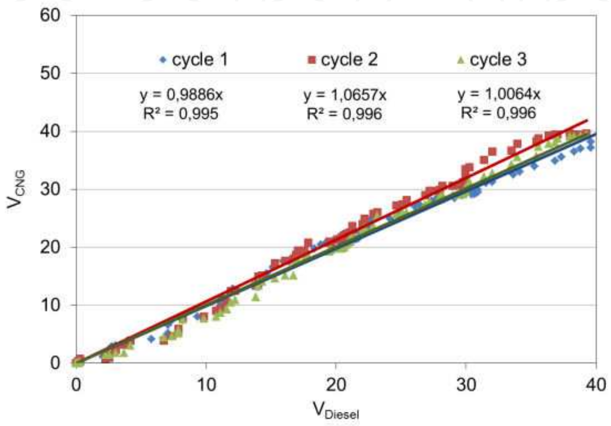

Figure 9. Comparison of speeds of vehicles in subsequent trials of SORT 1 cycles(time compliance allowed for).

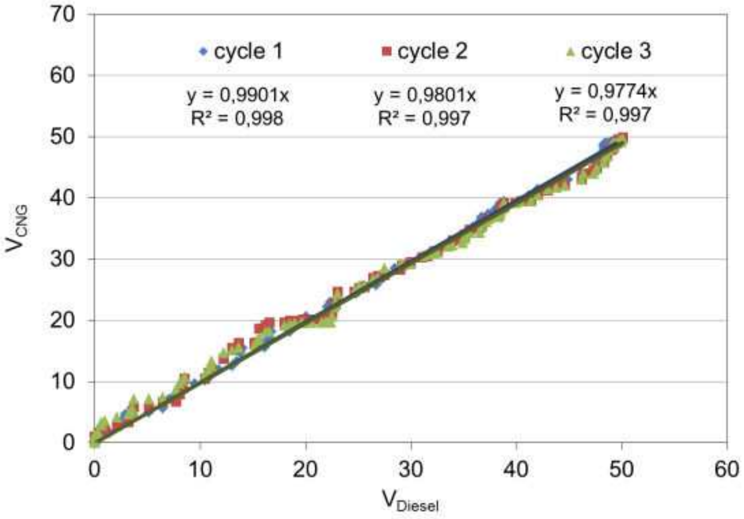

Figure 10. Comparison of speeds of vehicles in subsequent trials of SORT 2 cycles (time compliance allowed for).

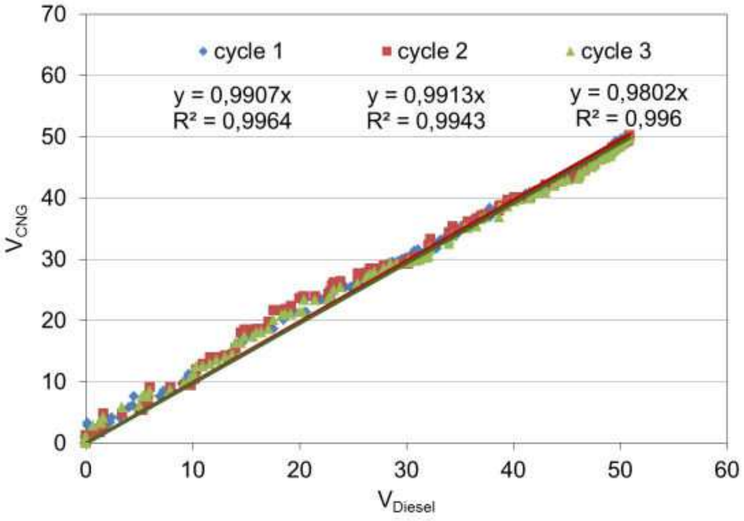

Figure 11. Comparison of speeds of vehicles in subsequent trials of SORT 3 cycles (time compliance allowed for).

Upon analysis of the emission rates it was observed that their greatest values for all emission components occurred in the time when the buses accelerated. It is a result of dynamic changes of engine operating parameters in the acceleration phase. During acceleration, very dynamic changes of engine speed and load take place, reaching momentary values close to maximum, which translates into momentary increase in the exhaust emissions. The greatest values of second-by-second emission of CO for the tested vehicles occurred for drive off and acceleration in the SORT 1 test (Figures 12–14). Momentary acceleration values had a significant influence on the CO emission rate, which is visible in each SORT test. In all analyzed driving tests, the CNG-fueled bus had a higher momentary CO emission rate (up to 307 mg/s) in the acceleration phase. The CO emission rate reduces significantly when the bus speed stabilizes.

