University of Banja Luka
Faculty of Mechanical Engineering

DEMI 2015
12. International Conference
on Accomplishments
in Electrical and
Mechanical Engineering
and Information Technology

APPLICATION OF BIOMETHANE IN PROPULSION AND MOBILE SYSTEMS

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Summary: *Human activities, in particular transport, are partially responsible for the problems associated with the greenhouse effect, and therefore global warming. The European Union is increasingly dependent on imported fossil fuel. From the second side, oil products come from politically unstable regions, oil prices are rising and resources are limited. This complex situation leads to significant ecological and economical risks for society. The European Commission is seeking to solve these issues through a series of initiatives, including many that focus on the transport, which is almost fully dependent on oil. In this context, it has launched every time a calls for projects that focus on biofuels. Our research inside of the paper is redirected on the training to take action with similar projects. We are analyzed here the possibilities for production of biogas from landfill and agricultural crops. By upgrading biogas to bio-methane we produce the high quality fuel for mobility systems causing lower exhaust emission specifically particulate matter, sulfur compounds, non-methane hydrocarbons and nitrogen oxide, as well as smog and noise pollution in the atmosphere.*
Key words: Global warming, Transport, Biomethane.

1. INTRODUCTION

From the vehicles are required to meet increasingly stringent regulations for emissions of toxic and harmful products of combustion. By this route the European Commission the Directive 93/116/EC prescribed permissible total emissions of carbon dioxide (CO_2) to an average of 130 g·km^{-1} for all newly produced passenger cars (vehicle category M1) starting from 2015, and 95 g·km^{-1} from 2020. From 2012 to 2018, the penalties are €5 per vehicle for the first g·km^{-1} of CO_2; €15 for the second gram; €25 for the third gram; €95 from the fourth gram onwards. From 2019, manufacturers will pay €95 for each g·km^{-1} exceeding the target [1,2].

The regulation is applicable also to vehicles category N_1 with a reference mass not exceeding 2610 kg. Light Commercial Vehicles (LCVs) must meet the following emission targets:

- 2017: The legislation for vans introduced a fleet-average CO_2 emission target of 175 g·km^{-1} fully phased-in by 2017.

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- 2020: The average CO_2 emissions of new LCVs registered from 2020 will have to meet 147 g $CO_2 \cdot km^{-1}$.

The penalties for manufacturers who fail to meet their average targets are:

- Until 2018 the penalty is €5 per vehicle for the first g·km^{-1} of exceedance, €15 for the second g·km^{-}, €25 for the third g·km^{-1}, and €120 for each subsequent g·km^{-1}.
- From 2019, the penalty is €120 for each g·km^{-1} exceeding the target.

Limit values for emissions of other toxic products of combustion are contained in the regulations Euro 6 for passenger cars and vans, and Euro VI for heavy duty vehicles. The emission standards are effective from 2014. Generally, the goal is to reach by 2020 significantly reduce the number of vehicles in traffic on driven with petrol and diesel engines [1].

Vehicles on biomethane/natural gas (NGVs) already meet the emission limit values, Fig. 1 [2]. By using other available technologies, it is not possible to reduce CO_2 emissions, without the enormous increase in vehicle price, which is not acceptable from the user's perspective. It is expected that over time the price difference between conventional diesel vehicles and NGVs to be lower and disappear completely. This is the reality because of lower price of biomethane/natural gas as fuel, as well as because the fact that gas engines with existing systems, can to meet Euro VI regulation with minor modification (process modification is defined in Regulation No. 595/2009 by the EC). Emissions of the mobile systems on methane, as well as part of the emission which refers to process of producing fuels, further are lower in the case of the use of biomethane as a fuel [2].

