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Feasibility study for the pilot biomethane refueling station for city buses in Rzeszow

Abstract: The subject of the article is to analyze the possibilities and conditions required to be fulfilled for the introduction of biomethane as a fuel to power city buses in Rzeszow. There will be examined various aspects of the prospects and opportunities for the delivery of biomethane for transport buses in the city, including the necessary costs associated with the production and distribution of the fuel. The environmental benefits associated with the use of biomethane will also will be presented, there will be determined the scale and technical capabilities for the delivery of biomethane for city transport in Rzeszow.

Key words: *CNG, biomethane, refueling station, city buses, Rzeszow*

Studium wykonalności pilotażowej stacji tankowania autobusów komunikacji miejskiej biometanem w Rzeszowie

Streszczenie: Przedmiotem zgłoszonego artykułu jest analiza możliwości i uwarunkowań koniecznych do spełnienia dla wprowadzenia biometanu jako paliwa do zasilania autobusów miejskich w Rzeszowie. Przeanalizowane zostaną różne aspekty związane z perspektywami i możliwościami dostarczania biometanu dla autobusów komunikacji miejskiej w tym mieście wraz z niezbędnymi kosztami związanymi z produkcją i dystrybucją tego paliwa. Korzyści dla środowiska związane ze stosowaniem biometanu zostaną również zaprezentowane, określona skala i techniczne możliwości dostaw biometanu dla potrzeb transportu miejskiego w Rzeszowie

Słowa kluczowe: *CNG, biometan, stacja tankowania, autobusy miejskie, Rzeszów*

Introduction

The purpose of this study is to analyze the possibility of using biomethane as fuel for this urban buses in Rzeszow. It has been compiled based on the analysis of several factors affecting the successfulness of the project involving the use of purified biogas to power buses. In order to make a proper analysis it was necessary to assess the factors determining the success of the entire venture.

1. Characteristics of the local public transport in Rzeszow

Public transport in Rzeszow is supported by the Municipal Transport Company in Rzeszow (MPK). At the moment the company is the exclusive provider of public bus transport services providing them on behalf of the Municipality of Rzeszow.

Transport services provided by the Municipal Transport Company are performed with 46 daytime lines and 2 night-time lines with the total length of routes being 657 km, of which 481 km within the administrative boundaries of the city of Rzeszow and 176 km in the neighbouring municipalities. Total number of stops is 828, with 354 stops in the administrative borders of the city, and 474 beyond the city. The 48 transport lines (21 urban lines, 20 urban-suburban lines, 5 special lines and 2 night lines) are operated by the following number of buses:

- on the working days 156 buses, (including night buses)
- on Saturdays 63 buses,
- on Sundays 54 buses.

Bus lines are operated with a frequency of 10 to 25 minutes on the urban lines and 20 to 90 minutes for extra-urban lines.

MPK bus network map of Rzeszow is shown in Figure 1.

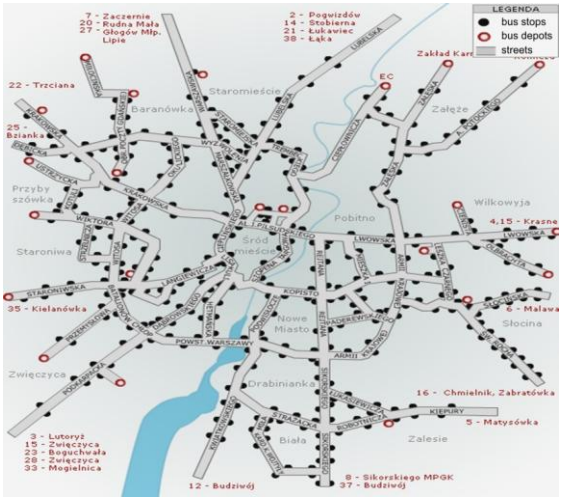

Fig. 1. MPK bus network map of Rzeszow [4]

Numbers of buses and their annual mileage in Rzeszow

Operation of CNG buses in the MPK Rzeszow began in 2004. Currently there are 188 buses, including 40 CNG buses, all of 12 m standard length. In 2009, the total mileage of CNG buses was 2 631 773 km, i.e. an average of 65 800 km/year per a bus. The oldest CNG buses have already reached the mileage up to 450 000 km. Since the beginning of their operation, CNG buses together with the diesel buses have covered in Rzeszow more than 10 mln km. Recently there were purchased 30 CNG buses of Mercedes.

