THE CONTRIBUTION OF CNG POWERED VEHICLES IN THE TRANSITION TO ZERO EMISSION MOBILITY
Example of the Light Commercial Vehicles Fleet

by

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The aim of paper was to discuss contribution of bi-fuel CNG powered light commercial vehicles to the well-to-wheel CO_2 equivalent emissions, both today and in the coming decades in which the development of new fuels and new vehicles is expected. Field research was done in Belgrade, during one year, using Euro 5 diesel/LPG/CNG light commercial vehicles driving under low vehicle speed, low engine load, low exhaust gas temperature and high number of stops. The well-to-wheel as neutral methodology was applied for understanding of each fuel pathway in terms of reducing greenhouse gas emissions and increasing energy efficiency.
Calculation showed that total energy consumption per kilometre is the lowest for diesel vehicles since petrol/LPG and petrol/CNG vehicles use 21% and 7% more energy. Tank-to-wheel emission of CO_2 equivalent is most favorable for petrol/CNG with 28.8% and 6.7% less CO_2 equivalent with petrol/LPG and diesel vehicles.
The same conclusion brings well-to-wheel analysis showing that diesel/CNG CO_2 equivalent emission is 13.5% less than petrol/LPG, apropos 1.5% less than diesel operated vehicles considered within this field research. Figures are not as high as previous, due to the results of well-to-tank emission, that were most favorable for petrol/LPG powered vehicles, with almost 51% and 32% better results regarding to petrol/CNG and diesel, respectively.
Within same time, lowest fuel cost per kilometre was achieved by petrol/CNG vehicles, with 32% and 35% less cost than petrol/LPG and diesel vehicles.
The available CNG technology should not be neglected, waiting for new solutions to be proven.

Key words*: zero emission mobility, CNG, LPG, light commercial vehicles*

Introduction

The paper presents an analysis of the results of CO_2 equivalent (CO_2e) emissions and total fuel cost upon the use of euro diesel (ED), liquefied petroleum gas (LPG) and compressed natural gas (CNG) powered vehicles. The vehicles with the stated drives are part of the light commercial vehicles (LCV) fleet (vans) operating under urban driving conditions which can be approximated with urban driving cycle (UDC) [1] in order to assess

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the performance of different vehicles in various ways, as for instance fuel consumption or polluting emissions. The key objective of the field research is to present the opportunities and limitations of increased participation of already available and widespread low carbon fuels in the process of transportation transition towards Zero-Emission Mobility. Their contribution to reduction of GHG emissions and global warming potential (GWP) could be significant given that the European Commission's plan is to implement the Zero-Emission Mobility by 2050 [2].

The intention of the paper is to point out that although the development of new solutions in the field of vehicles, fuels and supporting infrastructure is very much underway, it is necessary to take advantage of the available fossil fuels with lower GHG emission, as well as those obtained from renewable sources (biodiesel, ethyl, and synthetic fuels) in terms of cost effectiveness and operational efficiency, to stimulate their rapid application in organized fleets.

Having in mind that transport systems are deeply embedded in the socio-economic life of individuals, institutions and corporations, its significant role in GHG emissions is proving to be a roadblock to decarbonisation in Europe including the Republic of Serbia. Since transport in Serbia is second largest sector responsible for GHG emissions, with 12.4% share [3], encouraging more commercial vehicles fleet into use of already available low carbon fuels and associated vehicles technology should be one of Government's efforts to tackle climate change.

To decrease road transport's GHG emissions, many strategies have been developed to improve reduction of carbon intensity of fuels consumed, energy efficiency of transport vehicles and efficiency of the overall transportation system. After long period of intense research and development within automotive industry, vehicles powered by fuel other than today’s dominant petrol and diesel are present and available in the marketplace.

The EU passenger cars fleet increased by 8% in the period 2014-2018, going from 248 million to 268 million, out of which 33.2 million vans are in circulation throughout the EU. Share of non-petrol/diesel powered vehicles in the EU fleet in 2018 differ by vehicle segment and was around 4.1% in passenger cars, 3.8% in buses and 1.7% in LCV. Same data shows that trends are increasing in all segments pointing out that vehicles powered by low carbon fuels, other than electrically-chargeable vehicles or hybrid electric vehicles, are most present in EU vehicle fleets [4]. Although still insufficiently dominant, the aspect of environmental protection is present today in the decision-making model for the procurement of vehicles, especially for organized fleets.

