Economic and environmental aspects of using CNG in urban public transport – based on the experience of MPK Rzeszów

Introduction

Natural gas is used in a broad range of industries, it is a substrate for technological processes, it is widely used in energy sector and households. In recent years, in view i.a. of its economic and environmentally sound advantages, natural gas is also being increasingly used as an alternative fuel in internal combustion engine vehicles in transport in the form of compressed natural gas (CNG – pressurised at 16–25 MPa) and in the form of liquefied natural gas (LNG). It should be stressed that although over the past years a dynamic growth in the number of vehicles powered by natural gas has been seen (they are called NGVs, Natural Gas Vehicles) (in millions): 3 in 2004, 7.55 in 2007, 14.55 in 2011 and 19.63 in 2014 (as of May), the history of gaseous fuels used in internal combustion engines is older than the history of petrol and dates back to the 1860’s (the first two-stroke engine powered by natural gas was developed in 1860 by a French inventor Etienne Lenoir). Since then, gaseous fuels have been used for the propulsion of vehicles and enjoyed much popularity in times of crisis due to conventional fuel shortage.

Nowadays, also in countries with limited access to conventional fuels, e.g. in Iran, the use of CNG in the transport sector is expanding rapidly.

Natural gas is a natural high calorific fuel (H-gas) occurring alone or accompanying crude oil deposits. The composition of gas depends on where it was mined but methane (CH$_4$) always accounts for the major part, and its content usually ranges from 85% to 98%. Transport of natural gas does not depend on weather or road traffic conditions as it is mainly transmitted through pipeline network. The energy value of 1 m$^3$ of CNG is roughly equal to the energy value of 1 litre of petrol, and 1 m$^3$ of natural gas mass under normal conditions equals approximately 0.7 kilo.

Nowadays in Poland the most popular alternative fuel used in the transport sector is liquefied petroleum gas (LPG). The scale of using this fuel ranks Poland in the absolute global forefront (2.6 million of vehicles powered by this fuel provides Poland the second place in the world, behind Turkey, ranked first). However, some companies in urban public transport have been using CNG for several years and recently also LNG.

Using natural gas as an alternative fuel in transport

Primary sources of energy used for the propulsion of vehicles are fuels produced as a result of crude oil processing, that is gasoline and diesel oil. The search for alternative fuels is bolstered by depleting conventional fuels, their ever-increasing prices entailed, i.e. by armed conflicts in the countries being significant producers of crude oil, and adverse impact of fuels derived from crude oil on the environment (this impact has been reduced over the past decades by increasing quality requirements that fuels must meet).
Another contributing factor is the EU’s environmental policy which lays down pollution emission standards and limits, in particular with regard to greenhouse gases and the expanded use of bio fuels, and the climate-energy package is a clear example of this.

NGV vehicles powered by CNG or LNG are experiencing high popularity on global markets. Iran is the leading country in the number of cars with 3.5 million vehicles in place powered by CNG (1904 filling stations), overtaking Argentina, the former leader for many years [24] – Figure 1. It is worth pointing out the high growth rate of the number of CNG-powered vehicles in China and in the mid 2013 the country was ranked second in the world with 3 million vehicles (5730 stations), while in the early 2008 China was only ranked as number 7 in the world with 336,000 vehicles (561 stations). The analysis of increased number of vehicles in 2012–2013 shows the highest rates in the Unites States: 123%, in Indonesia: 76% and in China: 50%. In this period the US and China recorded the highest rates in the number of CNG stations: 105% and 39% respectively [24]. In Europe, however, as regards the number of NGV vehicles, the leading countries are Italy, Ukraine and Germany. In the case of Italy it is worth adding that the use of natural gas as an alternative fuel in transport has a long history. Before the war broke out in 1939, this fuel had been already used in the automotive industry [5]. Table 1 shows the developments in terms of CNG use in selected EU countries.

Table 1. EU countries with the largest number of NGVs

<table>
<thead>
<tr>
<th>No</th>
<th>Country</th>
<th>2007</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NGV</td>
<td>CNG stations</td>
</tr>
<tr>
<td>1.</td>
<td>Italy</td>
<td>432 900</td>
<td>609</td>
</tr>
<tr>
<td>2.</td>
<td>Germany</td>
<td>60 000</td>
<td>720</td>
</tr>
<tr>
<td>3.</td>
<td>Bulgaria</td>
<td>25 225</td>
<td>37</td>
</tr>
<tr>
<td>4.</td>
<td>Sweden</td>
<td>11 515</td>
<td>95</td>
</tr>
<tr>
<td>5.</td>
<td>France</td>
<td>10 150</td>
<td>125</td>
</tr>
<tr>
<td>6.</td>
<td>Spain</td>
<td>1 526</td>
<td>35</td>
</tr>
<tr>
<td>7.</td>
<td>Poland</td>
<td>1 400</td>
<td>26</td>
</tr>
<tr>
<td>8.</td>
<td>Austria</td>
<td>1 022</td>
<td>95</td>
</tr>
<tr>
<td>9.</td>
<td>Czech Republic</td>
<td>903</td>
<td>30</td>
</tr>
<tr>
<td>10.</td>
<td>Netherlands</td>
<td>858</td>
<td>16</td>
</tr>
</tbody>
</table>

