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Assessment of the potential of using CNG to power up passenger cars in Poland

Abstract: This article presents the results of an assessment of the potential for the use of CNG in Poland as a fuel for passenger cars powered by an internal combustion engine fuelled by petrol or diesel. The basis for assessing the potential was an analysis of the economic efficiency of converting a passenger car fuelled by petrol or diesel to a dual-fuel vehicle by installing a CNG system. On the basis of available literature data, the vehicle structure was characterised using the following criteria: vehicle age, engine capacity, car-segment, type of fuel used and unladen vehicle mass. The average fuel consumption (petrol or diesel) of the vehicle before conversion was determined on the basis of specially developed statistical models. The conversion and operating costs of a vehicle fuelled with conventional fuel and with CNG (after vehicle conversion) were estimated on the basis of a stochastic simulation model using probability density distributions of vehicle parameters and the Monte Carlo method. The vehicle parameters were estimated so that the obtained set of vehicles reflected the actual structure of passenger cars in Poland. The estimated costs of vehicle conversion (purchase and installation of a CNG system) and its subsequent operating costs made it possible to assess the economic efficiency of the car conversion process. The potential use of CNG as a fuel for combustion cars was estimated by comparing the operating costs of a vehicle before conversion

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and the operating costs of a vehicle after conversion, taking into account the costs of conversion. Analogous calculations were carried out for the conversion of a vehicle to run on LPG, i.e. the most important competitor to CNG. At the current CNG fuel price of over 9.50 PLN/m^3, the installation of a CNG system in passenger cars in Poland is not economically viable. Taking into account current fuel prices, the installation of a CNG system will start to be economically efficient for a small number of vehicles when the CNG price is 4 PLN/m^3 lower than the current price. Conversion most often has a positive economic effect when it takes place in cars with a petrol-fuelled engine characterised by high fuel consumption and an average annual mileage of more than 20,000 kilometres.

Keywords: economic efficiency, Monte Carlo, LPG, CNG vehicles, alternative fuels

Introduction

Air quality in Poland is one of the worst in Europe. In Poland, it is often linked to the use of hard coal for both electricity and heat and is also significantly affected by road transport, which is one of the main sources of emissions (Pepłowska 2021; Kryzia and Pepłowska 2019; Kousoulidou et al. 2008). In the face of an increasing number of vehicles, particularly passenger cars, modern methods of powering them are being developed. With the introduction of the Energy and Climate Package, European Union (EU) countries, including Poland, are required to comply with regulations limiting the emission of harmful substances into the atmosphere. Consequently, in every growing sector of the economy, EU residents are seeking new, environmentally friendly solutions aimed at reducing air pollution. This trend is moving towards lowering or completely replacing high-emission sources with so-called clean sources.

The road transport sector, along with industry and households, is one of the main sources of pollution emissions in the country, mainly due to exhaust fumes. Therefore, various measures are being taken in this area. The increasing number of vehicles, especially in large cities, contributes to the rise in pollution emissions. Additionally, in recent years, there has been an increased import of used cars, often old and worn out. Interest in electric vehicles is lower than originally forecasted due to high prices and limited availability of charging infrastructure and the range of these vehicles. It is significant that the advancement of electric-powered transportation is an expanding technology within land transport, serving as a crucial component of promoting sustainable economic progress (Wróblewski et al. 2021). Despite the announcement of the „Plan for the Development of the Electromobility Market in Poland", where there were government declarations of one million electric cars to be driven on Polish roads (Majchrzak et al. 2021). Implementing electromobility in public transport in Poland was the subject of research (Połom and Wiśniewski 2021). In the current situation, one of the solutions to reduce emissions seems to be the conversion of gasoline or diesel cars to dual-fuel vehicles by installing CNG (Compressed Natural Gas) systems (Khan et al. 2015). A comparison of methane and petroleum fuels indicates that methane is much cleaner, but requires far greater precautions to be taken during the use (Górniak et al. 2019). The feasibility of switching from internal combustion vehicles to CNG was also investigated by Aslam et al. (2006). The issue of comparing the emissions of diesel and CNG cars was raised by Hesterberg et al. (2008).