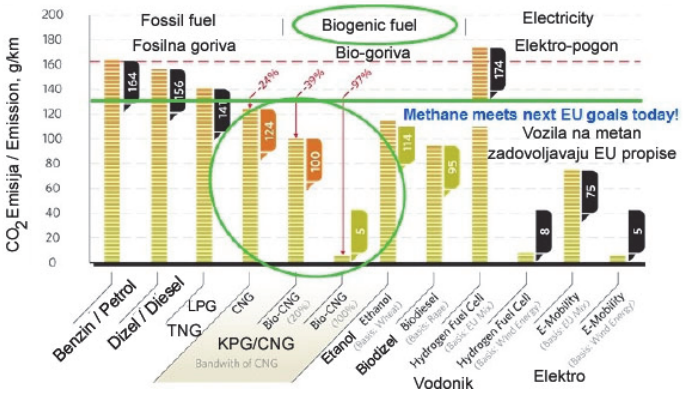
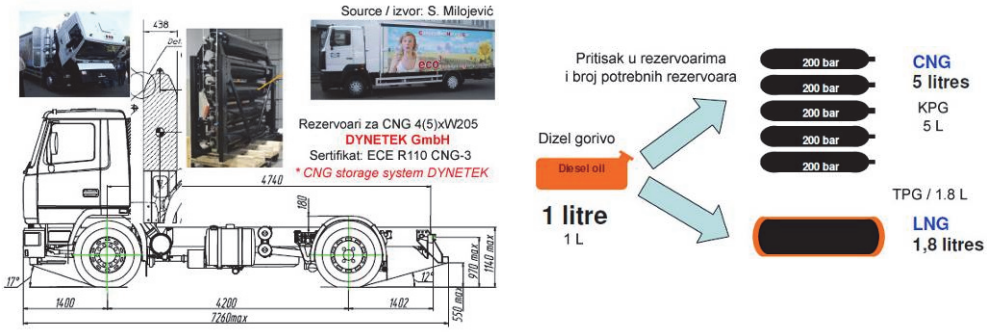


Fig. 1 *Methane (NG/biomethane) vehicles already meet the next EU goals today*

2. CONCEPTIONS OF MOBILE SYSTEMS ON BIOMETHANE

Biomethane is stored in motor vehicles similar to the natural gas: in gaseous state, as compressed natural gas CNG, or as liquid, *i.e.* liquefied natural gas LNG. We have proposed a project of domestic truck on CNG, whose is technically permissible maximum mass 18,000 kg. The truck chassis is equipped with the gas engines MAN, Cummins or Mercedes-Benz and storage tanks for CNG producer Dynetek GmbH, the volume of 1.025 L, or 202 m^3 [3], Fig. 2 (a).

The point is that by using trucks and vans, with similar concepts, the delivery of goods and operation of communal services in the area of the city center, can be facilitated. Contribution to reducing pollution these zones due lower emissions of vehicle on biomethane in compared to diesel propulsion is evident.



(a) *(b)*

Fig. 2 *(a) The CNG powered truck concept and storage system (b) Diesel vs CNG & LNG autonomy equivalence*

Vehicle with propulsion system on biomethane was designed according to a standard autonomy of movement with a full tank of fuel.

Taking as a reference the widely used CNG, we can see that the autonomy equivalence of one liter of diesel fuel is 5 L of CNG. LNG, by its condition as liquid, is the natural gas with a higher energy density, needing only a volume of 1.8 L to give the same autonomy that liter of diesel fuel, Fig. 2 (b) [2].

As an example, we will compare volume of the reservoir for CNG and LNG on the same truck chassis, depending on type of propulsion system. CNG (green truck): 8 tanks of 80 L is 640 L of CNG equivalent to 128 L diesel. LNG (white truck): one single LNG 360 L tank equivalent to 200 L diesel (56% more), Fig. 3.

(a) *(b)*

Fig. 3 *(a) Comparison CNG vs (b) LNG tank configuration on the same truck chassis*

In practice, the propulsion system of vehicles on the natural gas/biomethane, is best to be equipped with appropriate gas engines that are available in the market. Only conceptions of vehicles with specially designed gas engines can take all the advantages of these fuels.

A typical CNG fuel system is comprised of tank storage, a fuel fill system; engine

compartment components, fuel lines, regulators and a high pressure fill system. CNG is stored at higher pressures up to 25 MPa. Fuel lines are connected to a pressure regulator that reduces pressure to engine intake system (from 0.3 up to 0.5 MPa) [4,6,7].

LNG fuel system is a low pressure system designed for normal storage/operating pressure of 1.5 MPa. When LNG needs to be converted for use, it's drawn from the tank, run through a vaporizer, "warmed" back into gas and supplied to the engine at the required pressure [2].