2. Development of public bus transport in Rzeszow in the aspect of the application of renewable energy sources

2.1. Projected development of the urban bus transport for 10-20 years

During the next 10-20 years the primary means of public transport in Rzeszow will be buses. It is possible to increase the use of railway lines running through the city for urban and suburban communication. According to the studies currently performed for the "Building a public transport system integrating the City of Rzeszow and its environs" project, the number of buses required for transport in Rzeszow is approximately 160. Taking into account very high average age of buses being currently in operation (above 14 years), virtually entire owned stock should be replaced by new fleet, within that period.

2.2. Ecology aspect of the methane fuel application in the urban buses

Due to the high performance, in ecological terms, of vehicles powered by methane, the local authorities of the city of Rzeszow envisage further increase of the number of buses powered by methane. It is assumed that by the 2020, half of the fleet, operating in the city traffic, will be powered by such fuel. Right now it is only CNG taken into consideration, but with the possible biomethane production, it is assumed to shift some of these vehicles to run on biomethane. The important fact for environmental protection is a high environmental performance maintained in CNG buses throughout their life cycle and lack of the deterioration and wear of the power systems and emissions, not as in the case of diesel engines.

In the future it is expected that the number of buses powered by natural gas will surpass vehicles powered by diesels. The nature of the impact of lower greenhouse gas emissions from CNG vehicles can be further used by the optimization of the engine technology and new concepts for the vehicles engines.

CNG vehicles have a positive effect on improving air quality, comparable to the draft of the future national regulations for diesel engine emissions, especially for particulates emissions.

The main motive for the introduction, on a larger scale, of the natural gas as an automotive fuel is a concern to guarantee the alternative supplying of the transport sector currently dependent exclusively on oil products.

Natural gas is the only alternative fuel with a potentially significant market share above 5% by the 2020, which can compete with conventional fuels in economic terms. The development of refuelling infrastructure and related costs of the fleet should minimize costs during the transition. Natural gas could capture a wide market share if it had the support of the beneficial long-term mandatory taxes and excise duties, providing stable conditions until the development of the broader market. There is an advanced technology, but the variety of products and services must be continuously developed. Further efforts in research and development should encourage additional technology improvements.

Replacement of gasoline and diesel oil by natural gas may become technically and economically feasible, if it was done on a large scale, providing that will be benefits to the mass market for high volume production and use of CNG infrastructure (CNG filling stations). In the early stages, fleet and local markets, such as urban transport, offer potentially high use of the service stations on condition of income achieved from investments and network development.

Rules and standards for the use of natural gas as an engine fuel for vehicles should be adjusted to maintain a wide commercialization of CNG vehicles on the European level.

2.3. Estimation of CO_2 emissions reduction as a result of gaseous fuel using

Introduction of gaseous fuels (natural gas, methane) to power buses will contribute to climate protection by reducing of CO_2 and other pollutant emissions. This is particularly important for urban areas and areas with difficulties in complying with directives on air quality (Directive 96/62/EC [5] on ambient air quality and Directive 1999/30/EC [6] on limit values of pollutants in ambient air). EU has made efforts to green public procurement of road transport vehicles in the Green Paper on urban transport [KOM (2007) 551, "Towards a new mobility culture in the city"].

Currently, the EU legislation regulates emissions from vehicles using so-called Euro standards, and they set emissions limits which are becoming more stringent. By the 2020, emissions are expected to decline to a level of 25-50% of the emissions from 2000.

The biggest impact on the market and the most cost-effective results in terms of costs and benefits can be achieved by mandatory inclusion of energy costs during the life cycle and CO_2 and pollutant

emissions reductions as the criteria for the procurement of vehicles providing public transport services. These rules are subject to all purchases of vehicles for providing public passenger transport services subject to license, permit or authorization by a public body.