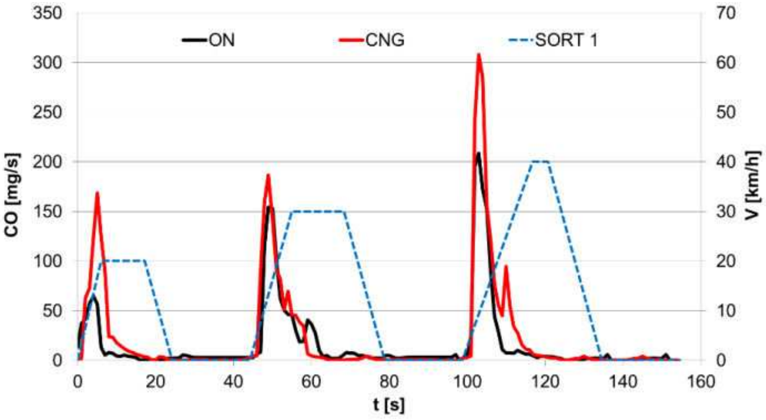

Figure 12. CO emission rate in the SORT 1 test along with the assumed velocity profile.

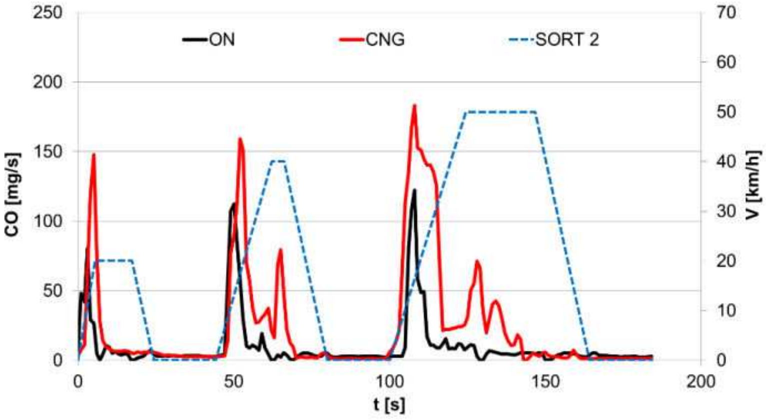

Figure 13. CO emission rate in the SORT 2 test along with the assumed velocity profile.

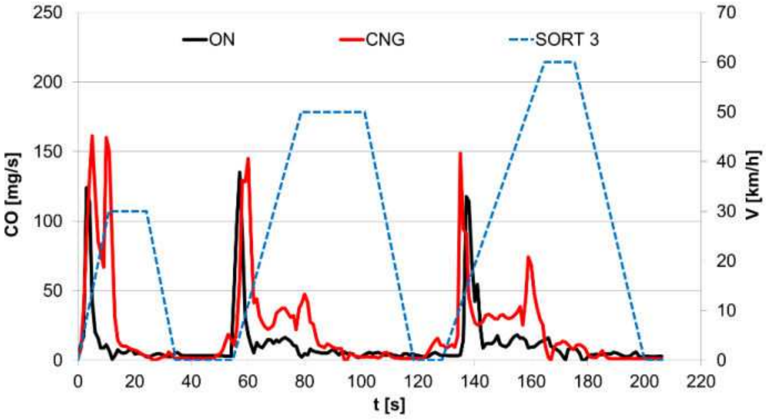

Figure 14. CO emission rate in the SORT 3 test along with the assumed velocity profile.

The emission rate of HC changes analogically to that of CO, higher values were recorded for the CNG-fueled bus (Figures 15–17). The acceleration phase also contributed to the HC emission rate – at this time the emission rate was several times higher than for a constant speed. It is also characteristic that the emission rate of the CNG-fueled vehicle is definitely higher compared to the conventionally fueled vehicle. In the SORT 1 test, the maximum values of the HC emission rate for the CNG-fueled vehicle were 49.2 mg/s, and for diesel- fueled vehicles 1.3 mg/s. For both emission rates (CO and HC) we can see changes resulting from the cooperation of the engine with the transmission. Momentary surges of the emission rates upon reaching the maximum values result from the cooperation of the engine with the transmission system.