One of the extensive studies within CONCAWE project [5], developed three different scenarios for EU LCV. The *high ECV* representing mass ECV adoption to ~90% battery electric vehicles (BEV) up to 2050, the *low carbon fuels* representing the use of significant proportions of bio-fuels and electricity, and the *alternative* scenario representing the use of more PHEV (plug and hybrids) together with increased use of bio-fuels and electricity. Having in mind stated scenarios that should lead, if not to *zero* emission in road transport by 2050, at least to values comparable to other sectors of the economy, this paper will discuss contribution of CNG vehicles, as alternatively-powered vehicles within LCV segment, as significant support to GHG reduction during transition to mass ECV adoption (90% BEV) expected by 2050 within *high ECV* scenario.

These changes in the structure of the vehicle fleets will also affect the GHG emissions, which, according to the simulation results for 2050 in *high ECV* scenario, should amount to 135 MtCO_2e. This is significantly less (78% less) than doing business as usual

(BAU) to reduce GHG emissions, since BAU approach will lead only to 30% of reduction in 2050, apropos to 624 $MtCO_2e$.

Starting from the fact that complete electrification requires a set of new and currently non-commercial technologies, that many ongoing researches still discuss best scenarios for transport electrification versus emission factor of electricity production [6], the transient solution over next decades could be sought in combination with internal combustion engines (ICE) more often considered as *dirty* and CNG, LPG, and liquid fuels derived from renewable sources. Common name for these fuels is *low carbon fuels* and from the point of view of available fuels whose use can improve the situation in terms of exhaust emissions and GWP without requiring large capital investments within vehicle (re)construction, CNG and LPG, bio-fuels and renewable synthetics fuels were considered as transit solutions to Zero-Emission Mobility.

Second possibility is use of bio-fuels as a 5-10% addition to petrol or diesel fuels requires no/or minimal additional changes to the vehicles. On the other hand, in order to run efficiently with 15-85% of ethanol, standard ICE require significant modifications. Both stated facts, at this point affect the limitation of the effect of bio-fuels application in reduction of CO_2 emissions from vehicles already present in LCV fleets. In addition, it should be emphasized that currently in Serbia there are no regulations in force, neither producers, nor pumps of such fuels, especially to the extent sufficient for the regular supply of the vehicle fleet.

Also, the use of synthetic fuels is envisaged. Renewable synthetic fuels or e-fuels (e-diesel and e-gasoline) are synthetic fuels created from CO_2, H_2O, and electricity with a process powered by renewable energy. In order to help reduce CO_2 emissions from road transportation, they can be used fully or as addition to petrol or diesel fuels without modifying vehicles. In this moment, their impact in GHG reduction is also limited by costly production process and market constraints.

What are fully available to us in this moment are low carbon fuels such as LPG and CNG with established filling infrastructure which is reflected not only in the sufficient number of stations, but also in the existence of the necessary regulations. Apart of ecological pressure, financial pressure is highly important factor in commercial fleets operation, and therefore market availability of LPG and CNG fuels, vehicles and infrastructure as well now as in the near future could represents good choice, especially having in mind their price (usually less expensive than diesel/petrol due to subsidies and tax differences). Although still insufficiently dominant, the aspect of environmental protection is present today in the decision-making model for the vehicles procurement, especially for organized fleets [7].

Methodology

The GHG are very important due to their GWP. Since CO_2, CH_4 and N_2O are three the most common and most influential GHG that result from combustion [8], and considering that GWP of CH_4 is 21 times greater than that of CO_2 and GWP of N_2O is 310 times greater than that of CO_2, it is important to take into account all of the generated GHG and their GWP and present values of those GHG emissions as CO_2e emission. Therefore, well-to-wheel (WTW) analyses that estimates GHG equivalent emissions and energy efficiency of different automotive fuels was used as neutral methodology to understand the involvement and problems associated with each fuel technology path, taking into account performance in terms of reducing GHG emissions and increasing energy efficiency. Main pathways of WTW are represented in fig. 1.