Natural gas, considered one of the most clean fuels, can also be used to power vehicles. Although this fuel is gaining popularity mainly abroad, there is also interest in this type of fuel in Poland. In the country, it has become known mainly through its use in public transport vehicles (city buses). This ecological fuel is used in transport in two forms, i.e. compressed, so-called CNG, and liquefied, so-called LNG (Liquefied Natural Gas) (Economides et al. 2006; Osorio-Tejada et al. 2017). In terms of domestic consumption, the liquefied form is far less popular than the compressed form. The most common substitute used by today's users is LPG (Liquefied Petroleum Gas), however, this is a mixture of propane and butane gases, not natural gas.

It should be noted that the use of a gaseous-fuelled vehicle is determined by a number of factors, which include the availability of refuelling stations, the price of gaseous fuel, the price of the vehicle, the public's mainly environmental awareness and a number of other factors. The review the current state and possibilities of developing electromobility and alternative fuels in Poland in which obstacles to development were identified was the subject of a publication (Burchart-Korol et al. 2020).

The aim of the study was to determine the impact of the price relationship of fuels such as petrol, diesel, CNG and LPG on the choice of propulsion type for passenger cars in Poland and to estimate the potential for demand for these fuels to power passenger cars and to forecast the level of carbon dioxide emissions from the engines of these vehicles.

The authors explored the topic by publishing a number of papers, i.e. Pepłowska and Kryzia (2016) – this article aims to attempt at creating model for the assessment of energy security in the road transport sector in the national realities; Orzechowska et al. (2016) – the article describes a model for assessing the state of energy security in the Polish road transport sector. It assesses to what extent a given motor fuel provides the level of energy security in the road transport sector as perceived in four dimensions, i.e. physical, economic, environmental and social dimensions; Kryzia et al. (2015a) – this article presents causes of seasonal changes in fuel consumption in internal combustion engines of passenger cars Kryzia et al. (2015b) – this article presents issues concerning the estimation of carbon dioxide emissions from passenger cars, Orzechowska and Kryzia (2015) – this article presents estimation of the future demand for natural gas in road transport in Poland, Orzechowska and Kryzia (2014) – this article presents SWOT analysis of the use of natural gas in road transport in Poland, Orzechowska et al. (2014) – this article presents economic and environmental aspects of using CNG in urban public transport – based on the experience of MPK Rzeszów.

The paper is structured as follows: the paper begins with an introduction, the next chapter describes the mathematical model, the next chapter presents the results of the analysis and their interpretation, and the paper concludes with a summary and literature list.

1. Materials and methods

In Poland, the passenger car fleet consists mainly of vehicles equipped with spark-ignition or compression-ignition engines that run on liquid fuels such as petrol and diesel. Passenger car operators deciding to install alternative fuels, such as LPG and CNG, should carry out an economic viability analysis, in which the key factors are the vehicle's fuel consumption and the ratio between conventional and alternative fuels, as well as the costs of purchasing, installing and maintaining the system. The total cost of ownership depends on the characteristics of the vehicle, the way it is operated and the road and weather conditions.

The potential for the use of CNG in Poland for fuelling passenger cars equipped with an internal combustion engine was estimated on the basis of a simulation carried out using a proprietary model of fuel consumption by a combustion engine. The model simulates a hypothetical vehicle by determining its key parameters. They are simulated in a random way (with correlations of the most important parameters – Tables 2 and 3) from empirical probability density distributions established in the course of the analysis of the parameters of the passenger car fleet in Poland. For each hypothetical vehicle simulated in this way, the petrol or diesel consumption per hundred kilometres travelled by the vehicle was calculated. For this purpose, econometric models were developed using data made available on the Autocentrum portal (Autocentrum 2023). A full description of the econometric models used to estimate fuel consumption is provided in (Kryzia et al. 2015).

One of the assumptions made in the analysis is that forms of powering passenger cars such as electricity, LNG and hydrogen have been omitted. The authors considered that the share of cars powered by these types of fuels in the passenger car market in Poland was so small that they could be omitted from the analysis; moreover, there is a great deal of uncertainty about their development.