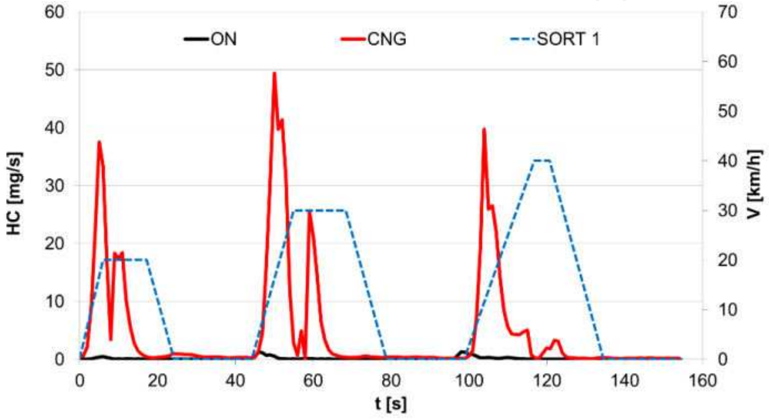

Figure 15. THC emission rate in the SORT 1 test along with the assumed velocity profile.

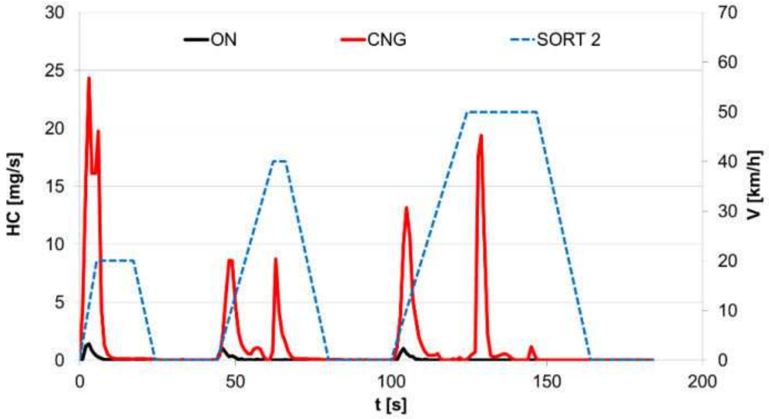

Figure 16. THC emission rate in the SORT 2 test along with the assumed velocity profile.

Very large differences between the CNG- and diesel-fueled vehicles occurred for the emission of NO_x (Figures 18–20). The greatest values were obtained for the diesel -fueled bus in the SORT 1 test. This value reached 302 mg/s during the last stage of acceleration. For the CNG-fueled bus, the NO_x emission rates are much lower (at some points of the SORT tests even tens of times lower) than the values obtained for the diesel- fueled bus. We should thus infer that the value of this emission was significantly influenced by the aftertreatment systems. In the

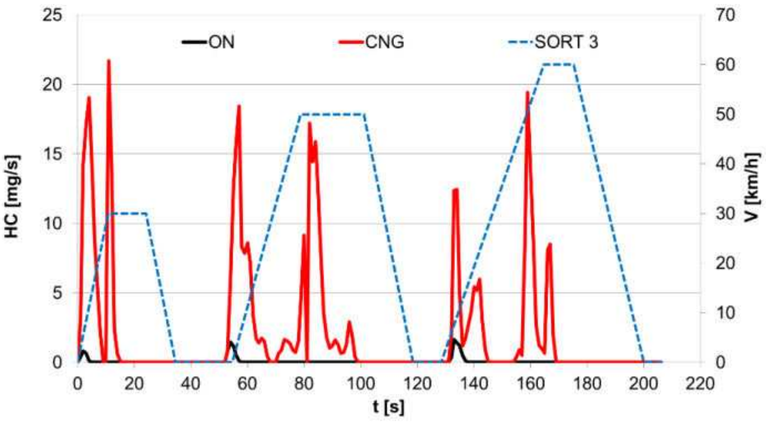

Figure 17. THC emission rate in the SORT 3 test along with the assumed velocity profile.

conventional system, Selective Catalytic Reduction was applied, whose conversion rate heavily depends on the exhaust mass flow (the conversion rate is lower at greater mass flow). The CNG-fueled bus operated with a three -way catalyst, whose conversion rate is not as heavily dependent on the exhaust mass flow as it is on the excess air coefficient.