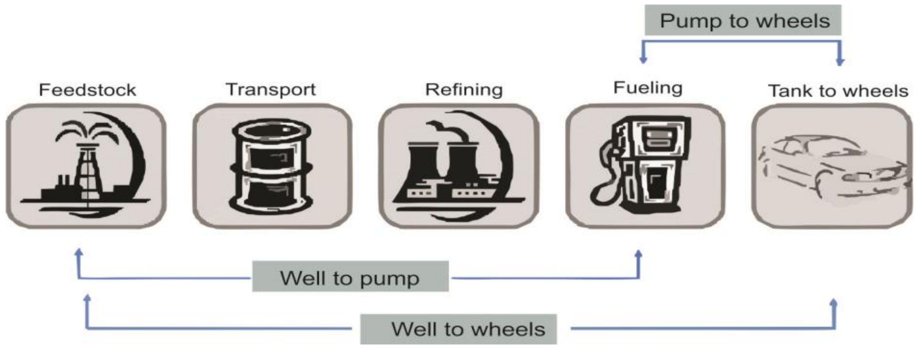

Figure 1. Graphic explanation of WTW approach [9]

A well-to-tank (WTT) or well-to-pump/(tank) emissions factor considers indirect emissions, taking into account the average emission values of all GHG resulting from the production, processing and delivery of fuel. Tank-to-wheel (TTW) or (tank)/pump-to-wheel factors, on the other hand, refers to a part of vehicle's energy chain that extends from the point where energy is absorbed (charge point; fuel pump) to discharge (in motion). When it comes to TTW emissions in the transportation sector, the method of storage and associated energy required is also considered.

A WTT or well-to-pump/(tank) emissions factor considers indirect emissions, taking into account the average emission values of all GHG resulting from the production, processing and delivery of fuel. The TTW or (tank)pump-to-wheel factors, on the other hand, refers to a part of vehicle's energy chain that extends from the point where energy is absorbed (charge point; fuel pump) to discharge (in motion). When it comes to TTW emissions in the transportation sector, the method of storage and associated energy required is also considered.

The WTW does not take in consideration emissions or energy related to buildings, vehicles or their disposal as end life aspects and therefore it differs from life cycle analysis (LCA). In the age of transition towards E-mobility and decarbonization, WTW approach that covers all energy consumption and all GHG emissions from fuels generated by fuel production, supply and operation has been selected due to its holistic review to the possibilities of the vehicle fleets operation contribution in the near future. It differs from life cycle assessment and can therefore be seen as a simplified LCA that treats energy consumption and CO_2e emissions only for the fuel consumed, without considering other phases of the vehicle life cycle. The WTW methodology is widely used for policy support in road transport [10].

The field research was performed within the LCV vehicle fleet that provide the service in city of Belgrade under specific driving conditions of low vehicle speed, low engine load, low exhaust gas temperature, and high number of stops. Such driving conditions are most similar to those prescribed as UDC – composing part of most recent New European Driving Cycle [1].

In order to conduct field research, a Euro 5 LCV vehicle fleet which includes diesel, CNG and LPG powered vehicles of the similar van type is required and in this case diesel, petrol/LPG, petrol/CNG vehicles have been the subject of research. For the purposes of the experiment same numbers of diesel, petrol/LPG, and petrol/CNG vehicles were considered. Those vehicles exceeded similar mileage with a very close number of stops (due to the delivery of goods) in similar operating conditions. These starting restrictions are necessary due to the fact that selected bi-fuel vehicles with spark-ignition engines use petrol for every start of the vehicle in order to switch to LPG or CNG driving cycle. Same starting conditions were also a guarantee of a fair comparison between all concerned vehicle configurations, to ensure that each power train fuel configuration meets the same customer expectations in terms of vehicle drivability/deliverability.

More specifically, for the annual field research 3 diesel, 3 petrol/LPG, and 3 petrol/CNG vehicles less than 2 years old, with average curb weight (excluding driver and fuel) of 1100 kg were considered (Skoda Fabia 1.6 TDI, Fiat Grande Punto 1.4 LPG/CNG, 55 kW). Those vehicles exceeded similar mileage after 12 months of observation with a very close number of stops (from 900 to 1100 stops per month with less than 2 km between stops) and with average speed under 14 km/h (from 9 km/h till 13.7 km/h). These reference vehicles are used as a tool for comparing the possible contribution of the use of available alternative fuels within currently available vehicle technologies to reduction of GHG emissions and consequently GWP.

The conducted experiment was open – LCV drivers, apropos their driving style were not part of the conducted analysis. The analysis is based on the results recorded in one Serbian transportation company through observation model given in fig. 2.