The parameters characterising the hypothetical vehicle were taken as (CEPIK – Central Register of Vehicles and Drivers):

- type of fuel supplying the vehicle (diesel or petrol),
- carcass of the vehicle (values from 660 to 2,180 kg),
- vehicle engine displacement (values from 0.8 to 4.2 dm^3),
- the age of the vehicle (values from 0 to 31 years),
- car-segment to which the vehicle belongs (8 categories, i.e. smallest cars, small cars, lower middle class, middle class, wany, small suvs, upper middle class, large suvs).

Table 1 contains values of descriptive statistics of probability density distributions of parameters characterising the passenger car fleet in Poland. The probability density distributions for the parameters indicated above were prepared on the basis of data obtained from the Central Register of Vehicles and Drivers CEPIK (pol. Centralna Ewidencja Pojazdów i Kierowców) database and Polish Automotive Industry Association PZPM (pol. Polski Związek Przemysłu Motoryzacyjnego) reports.

Values for all the above-mentioned car parmaters have a stochastic character and were determined on the basis of available statistics on the number of diesel and spark ignition passenger

Table 1. Descriptive statistics for a sample of the passenger car fleet in Poland

Tabela 1. Statystyki opisowe dla próbki floty samochodów osobowych w Polsce

Parameter	J.m.	Average	Median	Value min.	Value max.	Deviation standard	Coefficient of variation	Skewness	Kurtosis
Own weight	kg	1,546.0	1,540.0	780.0	2,675.0	257.4	0.167	0.597	1.405
Engine capacity	dm^3	1.53	1.48	0.8	4.2	0.54	0.35	1.69	7.50
Age	years	15.92	15	0	31	3.92	0.53	0.29	2.23
Car-segment	–	3.61	3	1	8	1.68	0.46	0.47	2.19

Source: own study.

Table 2. Values of correlation coefficients for parameters characterizing spark-ignition passenger cars

Tabela 2. Wartości współczynników korelacji dla parametrów charakteryzujących samochody osobowe z silnikiem iskrowym

Specification	Engine capacity	Own weight	Car-segment
Engine capacity	1.00	0.87	0.73
Own weight	0.87	1.00	0.78
Car-segment	0.73	0.78	1.00

Source: own study.

Table 3. Values of correlation coefficients for parameters characterizing diesel passenger cars

Tabela 3. Wartości współczynników korelacji dla parametrów charakteryzujących samochody osobowe z silnikiem wysokoprężnym

Specification	Engine capacity	Own weight	Car-segment
Engine capacity	1.00	0.83	0.72
Own weight	0.83	1.00	0.84
Car-segment	0.72	0.84	1.00

Source: own study.

cars registered in Poland. All vehicles whose age exceeded 30 years were classified as 31-year old vehicles. This assumption does not affect the obtained results of the analysis, as it was assumed that vehicles over 30 years old are eligible for scrapping and their conversion is an economically inefficient undertaking. The useful life of a vehicle is calculated as the difference between the maximum vehicle life and its current age.

Sports and luxury cars were omitted from the analysis on the assumption that these types of vehicles would not be converted to run on alternative fuels.

As a result of the Monte Carlo simulation, sets of parameter values characterising the hypothetical vehicles were obtained, creating a set of 17,618 elements, representing the existing passenger car fleet in Poland. In order to ensure that the combination of values of parameters characterising the hypothetical vehicle reflected the combination of values occurring in reality, correlation coefficients characterising relationships between parameters were included in the model. Their values were calculated from the empirical data and are presented in Tables 2 and 3.

The cost of operating a vehicle is calculated on the value of fuel consumption per hundred kilometres (the value from the statistical models described by formulae 1 and 2), the fuel price and the average value of the vehicle's annual mileage. In the analysis, constant fuel prices of PLN 6.50 per dm^3 of petrol and PLN 6.40 per dm3 of diesel were assumed. LPG and CNG prices did not change in the analysed period, however, in order to illustrate the changes in the value of the CNG demand potential on the price of these fuels, different variants were analysed, being a combination of LNG and CNG prices, whose values were changed with a step of 0.25 PLN per unit volume of fuel. The value of the average annual vehicle mileage in kilometres was determined on the basis of collected statistical data. This value depends on the car-segment to which the vehicle belongs and the type of fuelling. The average annual mileage values adopted in the analysis are shown in Table 4.