The application of these principles should definitely help to promote gas-powered buses. Unfortunately, currently adopted principles of charging for the use of the environment in Poland do not take into account the conversion of energy and the emission of pollutants but the amount of the fuels consumed, without taking into account their different calorific value.

Today's advanced bus gas engines design (natural gas, biomethane) makes their CO_2 emissions lower by 16% compared to petrol vehicles and 13% to diesel engine ones. This means that in terms of CNG rolling stock owned by the MPK Rzeszow, with an annual consumption of about 1.5 mln Nm^3 of natural gas and biomethane of 1.7-1.8 mln Nm^3 obtained reduction of the CO_2 emissions was by about 16% compared to before the introduction of gas fuel.

2.4. Estimation of the scale of the demand (daily, yearly) by the MPK in Rzeszow for bio-methane

Currently, CNG consumption by 40 buses in service averages 4 300 m^3 of gas per day which gives an annual consumption of approximately 1.5 mln Nm^3.

MPK assumed that the amount of methane-fuelled buses will double, to 80, half of which could be powered by biomethane (if their acquisition would be possible). While maintaining similar mileages and the likely increased use of biomethane and CNG, arising the content of pure methane in these two fuels, it can be estimated that the demand for bio-methane will increase.

3. Development of biomethane using in Rzeszow bus transport

There are three possible variants of biomethane fuelling methods.

Among the possibilities of supplying biomethane produced at a biogas plant located on the territory of the currently operating municipal wastewater treatment plant on Ciepłownicza Street in Rzeszow to the Bus Depot on Lubelska Street or on Trembeckiego Street, the following solutions must be analysed:

- Biomethane compressed to the pressure of 25-30 MPa for cylinder vehicles, pipe-vehicles or cylinder batches, and then delivery to bus depot, where partial de-fuelling would occur directly to buses, and partially to CNG warehouses located at the existing CNG station.
- Biomethane compression to the pressure of 3-5 bars and its transmission via a specially built pipeline between the biogas plant located on Ciepłownicza Street and the Bus Depot on Lubelska Street. Biomethane would be then supplied to the pipeline feeding the existing CNG bus filling station.
- Biomethane liquefaction and its supply as LNG to the LCNG station or after partial or complete adjustment of buses to LNG fuel - as LNG.

The selection of the appropriate solution must be supported with a detailed economic analysis. At the present phase, we have no data that would allow for full economic analysis, but basing on estimate values, it is possible to assess the outlays necessary to execute each of the four presented variants of the method for supplying biomethane produced in the volume of about 300 Nm3 per hour from the water treatment plant to the bus depot on Lubelska Street.

Due to the need to gather approx. 5 000 Nm^3 of biomethane, the variant with virtual pipeline (cylinders trailer vehicles) seems to be very cost-effective to start using biomethane pilot fuelling station located at a bus depot. Ultimately, the best solution for Rzeszow would be pipeline connection of the bus depot with the water treatment plant.

3.1. Biomethane compression to the pressure of 25-30 MPa (virtual pipeline)

When selecting this variant of biomethane transport from its production site to the bus depot in the compressed form, the following must be done:

a) biomethane compressor station must be designed and built, together with the infrastructure necessary to support complexes for do transport of compressed biomethane (cylinder-vehicles, pipe-vehicles, cylinder batches) on the territory of the treatment plant
b) it must be decided what means of transport among the ones available will be used for biomethane transport (cylinders trailer vehicles, pipe-vehicles, cylinder batches)
c) sites for biomethane de-fuelling must be designed and built on the territory of the bus depot.

With the assumption that biomethane would be transported in the compressed form, apart from the appropriate selection of compressors at the CNG station, it would be a significant problem to select the appropriate means of transport and organization of de-fuelling operation. Several global companies offer cylinders trailer vehicles and pipe-vehicles with capacity of from 3000 Nm^3 to 8500 Nm^3, where gas is stored at the pressure of 20-30 MPa.

The size of cylinder-vehicle (pipe-vehicle) decides on its mobility. Usually, cylinders trailer vehicles or pipe-vehicles are designed to transport possibly large volume of gas. As a result, maximum permissible loads per axis are applied, and the entire complex reaches the weight of almost 40 Mg, which largely limits the opportunity of free movement on all domestic roads. When selecting a cylinder-vehicle or pipe-vehicle for biomethane trans-

port, one must also consider the time needed for their fuelling.