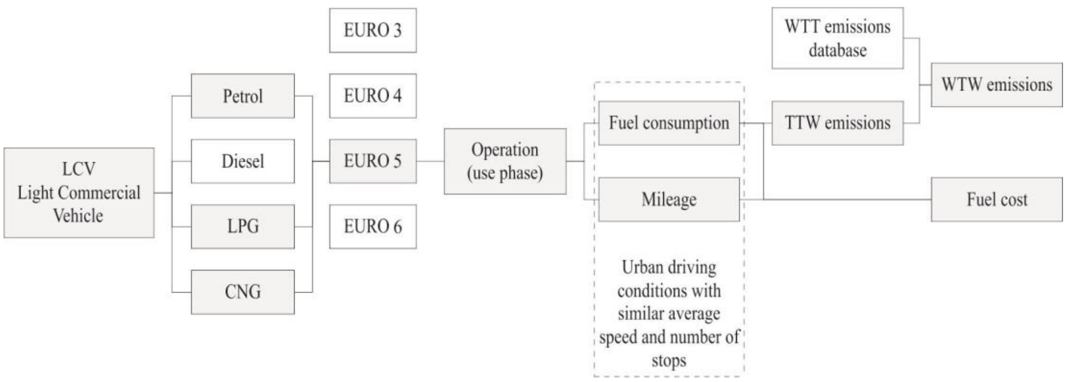

Figure 2. Observation model

The monitored parameters were mileage (km), amount of the fuel purchased (L and kg of considered fuels) and fuel costs (EUR/L, EUR/kg). The monitoring period was one year with one control measurement after 3 months. Data on mileage were taken from travel orders; data on the amount and price of purchased fuel were gathered from relevant accounting documentation.

The GHG emissions were not directly measured, but determined using relevant TTW factors for CO_2e emission of considered fuels per kilometer traveled given in World LPG Association report [11]. In order to determine such a defined parameter for comparison, energy released from the considered fuels was calculated in MJ based on the amount/volume of fuel consumed and the net calorific value (NCV) [12, 13]. The data thus obtained were used to calculate the TTW CO_2e emission per kilometer traveled. Having in mind that monitored vehicles traveled very similar mileage in the very similar driving conditions, that coincide to available statistics, where average mileage of a passenger car within the EU is 15000 km and average lifetime is 10.5 years [14, 15], further calculation considered annual emission contribution.

Since similar research in Serbia has focused mainly on bus fleets and public transport [16, 17], thus obtained results were compared with the results of Joint Research Centre of the EU Commission on their joint evaluation of the WTW energy use and GHG emissions for a wide range of potential future fuel and power-train options [18] as well as with the analysis of exhaust emissions from the study of Deutsches Zentrum für Luft und Raumfahrt e.V. (DLR) regarding potentials of CNG and LPG as transportation fuels [19].

Since the change of fuel prices on annual (even monthly and weekly) level is very important for the management of the fleet, comparison of the cost takes in consideration annual fuel price value change in 2016th, fig. 3.

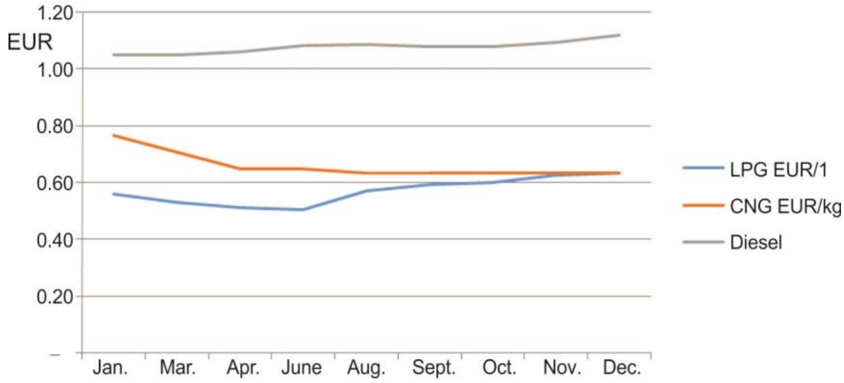

Figure 3. Annual price value change of petrol/LPG/CNG

Explanation of strong difference between total fuel price lies within the fact that diesel price increase was 7%, LPG 13% on annual level, while CNG price decrease 17% for the same period. Strong difference in price change and trends is also due to the long term state policy to support CNG as environmentally friendly fuel by omitting excise duty on this fuel.