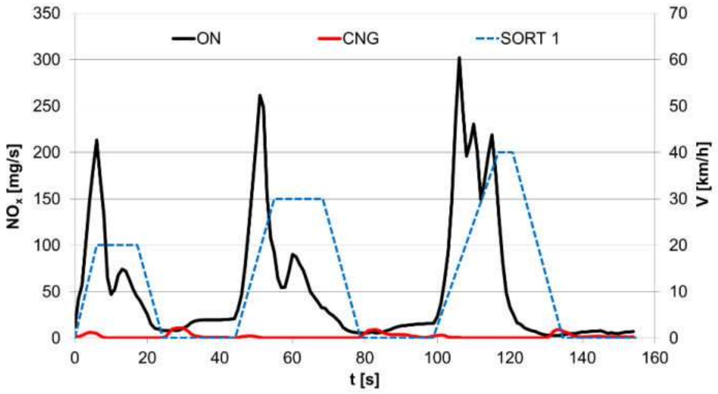

Figure 18. NO_x emission rate in the SORT 1 test along with the assumed velocity profile.

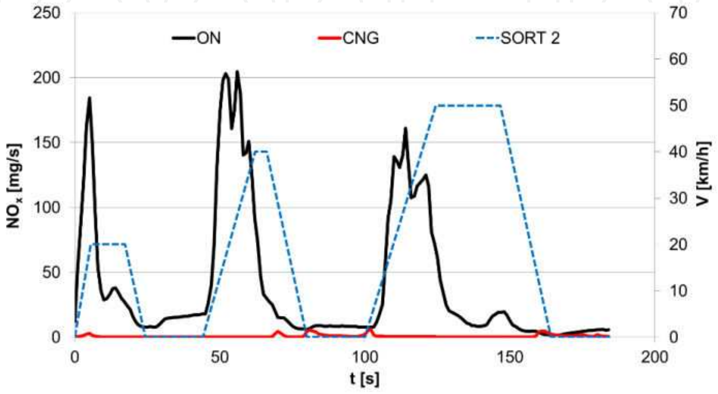

Figure 19. NO_x emission rate in the SORT 2 test along with the assumed velocity profile.

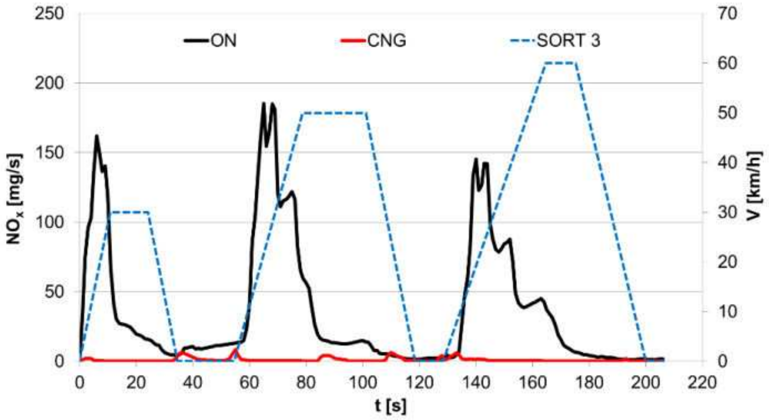

Figure 20. NO_x emission rate in the SORT 3 test along with the assumed velocity profile.