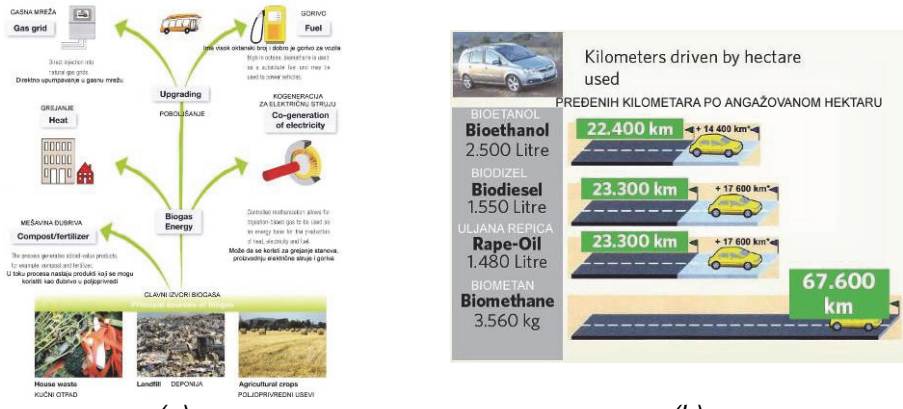
3. PRODUCTION AND SUPPLY OF MARKET WITH BIOMETHANE - OPTIONS

Security in market supply with natural gas is required to successful and global introduction of NGVs. By 2030, natural gas consumption in the EU, according to estimates will grow by about 16% compared to the current situation. Since the supply of natural gas is dependent on imports, parallel is important his replacement with biomethane or other similar products. In reality, to produce biomethane we use two the different technologies [2,5]:

- Production of biogas during anaerobic fermentation of biomass. Purification process is obligatory, after that biogas can be used as fuel, *ie*. biomethane;
- Production of synthesis gas during gasification of biomass, in form of solid or liquid or wood waste and agricultural crops. Synthetic biogas, must be purified, after which can be used as fuel. The process of conversion is in the stage of demonstration and is limited to raw materials and technologies.

In the first case the biomass was obtained in the course of biochemical fermentation process of biomass, which can be obtained from domestic waste, organic waste, urban landfills, and animal and plant residues or by processing of various agricultural crops, Fig. 4 (a). Specifically, the production of biogas is a natural process and takes place by converting biodegradable organic compounds (which are contained in the biomass with a high degree of moisture) with the assistance of bacteria in the absence of oxygen (anaerobic digestion - AD). Thus obtained biogas can be used to produce electricity and heat (cogeneration) or as fuel in mobile systems. The rest after anaerobic digestion (compost) does not contain polluters and represents very good quality fertilizer for agricultural and arable land. Biogas consists of methane, which is also one of the greenhouse gases whose emission must be controlled. Production of biogas from waste may be one of the ways for waste treatment. Then, the remains of the digestion process can also be used later in the processing of agricultural land as fertilizer. In this way, the nitrogen, phosphorus and potassium are flowing back into the soil.

Passenger vehicle on biomethane which was obtained from one hectare of arable land has up to three times longer radius of movement in comparison with a vehicle that uses biodiesel or other biofuels, which are produced from the same land area, Fig. 4 (b). Radius of movement is 50% longer with respect to the case with ethanol. For comparison was adopted the average fuel consumption; for the vehicle with a gasoline engine of 7.4 L or 6.1 L per 100 km for a vehicle with a diesel engine [2].



(a) *(b)*

Fig. 4 *(a) The biomethane production by steps: waste-biogas-biomethane-fuel; (b) Range of a personal car, running on biofuels produced on feedstock/ energy crops from one hectare arable land*

In short, the conditions for the production/ application of biomethane as fuel for mobile systems in Europe are very favorable [2]:

- City area, agriculture and forestry have a great capacity for the production of biomass that after processing becomes the biogas.
- Wider the distribution network for the natural gas supply in Europe.
- There are more than 5,000 pump stations for vehicles on natural gas and
- On the market there are over 2,000,000 passenger cars, buses and trucks powered by natural gas, which may run on biomethane, too.

Biogas is created when organic material is broken down in an oxygen-free environment, called (AD). The composition largely depends on the organic matters formed during the fermentation process. The biogas contains combustible and non-combustible matters shown in Table 1 [5]. Biogas, in its raw form, can be combusted in specially designed engines. However, it does not produce as much energy as natural gas delivered from pipelines which contains approximately 98% methane. However, it can be improved by removing the share of non-combustible matters. The purified or upgraded gas is called biomethane or renewable natural gas (RNG).

Table 1 *Combustible and non-combustible ingredients of raw biogas*

A. Combustible ingredients of biogas:	*Concentration, %*
Methane (CH_4)	*50 – 70 (55 – 60)*
Hydrogen (H_2)	*< 1*
Sulphuretted hydrogen (H_2S)	*2*
B. Non-combustible ingredients of biogas:	
Carbonic hydrogen (CO_2)	*25 – 50 (45 – 50)*
Water steam (H_2O)	*2 – 7*
Oxygen (O_2)	*0 – 0.5*
Ammonia (NH_3)	*0 – 2*

The biomethane can be compressed and pumped into the existing network of natural gas is supplied to households, gas stations and vehicles or directly stored in tanks for further use of the same.