The supply pathways as well as origin of the natural gas are critical to the overall GHG emission and balance, but most of all to WTT emission. In this moment, beyond the local natural gas reserve, Russia is the most credible long-term major supply source for Serbia.

Results

The first step of the calculation was to determine the specific energy consumption expressed in MJ/km. It was followed by the calculation of CO_2e emission through TTW, WTT and WTW pathway, explained in more details in Figure 1. Stated calculation provided results of CO_2 equivalent emission in gCO_2e/km. Along with so calculated emissions, the operating costs of vehicle use in terms of fuels consumption were observed and expressed in EUR/km.

Fuel consumption

Average data collected and calculated over 3 and 12 months for petrol/LPG, petrol/CNG and ED vehicles are given in tab 1.

The monitoring period was one year with one control measurement after 3 months. Data collected as described in methodology are mileage and diesel/LPG/CNG total consumption and purchase costs. Petrol consumption per travelled km and participation in overall bi-fuel consumption are calculated.

Control point, in order to check the mileage of selected vehicle sample was realized after 3 months. Since the mileage difference was up to 14%, minor route changes were introduced which resulted in difference being reduced, so that at the end of the observed period it was less than 2%. In this way, same starting conditions provided fair comparison between all investigated vehicle configurations.

Table 1. Average values over 3 and 12 months for petrol/LPG, petrol/CNG, and ED vehicles under urban driving conditions

Vehicles	Petrol/LPG		Petrol/CNG		ED	
Months	3	12	3	12	3	12
Total consumption; LPG/ED [L], CNG [kg]	630.29	1,513.30	389.18	834.25	409.27	1010.91
Consumption of specific fuel; LPG/ED [L/100 km], CNG [kg/100 km]	9.85	10.27	5.47	5.45	6.61	6.55
Total consumption of petrol [L]	91.93	199.76	55.44	116.54	–	–
Consumption of petrol [L/100 km]	1.47	1.33	0.80	0.76		
Mileage total [km]	6,479.00	15,151.33	7,165.33	15,300.67	6187	15,435.00
Cost of petrol [€]	405.24	924.85	300.55	606.84	–	–
Cost of specific fuel [€]	59.34	121.45	42.18	82.16	–	–
Cost total [€]	464.58	1,046.30	342.74	689.00	445.09	1,133.06
Fuel total [–]	722.22	1,713.07	444.62	950.79	409.27	1,010.91

The CO_2e emission – tank-to-wheel

In order to calculate TTW CO_2e emission for running 1 km of diesel/LPG/CNG operated vehicle, specific energy consumption expressed in MJ/km was required and NCV of considered fuels was used for calculation within following formula:

$$TTW\,\mathrm{GHG}\left(\frac{g\mathrm{CO_2e}}{\mathrm{km}}\right)=\text{Fuel Energy Consumption}\left(\frac{MJ}{\mathrm{km}}\right)\;TTW\,\mathrm{GHG}\left(\frac{g\mathrm{CO_2e}}{MJ\,\mathrm{fuel}}\right)$$

Based on NCV of 35.94 MJ/l for diesel, 24.67 MJ/l for LPG and 45.86 MJ/kg for CNG, following determined petrol/LPG participation, apropos petrol/CNG participation, it can be concluded that total energy consumption per kilometer is the lowest for diesel operated vehicles. Petrol/LPG and petrol/CNG operated vehicles use 21% and 7% more energy than diesel ones, tab. 2.

Table 2. Specific energy consumption of diesel/LPG/CNG operated vehicles and TTW CO_2e emission

	NCV	Average fuel energy consumption MJ/km		Average TTW emission gCO_2e/km	
		3 months	12 months	3 months	12 months
Petrol/LPG					
LPG	24.67 MJ/L	2.43	2.53	159.41	166.14
Petrol	32.7 MJ/L	0.48	0.44	38.06	34.64
Total	–	2.91	**2.97**	197.46	**200.78**
Petrol/CNG					
CNG	45.86 MJ/kg	2.51	2.50	123.46	123.17
Petrol	32.7 MJ/L	0.26	0.25	20.70	19.78
Total	–	2.77	**2.75**	144.16	**142.96**
Diesel					
ED	35.94 MJ/L	2.38	**2.35**	189.24	**187.37**

The TTW emission of CO_2e is most favorable for CNG powered vehicles, with 142.96 gCO_2e/km.