The on-road emissions show similar trends in all SORT tests. From the comparison of these emissions we know that higher values of CO, HC and CO_2 were obtained for the CNG-fueled bus (Figures 21–23). As for CO and HC, it is mainly the effect of engine operation at stoichiometric mixture, which contributes to a greater share of incomplete combustion. It is noteworthy that three-way catalysts have little efficiency in the oxidation of methane one of the main CNG components. Oxidation of methane in catalytic converters requires high temperatures that are usually unobtainable under regular urban traffic operation (hence the lower conversion rate of methane leading to a higher emission of HC for the CNG-fueled bus). It is the HC emission differences that were the highest in all the driving tests (in SORT 2 and 3 they were over 20 times higher for the CNG-fueled bus compared to the diesel- fueled one). The differences in the road emissions of CO and NO_x were lower than those of HC. From the comparison of individual components, we know that the CNG-fueled bus had higher emissions of CO_2 (fuel consumption) in all driving tests. These were small differences. The greatest differences in the SORT 1 test reached 15%. Given the much lower price of CNG compared to diesel fuel, this fuel is far more interesting for the users.

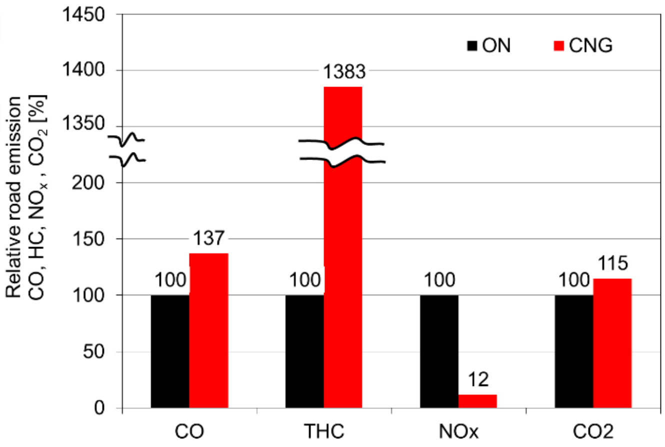

Figure 21. Comparison of relative road emissions in the SORT 1 test.

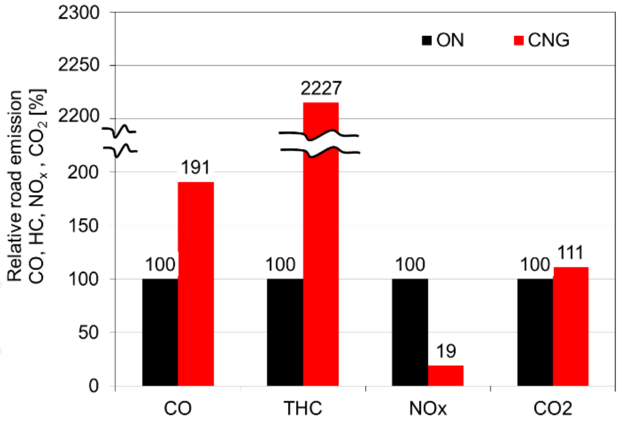

Figure 22. Comparison of relative road emissions in the test SORT 2 test.

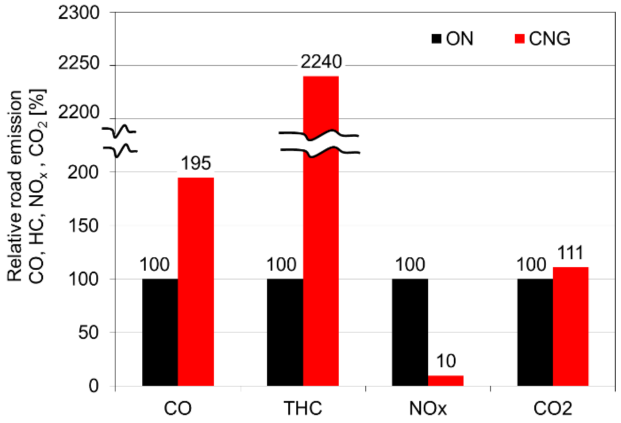

Figure 23. Comparison of relative road emissions in the SORT 3 test.

5. Tests under actual traffic conditions

Another stage of the investigations were measurements performed under actual traffic conditions. In order to reflect true operating conditions, regular passengers were carried during the tests and the buses serviced an actual route (Figure 7). The number of vehicle stops resulting from the process of passenger carriage was preserved. It is, however, difficult to reproduce identical parameters of the vehicle drive due to a variety of factors independent from the vehicle or the driver. One of such factors is the traffic congestion. For the compared drives an analysis of speed changes was performed (Figure 24). From this comparison we know that the speeds of the CNG and the diesel- fueled buses differed. The average speed of the diesel- fueled bus was 18.9 km/h (maximum 68.9 km/h), and the CNG-fueled bus 19.8 km/h (maximum 57.3 km/h). Average speeds, which are the most objective parameter of the assessment of the two drives differed slightly (by 1 km/h). We can thus assume that the comparison of the obtained results of the exhaust emission tests was justified.