CONCLUSIONS

From the vehicles are required to meet increasingly stringent regulations for emissions of toxic and harmful products of combustion. Vehicles on biomethane/natural gas already meet the emission limit values. By using other available technologies, it is not possible to reduce emissions, without the enormous increase in vehicle price.

In practice, the propulsion system of vehicles on the natural gas/biomethane, is best to be equipped with appropriate gas engines that are available in the market.

The production of biogas is a natural process and takes place by converting biodegradable organic compounds with the assistance of bacteria in the absence of oxygen (anaerobic digestion). The biogas can be used to produce electricity and heat (cogeneration) or as fuel in mobile systems (as biomethane, purified of non-combustible matters).

The rest after anaerobic digestion (compost) does not contain polluters and represents very good quality fertilizer for agricultural and arable land. In this way, the nitrogen, phosphorus and potassium are flowing back into the soil.

ACKNOWLEDGEMENT

The paper is a result of the research within the project TR 35041 financed by the Ministry of Science and Techno-logical Development of the Republic of Serbia.

REFERENCES

[1] Cars and Light Commercial Vehicles. Greenhouse Gas Emissions, from *https://www.dieselnet.com/standards/eu/ghg.php,* accessed on 2015-02-03.
[2] Lage, M. (2012). Fuelling of LNG/L-CNG Vehicles. *IGU Working Committee 5 – Utilisation of Gas, Study Group 5.3 – Natural Gas Vehicles (NGV) and UN ECE Working Party on Gas, Joint Report,* p.100-127.
[3] Milojević, S., Pešić, R. (2011). Logistics of Application Natural Gas on Buses. *CAR 2011 Conference Proceedings, CAR2011_1105,* p. 1-10.
[4] Milojevic, S., Pesic, R. (2012). Theoretical and Experimental Analysis of a CNG Cylinder Rack Connection to a Bus Roof. *International Journal of Automotive Technology*, 13, 3, 497-503, DOI 10.1007/s12239−012−0047−y.
[5] Mursec, B., Vindis, P., Janezekovic, M., Brus, M., Cus, F. (2009). Analysis of different substrates for processing into biogas. *Journal of Achievements in Materials and Manufacturing Engineering*, 37, 2, 652-659.
[6] Rasche, C., Dynetek. Advanced Lightweight Fuel Storage Systems TM, from *http://www.dynetek.com/pdf/AGMPresentation2009.pdf*, accessed on 2013-08-18.
[7] UN ECE Regulation No. 110, Add. 109:2008. *Specific Components of Motor Vehicles Using CNG in Their Propulsion System.* United Nations Economic Comission. New York.

12TH INTERNATIONAL CONFERENCE ON ACCOMPLISHMENTS IN ELECTRICAL AND MECHANICAL ENGINEERING AND INFORMATION TECHNOLOGY

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MINISTRY OF SCIENCE AND TECHNOLOGY OF
THE REPUBLIC OF SRPSKA

Organizer and publisher:
FACULTY OF MECHANICAL ENGINEERING
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Co-organizer:
FACULTY OF ELECTRICAL ENGINEERING
UNIVERSITY OF BANJA LUKA

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CIP - Каталогизација у публикацији
Народна и универзитетска библиотека
Републике Српске, Бања Лука

621.3(082)(0.034.2)
621(082)(0.034.2)
004(082)(0.034.2)

INTERNATIONAL conference on accomplishments in Electrical and Mechanical Engineering and Information Technology (12 ; Banja Luka) (2015)
Proceedings [Elektronski izvor] = Zbornik radova / 12th International conference on accomplishments in Electrical and Mechanical Engineering and Information Technology, Banja Luka, May 2015 ; [editor in chef Vid Jovišević]. - Banja Luka : University of Banja Luka, Faculty of Mechanical Engineering =Univerzitet u Banjoj Luci, Mašinski fakultet, 2015 (Laktaši : Grafomark). - 1 elektronski optički disk (CD-ROM) : tekst, slika ; 12 cm

CD ROM čitač. - Nasl. sa nasl. ekrana. - Bibliografija uz svaki rad.

ISBN 978-99938-39-53-8

COBISS.RS-ID 5049624