Results considered fuel emission during vehicle operation (from the point where energy is absorbed to its discharge) showed that emission of CO_2e with CNG is 28.8 % less than with petrol/LPG and 6,7 % less than with ED powered vehicles, fig. 4.

The CO_2e emission – well-to-tank

Since WTT emissions factor considers indirect emissions as an average of all the GHG emissions released into the atmosphere from the production, processing and delivery of a fuel, as explained in fig. 1, for full understanding of obtained results it should be said that most of natural gas comes to Republic of Serbia from Russia.

Data calculated for WTT CO_2e emissions of diesel/LPG/CNG operated vehicles after 12 months of field research are given in fig. 5.

The WTT CO_2e emission factors were taken from research conducted by the World LPG Association [11] and together with previously calculated specific fuel consumption, tab. 2, provides WTT CO_2e emission per kilometer. In difference of TTW emission results, petrol/CNG powered vehicles did not show best results in WTT emission model of calculation. Emissions results considering mentioned indirect emissions were most favorable for petrol/LPG powered vehicles, with almost 51% (50.9) and 32% (32.3) better results in regards to CNG and ED, respectively.

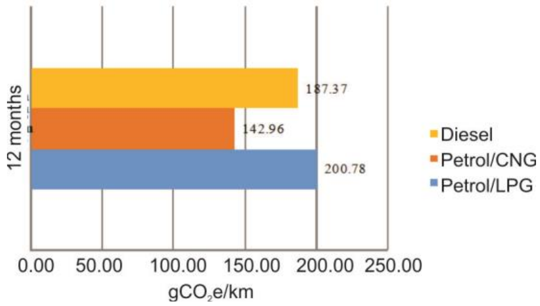

Figure 4. The TTW CO_2e emission after 12 months

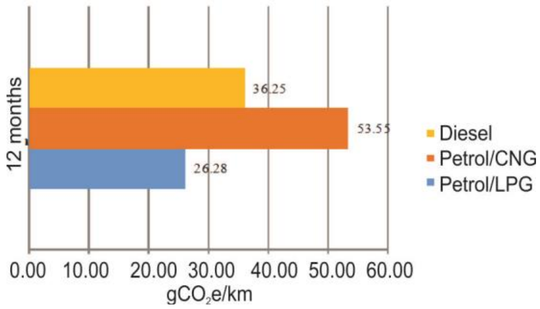

Figure 5. The WTT CO_2e emission after 12 months

The CO_2 equivalent emission – well-to-wheel

The WTW analyses, estimating GHG emissions and energy efficiency of automotive fuels, showed that operation of CNG powered vehicles brings the greatest reduction in CO_2e emission. Data calculated are given at fig. 6 following application of:

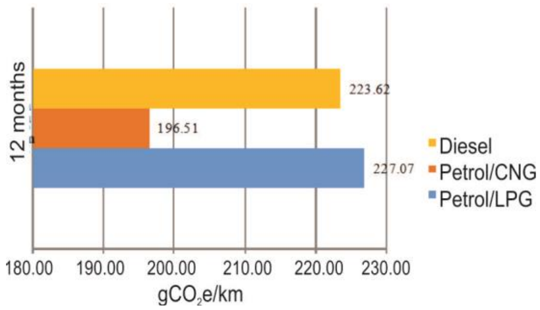

Figure 6. The WTW CO_2e emission after 12 months

$$WTW\left(\frac{\text{gCO}_2\text{e}}{\text{km}}\right)=TTW\left(\frac{\text{gCO}_2\text{e}}{\text{km}}\right)+WTT\left(\frac{\text{gCO}_2\text{e}}{\text{kg}}\right)$$

The WTW CO_2e emission results present sum of TTW and WTT results, and even though in the first case favorable and in the second case unfavorable for CNG, total WTW results showed that CNG WTW CO_2e emission is 13.5% less than petrol/LPG, apropos 1.5% less than diesel operated vehicles.

Fuel costs

Gathered data regarding total annual fuel cost, mileage and fuel consumption for diesel/LPG/CNG operated vehicles on annual level are given in tab. 5.