Using the data pulled from the CAN network, time density characteristics of the tested engines were developed (Figure 25). The diesel- fueled engine most frequently operated in the speed range up to 1600 rpm. There existed two most frequent load ranges 0–400 Nm and 1000–1400 Nm. The share of the work area when the engine operated at high idle (up to 1600 rpm) is also significant and constituted 18% of the total test time. For the CNG-fueled engine two areas were most frequently used. The first one (of the largest operating time share) occurred for the engine speeds up to 800 rpm and loads up to 200 Nm and, which was 35% of the operating time. The other fell in the range from 800–1200 rpm in the entire load range constituting 49% of the total operating time. It can thus be confirmed that it predominantly operated under load characteristics.

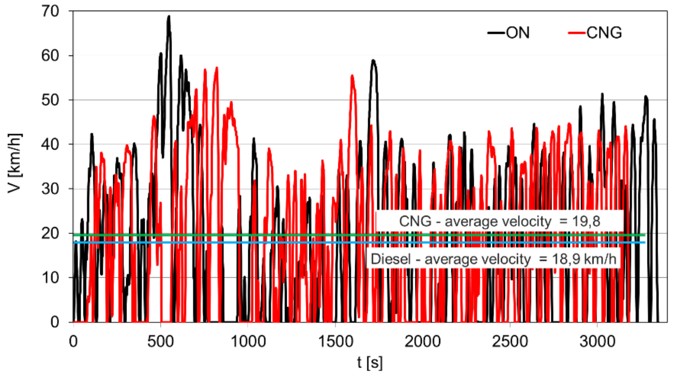

Figure 24. Velocity profiles of CNG and diesel- fueled buses obtained under actual traffic conditions on the city route.

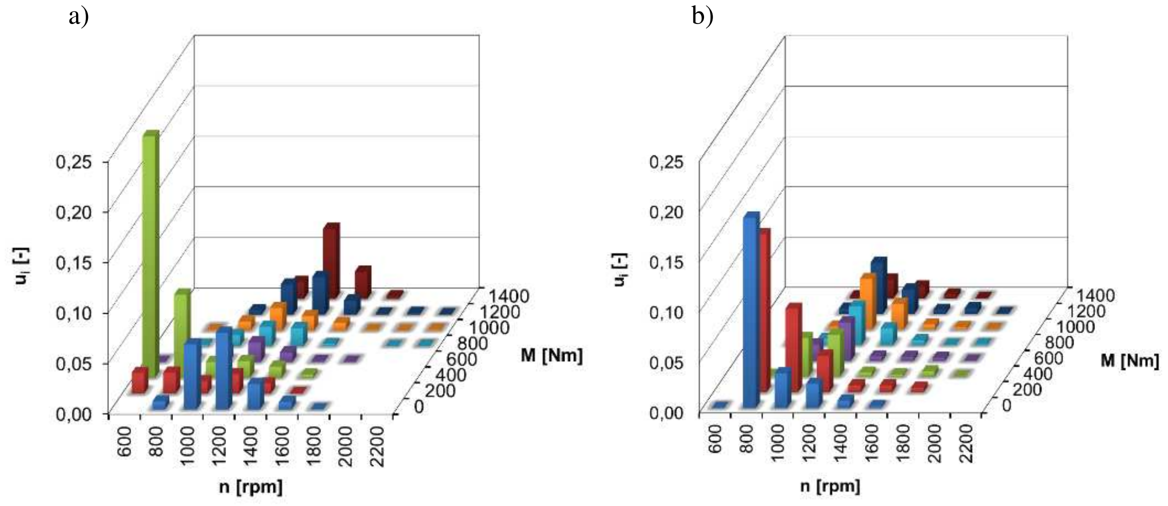

Figure 25. Time share characteristics of the engine speed and engine load during the test on the city route: a) diesel- fueled vehicle, b) CNG- fueled vehicle.