For example, in the case of a station with capacity of 300 Nm^3/h, fuelling of an empty cylinder-vehicle with capacity of 8 500 Nm^3 would take over a day (28 hours), which is unacceptable for logistic reasons (we must have 4-5 hours per day available for fuelling CNG buses and cylinder-vehicle transport). Time available for biomethane fuelling and transport amounts to about 18 – 20 hours. It would be thus beneficial to apply two cylinder-buses with smaller capacities (e.g. 4200 – 5000 Nm^3 each).

The obtained reserve of CNG storage capacity would increase the flexibility and security of biomethane deliveries. Another possible solution would be to transport biomethane in cylinder batches transported with tractors on agricultural trailers. Due to small distance, batch transport time would not play a significant role, and the proposed system would additionally allow for significant flexibility and reduction of the investment and transport costs.

3.1.1. Equipment of biomethane compression station located at the wastewater treatment plant

The station for filling cylinder trailer vehicles with biomethane would comprise:

- Metering system for volume of biomethane collected before the compressor unit;
- Two gas compressors with capacity of e.g. 150 - 250 Nm^3/h;
- Sound-attenuating compressor casing with foundations;
- External technological installation;
- Electrical installation;
- Energy connection,
- Instrumentation systems,
- Lightning-arrester, surrounding installation and technological earth electrodes,
- Traffic lines;
- Considering in the compressor control system of an algorithm that would ensure shutdown in the event of flow reduction below the present threshold value and readiness for launch upon possibility of supplies with the minimum assumed output;
- Algorithm preventing the possibility of launching two compressors in the event of reducing the supply output below the threshold value of their total capacity (e.g. 500 Nm^3/h);
- Reduction of the output causing compressor shutdown can also significantly elongate the fuelling time.

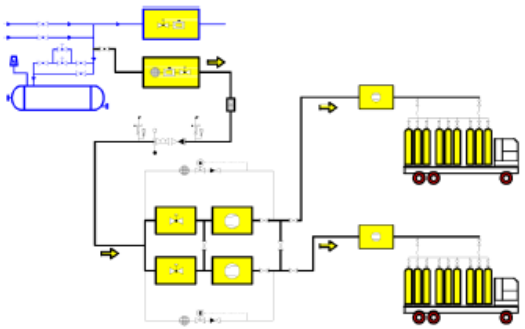

Fig. 2. Block diagram of filling station in the wastewater treatment plant

3.1.2. Location of the station

The most favourable location of the station for cylinder-vehicle filling with compressed biomethane would be the gas acquisition site, namely the area of the wastewater treatment plant. Before confirmation of the assumed location on the territory of the plant, one must determine categories and explosion danger zones, according to PN-EN 1127-1:2001 "Explosive atmospheres. Explosion Prevention And Protection" and classify dangerous areas according to standard: PN-EN 60079-10:2003 "Electrical apparatus for explosive gas atmospheres. Classification of hazardous areas". One must account for the existing land management in the Wastewater Treatment Plant and the existing explosion danger zones. Due to lack of regulations in the Polish legislation as regards the method for setting explosion danger zones for gas compressing equipment to the pressure of 30 MPa, one must rely of national guidelines and similar studies based on European literature, prepared for CNG vehicle fuelling stations. Explosion danger zones set for vehicle fuelling stations must remain within the fencing limits of the treatment plant, and must not affect the equipment installed there. It is assumed that the distances are determined with the size of explosion danger zones and protective zones around the compressor station and loading terminals.

The location will require building of a maneuver square with the bearing strength of 40 Mg on the area of 1100 m^2. The area around the compressor station will require hardening – the area of this land amounts to: 200 m^2.

One must also consider the need for locating the cabinet with compressor and metering-settlement system powering and control elements for fuel collected. The duct with biomethane from digesters for compression can also be run e.g. on a trestle over the access road.