Table 5. Total annual fuel cost for diesel/LPG/CNG vehicles

	ED	Petrol/LPG	Petrol/CNG
Period (months)	12	12	12
Total mileage (km)	15435.00	15151.33	15300.67
Total fuel cost (EUR)	1133.06	1046.3	689.00
Fuel cost per mileage (EUR/km)	0.073	0.069	0.047

Considering that the field research was conducted in a manner that vehicles with similar characteristics in similar urban driving conditions achieve close values of mileage, the conditions for an objective comparison were created. As can be seen, for very similar mileage lowest total fuel cost was achieved by petrol/CNG powered vehicles. In terms of fuel cost per mileage petrol/CNG vehicles generated 35% less costs then diesel and 32% less costs then petrol/LPG operated vehicles.

All considered vehicles generated the same transport work, but petrol/LPG and petrol/CNG vehicles done it at lower fuel costs. From previous results it is obvious that petrol/CNG vehicles provide transport service at lowest fuel costs, with a lowest WTW CO_2e emission – which makes petrol/CNG powered vehicles at the same time energy friendly and cost effective for operation in LCV fleet.

Discussion

Fleet management has been analysed for many years, but in recent times this segment has become very important due to the benefits that can be achieved in environmental protection. Therefore, decisions on the composition of the vehicle fleet should be made taking into account environment friendly fleet operation. The aim of this research was to provide conclusions relevant both from the point of costs and contribution to the reduction of GHG and GWP in order and to promote instant solutions among available technologies both in terms of fuels and vehicles.

In 2014 EU has published report regarding WTW analysis of future automotive fuels and power-trains in the European context with expectations for 2020+ [18]. Mentioned report has taken in consideration due to same vehicle segment and same fuels as in field research from this paper. Result given in Report EUR 26236 EN for 2020+ are given from the point of vehicle improvements expected in 2014, mainly through technological progress (*e.g.* friction reduction, engine control, combustion improvements, improvements in aerodynamics, rolling resistance and a weight reduction, *etc.*) and predicts around 4% and 9% reductions in CO_2e LPG and Diesel emissions relative to CNG emissions, mostly due to significant influence of WTT part.

By comparing the results obtained on the basis of the conducted field research (fig. 6) and the predictions for 2020+ (based on laboratory tests), given in the Report EUR 26236 EN, fig. 7, it is possible to establish difference between obtained and foreseen WTW CO_2e emission.

Another similar research was conducted in 2013th by Deutsches Zentrum für Luft und Raumfahrt e.V. (DLR Report) investigating the utilization of CNG and LPG in motor vehicles with predictions for 2030. Comparison shown that highest WTW emission has LPG fuel, followed by 2% lower emissions from diesel and 7% lower WTW CO_2 emission from CNG powered vehicles.

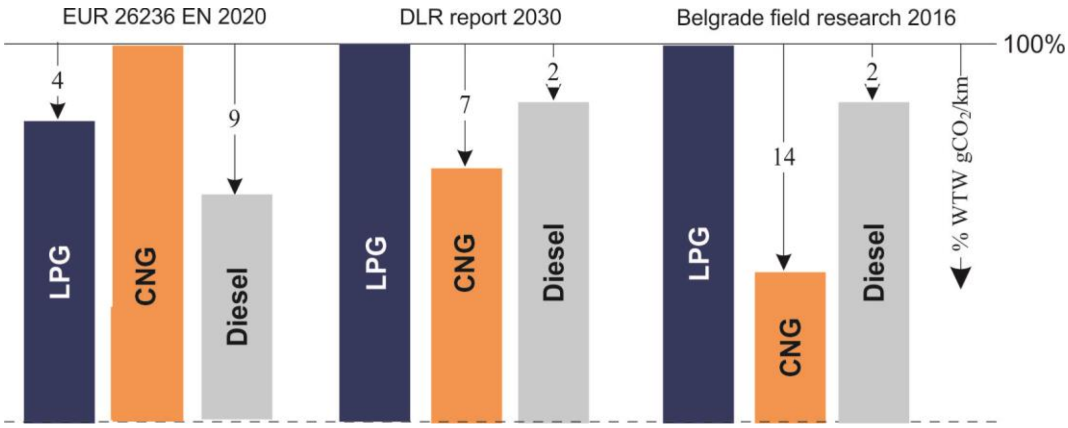

Figure 7. The WTW CO_2e emission compared to results of EUR 26236 EN report [18] **and DLR report** [19]

It can be noticed that WTW emission results for CNG/LPG powered vehicles vary and that DLR study and Belgrade research results are in favour of CNG > Diesel > LPG powered vehicles, while EUR report are very optimistic towards Diesel > LPG > CNG powered vehicles. Predictions given in Report EUR 26236 EN were directed towards higher improvements in vehicle technology and combustion processes (TTW) leaving supply pathways (WTT) at lower development level. Main focus on TTW emissions and vehicle technology could be compromised due to, for instance, Volkswagen emission scandal where USA regulators accused the company of programming perhaps 11 million vehicles worldwide to falsely show on official tests that the vehicles were emitting lower levels of harmful emissions than they actually were when being driven on the roads [20, 21].