Based on the research performed under actual traffic conditions the values of road emissions were determined and compared (Figure 26). Similarly to the SORT tests, the CNG- fueled vehicle was characterized by a higher emissions of CO, THC and CO_2. For the mentioned exhaust components the differences between the CNG and diesel- fueled vehicles were 78%, 1843% and 18% respectively (Figure 27). The emission of NO_x from the CNG bus was lower by 87%. The specificity of the city route allows for the urban traffic conditions and the obtained results indicate that none of the performed SORT tests fully reflects the parameters characteristic of this route. The obtained exhaust emissions values were influenced by the properties of the applied fuels and the type of thermodynamic cycle of the tested engines.

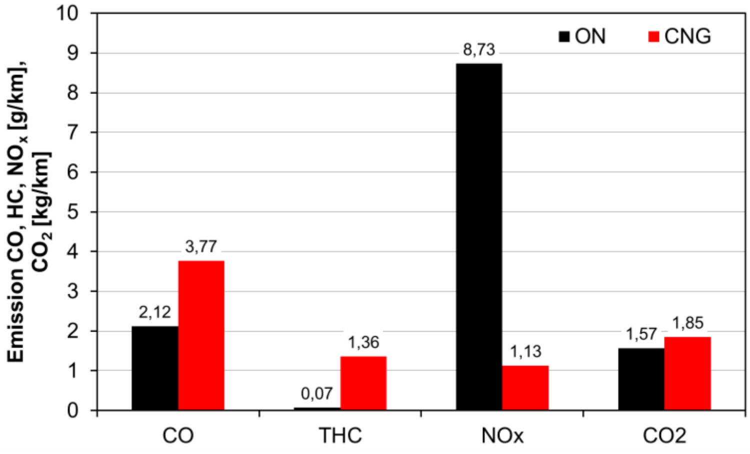

Figure 26. Comparison of the relative road emission obtained in the tests on the city route.

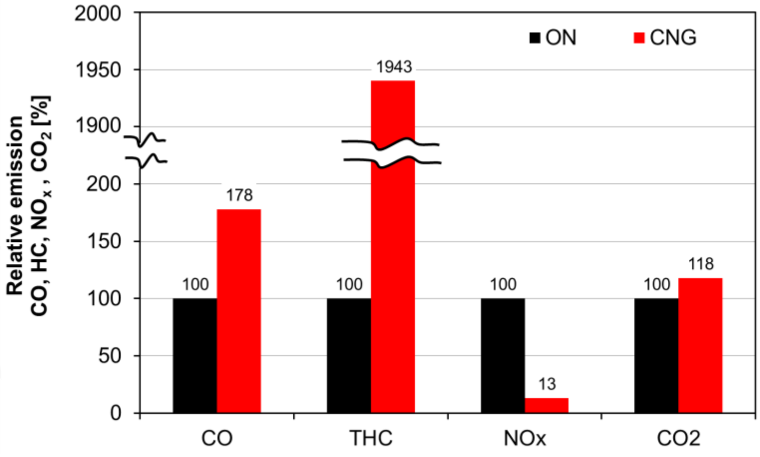

Figure 27. Comparison of the relative road emission obtained in the tests on the city route.

6. Summary

The conducted tests and their results confirm that CNG fuel is a viable alternative to diesel fuel. The results of emission of toxic compounds indicate a high potential for the use of CNG to power city buses and other vehicles. However, the emissions of HC and CO from CNG engines remain a problem. In case of HC emission, the key element is methane, which is a compound difficult to burn even in the oxidation catalysts. Thus, the development of catalytic converters is still an important issue; this should be seen primarily as a possibility of reducing the HC and CO emissions, of course in combination with the optimization of the combustion process. A positive aspect of the presented test is less NO_x emissions from the CNG engine when compared to a diesel engine. Taking into account the aftertreatment emission control methods of NO_x reduction is still the most problematic process. CNG buses, offering low PM and NO_x emissions, should be regarded as eco-friendly means of public transport. In addition to environmental concerns, the economic considerations should also be taken into account and currently CNG is a much cheaper fuel than diesel. Another argument for using CNG to power vehicles is the availability of this fuel. According to estimates Poland alone holds shale gas resources that may even equal 5.4 trillion m^3.

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