Data source: [16, 24]
Table 1 confirms that over the past years the CNG market has been developing dynamically in EU countries. Regrettably, in the case of Poland, the market developed quite moderately. Considerably more rapid market development can be seen, i.a., in the Czech Republic, Poland’s southern neighbour. It is expected that in 2014 the number of methane filling stations will double [7].

When analysing market development in individual EU countries it is worth pointing out that this development depends, i.a., on fiscal policy of these countries which support (by lowering taxes) green fuels. In addition, in Italy for instance, the government have contributed to the development of this clean fuel by having dealt effectively with the CNG vehicles which are exempt from the ban on vehicles entering Italian city centres. What is more, since 2005 it has been possible to obtain financing means for the purchase of a vehicle powered by compressed natural gas and to be granted a refund to convert the vehicle to be run on CNG.

The development of CNG will of course be supported by the Directive of the European Parliament and of the Council on the deployment of alternative fuels infrastructure COM(2013)18 (guidelines to 2020), included in the ‘Clean Power for Transport’ package, which imposes on Member States an obligation to develop CNG infrastructure. The package provides that the maximum distance between filling stations cannot exceed 150 kilometres.

**Using CNG in public transport**

The use of CNG in public service buses seems particularly beneficial due to the reduced air pollution in conurbations. The problem occurring in passenger cars, namely the placement of the gas cylinder, virtually disappears in the case of buses. In public service buses the gas cylinders are usually placed on the roofs (low floor buses), and in older models (e.g. Jelcz 120 M/4) under the floor. Figure 2 shows developments in the bus fleet powered by CNG in individual public transport companies. The number of vehicles have slightly picked up, and in the case of MPK Rzeszów the rise was significant (30 items). Nowadays, the company is a clear leader in using CNG in public transport.

![Fig. 2. Number of CNG buses in Polish urban public transport in 2012 and 2014](image)

*Source: Authors’ own work based on [19, 21]*

As mentioned before, Poland has 3392 (in 2013) NGV vehicles [23]. It is not an encouraging sign for further development of the CNG market that over the past two years the stations have been closed in Bydgoszcz (January 1, 2012), in Dębica (January 1, 2013), in Gdynia (July 14, 2012), in Jarosław (January 1, 2013), in Jasło (January 1, 2013), in Kielce (August 31, 2012), in Legnica (March 1, 2013) and in Olsztyn (January 1, 2012). Establishing excise duties on CNG in 2013 also does not correspond with regulations and actions taken in selected EU countries which strive to support and expand the use of natural gas as an alternative fuel in the transport sector.
One of the Polish pioneers in using CNG in urban public transport is Miejskie Przedsiębiorstwo Komunikacyjne (MPK) Rzeszów. In relation to 2012, the company has almost doubled its fleet of CNG-powered vehicles and currently has 70 buses of this type (as of May 2014). Such a broad use of CNG in Rzeszów is possible because the MPK company owns a fast-fill CNG station. It is also publicly available for customers outside the MPK who have CNG powered vehicles. The very process of refuelling a bus takes from 10 to 15 minutes; it is therefore comparable with the time needed to fuel a vehicle with diesel. Fast-fill stations for buses were not sufficient compared with continuously increasing fleet; therefore a decision was made to build a time-fill station. Currently, there are 12 double fuel dispensers that allows to fuel up 24 buses simultaneously. Further actions are to be taken towards the expansion and modernisation of a bus depot, among which a new CNG bus service station and a facility for day-to-day services. Since the company’s CNG bus number is very large, MPK Rzeszów has no plans to further purchase other CNG-powered buses in the next two years. It should be stressed that MPK Rzeszów also owes its large fleet to funds obtained by the municipality in the frame of the project Development of Eastern Poland. Approximately PLN 80 million were intended for the acquisition of new buses, being part of a large project entitled ‘Building an integrated public transport system for the City of Rzeszów and the surrounding areas’. The environmental aspect is highly supported by the municipality. New buses are very welcomed by the customers and enjoy public support.