Having in mind that Belgrade field research was done in 2016th, this conceptual difference in shown results could indicate that the development in the field of vehicle technology in just 3 years' time did not go along with predicted level in Serbian region.

Presented Belgrade field research results and DLR study is similar. Since DLR study takes in consideration development in alternative pathways also (WTT), assuming that CNG engines may utilize renewable methane from additional supply pathways, *e.g.* synthetic methane derived from biomass or renewable electricity, results differs from EUR 26232 EN with prediction in favour of CNG. Within this paper, emissions were indirectly calculated, based on a field experiment, and since the results of the CNG emission do not conflict with those obtained by the Deutsches Zentrum für Luft und Raumfahrt e.V., current potential of CNG WTW contribution to GHG and GWP reduction should be taken with greater attention.

Conclusion

The main aim of this paper was to discuss the contribution that CNG-powered LCV vehicles can make to WTW CO_2e emissions, both today and in the coming decades during which the development of new fuels, new pathways and new vehicles is expected.

Bearing in mind the aim of strengthening the decarbonization of transport even before the full implementation of new solutions in the field of fuel and vehicles, in the so-called transition period, WTW approach, with WTT as indirect and TTW as direct parameter, was, in our opinion, the right angle for analysis as considers a sum of contributions to GHG emissions.

Calculation based on field research showed that total energy consumption per kilometer travelled is the lowest for diesel operated vehicles, while petrol/LPG and petrol/CNG operated vehicles use 21% and 7% more energy than diesel one. On the other hand, TTW emission of CO_2e is most favorable for CNG powered vehicles with 142.96 gCO_2e/km, which is 28.8% less than petrol/LPG and 6.7% less than Diesel powered vehicles. Since TTW emission is considered as tailpipe emission, vehicles combustion process is most relevant for these results.

In difference of TTW emission results, petrol/CNG powered vehicles did not show best results in WTT emission model of calculation. Emissions results considering mentioned indirect emissions were most favorable for petrol/LPG powered vehicles, with almost 51% and 32% better results in regards to CNG and Diesel, respectively. This result is due to the smaller amount of energy required to produce and deliver LPG/Diesel fuels locally, in difference to CNG-related delivery process.

The WTW CO_2e emission results present sum of TTW and WTT results, and even though in the first case favorable and in the second case unfavorable for CNG, total WTW results showed that CNG WTW CO_2e emission is 13.5% less than petrol/LPG, apropos 1.5% less than diesel operated vehicles.

Lowest total fuel cost per mileage during field research was also achieved by petrol/CNG powered vehicles. In terms of fuel cost per mileage petrol/CNG vehicles generated 35% less costs than diesel operated vehicles and 32% less costs then petrol/LPG operated vehicles.

Fact that petrol/CNG operated vehicles provide expected transport work in the same driving conditions at lower fuel costs together with a lowest WTW CO_2e emission classifies them as most energy friendly cost effective vehicles within observed LCV fleet. This shows that introduction of more currently available CNG powered LCV within such fleets could be solution for better emission result in local environment, and consequently global as well. Having in mind that in 2012 share of LCV in overall natural gas consumption in transport was 28%, such immediate contribution of CNG available technology along the path towards developing zero emission mobility solutions, should not be neglected.

The research was carried out on EURO 5 CNG vehicles and showed that those vehicles, could represent a good choice for local air quality, as well as the climate. Although the improvement of various technological solutions in the field of vehicle propulsion and fuel is slower than expected, it is still going at the same pace for all types of propulsion, which allows CNG-powered vehicles to maintain a good *green* position even in the coming period. With Euro 6 and Euro 6D, emissions will be reduced for all three considered vehicles groups, but the ratios will remain approximately the same. The change in the structure of the vehicle fleets affects the GHG emissions and therefore, a rapid shift of LCV fleets to CNG as available low carbon fuel through currently available vehicle models may offer a significant GHG reduction potential, necessary in transition period towards clean fuels and *green* vehicles.

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