3.2. Biomethane compression to the pressure of 3-5 bar and transmission with pipeline

For the purpose of performing the analysis of the possibility of biomethane transmission via gas pipeline between the biogas plant (Ciepłownicza Street) and bus depot (Lubelska Street) at the dis-

tance of 1.8 km, in the line similar to a straight line, a draft study was requested from a specialist Company.

The Draft Study, containing technical-economic assumption for: "Construction of pipeline for biomethane transmission from the areas near the Wastewater Treatment Plant in Rzeszow to CNG station for MPK bus fuelling on Lubelska Street in Rzeszow" constitutes Annex 2 to 5.8 report entitled Feasibility study of new biogas fuelling station in Polish city of Rzeszow [2].

Gross value for performance of the pipeline according to prices from February 2010 amounted to approx. 260-305 thous. PLN, depending on the variant selected (Variant No. 1 was proposed with underground crossing of the Wisłok River, and Variant No. 2 with placement of the pipeline on the existing overground structure – trestle crossing the Wisłok River).

The costs of pipeline construction must be enlarged by the cost of compressor station construction to allow for gas transmission. The assumed parameters include hourly transmission of 300-500 Nm^3/h, pressure at the start point of pipeline feeding of 2-3 bar (compression), maximum operating pressure of 5 bar. It is estimated that the cost of construction of such a compressor station will amount to approx. 550-600 thous. PLN. The planned route of the pipeline has been set aside the controlled zone of the existing high-pressure gas pipeline owned by OPG "Gaz-System" – Branch in Tarnów.

3.3. Biomethane liquefaction (LBG)

Biomethane liquefaction would create a qualitatively different alternative to classic compression and distribution of biomethane via virtual pipeline at high pressure. When deciding on a more expensive technology of biomethane liquefaction, there would be an opportunity for comparable in the CNG cost aspect, but easier distribution of biomethane in the liquid form. It must be stressed that, as a result of biomethane liquefaction, we would obtain a much greater density of energy storage, both during transport of liquid biomethane to the recipient and in the vehicle (LBG buses).

Probably, if the Management of Municipal Transport in Rzeszow had the opportunity of gas supplier selection, the alternative to LNG-LBG application would also be more attractive due to the opportunity of achieving almost twice greater bus ranges at comparable weight (tank + fuel). The present LNG price is maintained at the level of 1.46-1.5 PLN/m^3 and is competitive to duct gas also because it does not contain the transmission fee and other fee (including fixed fee). However, it must be transported from the manufacturer to the customer, which will constitute certain cost proportionate to distance. With the application of LBG, lower costs than for CBG distribution station are achieved, and also of its later operation, as we avoid the need to collect high volumes of electricity for gas compression (0.2 – 0.35 kWh/Nm^3).

Costs of LBG station construction with similar capacity as CNG station is lower by approx. 30%, but the assurance of continuous operation of the LBG station requires higher qualifications and skills.

LCNG station allows for fuelling both CNG and LNG vehicles, yet for this purpose, it must be more extended and thus more expensive. LNG production is a technically complex and costly enterprise. The selection of natural gas or biomethane liquefaction technology depends on the required installation capacity and the composition of the liquefied gas (content of carbon dioxide, sulphur, abstract compounds, nitrogen compounds, heavy hydrocarbons) and its initial pressure. LNG is natural gas with high methane content (97-98% methane) cooled to the temperature of –163°C.

At this temperature and at atmospheric pressure, the fuel is liquefied, and thus reduces its volume by about six hundred times. Owing to this, it can be easily transported e.g. via cistern vehicles. LNG is non-toxic and non-corrosive. Its density is by half lower than water density. It is also colorless and odorless.

4. Conclusion

- In Rzeszów, there are opportunities to use biomethane as a fuel to power the city buses.
- MPK has good opportunity for the fuelling part of their buses with compressed biomethane due to the proximity of sewage treatment plant
- Biomethane produced in city waste water treatment plant is sufficient for supply 80 buses.
- The cost of a new biomethane filling station with the installation of biogas upgrading will be about 2 mln Euro.

Nomenclature/*Skróty i oznaczenia*

CNG Compressed Natural Gas/*sprężony gaz ziemny*

LPG Liquified Petrolum Gas/*gaz skroplony*

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[6] Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air

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