It is worth adding that in 2015, as a result of co-financing from the National Fund for Environmental Protection and Water Management, in the framework of the programme ‘Gazela’, the MPK Częstochowa will introduce 40 gas-electric hybrid vehicles. Further extended use of natural gas in the urban public transport will be seen in Gdynia (currently having 16 CNG-powered buses) where by the end of March next year there will be 10 gas-electric hybrid vehicles on the roads.

Environmental and economic aspects of using CNG

Air pollution is mainly compounded by too rapid development of industries and the automotive industry. It is not without significance that the emission sources are situated on relatively small areas in the city regions. Air pollution is the introduction of harmful quantities of natural and synthetic compounds into the Earth’s atmosphere as a result of direct or indirect human activities [18]. Nitrogen oxides are a key pollutant of the air ($\text{NO}_x$) – Fig. 3.

![Sector share in total nitrogen oxides emissions in Poland, in 2010 and 2012](image)

Source: Authors’ own work based on [8,9]

Figure 3 shows that in 2012 transport was responsible for the bulk of nitrogen oxides emission; this sector is seen to emerge as having an increasing share in the emission of nitrogen oxides over the past years. Also the noise is included to air pollutants. It is estimated that in Poland the noise pollution area
accounts for approximately 20% of the total surface area of the country. The Inspection for Environmental Protection (PIOŚ) reported that over 10 million people who live in large cities, and 4.5 million people in small towns are continuously exposed to noise, the levels of which exceeding 70 dB [20]. Travelling hundreds of kilometres in congested conurbations puts urban public transport at the forefront among major emitters of pollution generated by the automotive industry. It is well known that numerous bus stops along the bus route increase the consumption of fuel, and when it is powered by diesel oil it produces additional exhaust emissions and is source of noise. Therefore, introducing CNG-powered buses is a reliable solution that results in reduced pollutant emissions and decreased noise levels. MPK Rzeszów made a comparison of annual emissions for the city bus Jelcz M125 powered by diesel oil and CNG. Table 2 summarises its outcomes.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Annual emission [t/year]</th>
<th>Ratio CNG/DIESEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO&lt;sub&gt;x&lt;/sub&gt;</td>
<td>0.64</td>
<td>1.68</td>
</tr>
<tr>
<td>CO</td>
<td>0.64</td>
<td>0.96</td>
</tr>
<tr>
<td>HC</td>
<td>0.16</td>
<td>0.26</td>
</tr>
<tr>
<td>PM</td>
<td>0.02</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Data source: Data obtained from MPK Rzeszów

For each of the pollutants a difference in emission values can be observed and all the parameters speak in favour of the CNG. The combined emissions of pollutants generated by engines running on compressed natural gas are lower as compared with Diesel engines. Therefore, the CNG makes it possible for engines to comply with already existing polluting emission limits laid down by the European Union – Table 3.

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>CO</td>
<td>0.12</td>
<td>5.45</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
</tr>
<tr>
<td>NMHC</td>
<td>0.0</td>
<td>0.78</td>
<td>0.55</td>
<td>0.55</td>
<td>0.16</td>
</tr>
<tr>
<td>CH&lt;sub&gt;4&lt;/sub&gt;</td>
<td>0.02</td>
<td>1.6</td>
<td>1.1</td>
<td>1.1</td>
<td>0.50</td>
</tr>
<tr>
<td>NO&lt;sub&gt;x&lt;/sub&gt;</td>
<td>0.36</td>
<td>5.0</td>
<td>3.5</td>
<td>2.0</td>
<td>0.40</td>
</tr>
<tr>
<td>Dust</td>
<td>0.007</td>
<td>0.16</td>
<td>0.03</td>
<td>0.03</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Data source: [11, 14]

The research also confirmed reduced noise levels for NGVs within the range of 1 to 3 dB. In practice, this means that from a distance of 7 metres, the noise transmitted by a passing vehicle is about 40% lower for NGV vehicles as compared with diesel engine vehicles [22]. In the context of air pollution levels in Polish cities, it is worth recalling the findings of the European Environmental Agency of October 2013 which show that among 10 most polluted EU cities are 5 Polish cities (Krakow is labelled third with its 150 days above target pollution limits for particulate matter in urban areas). Also the results of tests conducted by the association ‘Respire’ in 2014, where three hazardous components of smog were analysed: PM10 (particulate matter), ozone and nitrogen dioxide, and a list of cities was established on this basis with an indication of the number of days above pollution limits, confirmed high pollution levels in Polish cities. Among ten most polluted European cities are three cities from Poland (Cracow is also labelled third with 210 days). The key problems of transport economics are cost and price issues [1]. Before implementing CNG buses in the urban transport company it is necessary to assess the needs for investment.
Therefore, not only gas prices are taken into account but also higher prices of vehicles powered by this green fuel, and the need to build or modernise the infrastructure, filling and service stations. Currently, with an excise tax set, the MPK Rzeszów made no savings as a result of using CNG buses in 87% of the fleet (except for Solaris Urbino 12).

In 2012 the sales of CNG in Poland accounted for about 14 million cubic metres of gas. Compared with 2011 there was a rise of 15%. This rise was mainly due to attractive CNG prices in comparison with conventional fuels prices. In 2012 the cost of 100 km driven by a large commercial vehicle powered by CNG did not exceed PLN 40.00 [17]. As mentioned before, one of the key issues in using natural gas as a fuel for vehicles is its price. Figure 4 summarises developments in gas prices in comparison with diesel oil prices.

![Fig. 4. Diesel oil and CNG prices in 2004 to 2012](image)

*Data source: Authors’ own work based on [12]*

It should be stressed that under the communication of the President of the Office for Energy Regulation (7/2008) of 25 March 2008 energy companies were exempted from the obligation to submit for approval tariffs for CNG used in motor vehicles. On July 14, 2010 PGNiG SA introduced a variable CNG price at its filling stations. The price is set based on the parity of quotations of the average wholesale net price of Ekodiesel PKN Orlen from the preceding four entire weeks, published on the PKN Orlen website. A parity of 1 m³ CNG price to the wholesale net price per 1 litre of diesel accounted for 55% until November 2013. The introduction of excise duties changed this ratio. Purchasing large quantities of compressed natural gas by transport companies in no way affects the price set per 1 cubic metre of compressed gas – there is no wholesale trade margin. Unlike other fuels, non compressed gas including, the price for a wholesale customer is the same as for a retail customer. Bearing in mind the liberalisation process of natural gas market, discussed i.a. in publications [4, 6, 15] as well as the declining trend of natural gas price in recent months, both on European Exchanges and the Polish Power Exchange, it seems there is ground for carrying out an analysis justifying a reduction in CNG prices by domestic service station operators. In the future, when industrial development of unconventional natural gas is launched, an increased gas supply may be an additional incentive to the extended use of this fuel in the transport sector [3].

**Summary**

An extended use of CNG as an alternative fuel in transport can be observed globally over the past years. The key factor with implications for CNG extended use in transport is the price relationship in favour of CNG if compared with conventional fuels. The analysis of the rapidly expanding use of CNG for fuel in the global and European markets shows a small use rate in the national realities, which may be caused by a number of components. Among the most importance are insufficient and still decreasing number of publicly available CNG filling stations and the lack of adequate fiscal policies of the state.
As the experience of MPK Rzeszów shows, the operation of CNG buses does not pose any technical problems but economic effects were more positive in the first years of using CNG buses [2].

Abstract

The papers discusses selected economic and environmental aspects of using compressed natural gas (CNG) as an alternative fuel in the urban public transport, on the basis of MPK Rzeszów experience (the company is a national leader in the use of CNG). The progress made in the use of CNG as a fuel was shown at EU and global levels (countries with largest numbers of NGV vehicles were pointed out). Then, the paper presents key conditions for the extended use of CNG in Poland, compared with selected EU countries, paying particular attention to the use of this fuel in the urban public transport.

Keywords: natural gas, CNG, NGV, MPK Rzeszow, ecological transport

WYBRANE ASPEKTY EKONOMICZNE I EKOLOGICZNE WYKORZYSTANIA CNG W KOMUNIKACJI MIEJSKIEJ – DOŚWIADCZENIA MPK RZESZÓW

Streszczenie

W artykule przedstawiono wybrane aspekty ekonomiczne i ekologiczne w zakresie wykorzystania sprężonego gazu ziemnego (CNG) jako paliwa alternatywnego w komunikacji miejskiej na przykładzie MPK Rzeszów (przedsiębiorstwo to jest krajowym liderem w zakresie wykorzystania tego paliwa). Przedstawiono postęp w stosowaniu CNG jako paliwa zarówno w skali Unii Europejskiej, jak i świata (pokazano państwa, które w których jest najwięcej pojazdów na CNG). Przybliżono główne uwarunkowania rozwoju wykorzystania CNG w Polsce na tle wybranych krajów UE, zwracając szczególną uwagę na zastosowanie tego paliwa w komunikacji miejskiej.

Słowa kluczowe: gaz ziemny, CNG, NGV, MPK Rzeszów, transport ekologiczny

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