TABLE 4. Annual average passenger car mileage values by fuel type and car-segment [km/year]

TABELA 4. Średnie roczne wartości przebiegów samochodów osobowych według rodzaju paliwa i autosegmentu [km/rok]

Car-segment	The smallest cars	Small cars	Lower middle class	Middle class	Vans	Small SUVs	Higher class	Large SUVs
Diesel-powered vehicle	12,000	12,000	20,500	20,800	20,800	22,000	23,100	21,600
Petrol-powered vehicle	10,000	10,000	13,800	16,000	16,000	14,500	17,200	16,700

Source: own study.

$$S_g = 0,1117 \cdot A_s - 0,0269 \cdot R_p + 2,4642 \cdot P_s + 0,0013 \cdot M_w + 56,0856 \quad (1)$$

$$S_d = 0,2864 A_s - 0,0084 \cdot R_p + 1,1688 \cdot P_s + 0,0019 \cdot M_w + 16,1199 \quad (2)$$

where:

S_g – value of the specific petrol consumption of the vehicle [dm/100 km^3],
S_d – value of the specific consumption of diesel by the vehicle [dm/100 km^3],
A_s – the car segment to which the vehicle belongs,
R_p – the year the vehicle started production,
P_s – engine capacity of the vehicle [dm^3],
M_w– unladen vehicle mass [kg].

The adjusted coefficient of determination R2, a measure of model fit, reached a value of 0.813 for the model of fuel consumption of diesel-fuelled vehicles and 0.869 for the model of fuel consumption of petrol-fuelled vehicles. This demonstrates a statistically good explanation of the fuel consumption values by the explanatory variables (vehicle parameters).

In addition to fuel consumption, the operating costs of a CNG vehicle consist of:

- the cost of the technical inspection, which is carried out annually and is 69 PLN more expensive than the inspection of a vehicle without the installation,
- the cost of legalisation of the fuel tank, which is carried out every three years and amounts to 150 PLN per tank,
- the cost of carrying out a leak test of the installation and fuel tanks, which is carried out every 10 years and amounts to 300 PLN per tank.

The cost value of installing a CNG system is influenced by parameters such as the number and capacity of fuel tanks and the type of engine and number of cylinders. Table 5 summarises the cost values for the installation of CNG systems. These data were obtained from consultations with service companies installing CNG systems and from officially available price lists.

Table 5. Costs of installing CNG systems

Tabela 5. Koszty montażu instalacji CNG

Specification	Unit	Values				
Engine displacement from	dm^3	0.6	0.8	1.0	2.5	4.0
Engine displacement up to	dm^3	1.0	1.4	3.0	5.0	4.2
Number of cylinders	pieces	2	3	4	6	8
Cost of installation including assembly	PLN	3,000	3,300	3,500	3,900	4,500

Source: own study.

The unladen vehicle mass after conversion increases, which has an impact on the vehicle's fuel consumption. The change in vehicle weight (but also the maximum range) is mainly determined by the number of CNG fuel tanks fitted to the vehicle. The increase in vehicle weight is limited by the vehicle's permissible gross vehicle weight and the design parameters of the chassis. It has been assumed that one type of tank is used, i.e. a tank with a capacity of 75 dm^3 and a weight of approximately 75 kg, costing approximately 1,300 PLN. It was assumed in the analysis that the number of tanks included in the model depends on the car-segment to which the vehicle belongs (Table 6).

It was assumed that the cost of installing a CNG system in a diesel vehicle is about 20% higher than installing one in a passenger car with a spark-ignition engine. The analysis assumes that, in the case of diesel engines, a mixture of natural gas and diesel is introduced into the combustion chamber at a ratio of 3:2. During the start-up phase, both types of engine with a CNG installation are (for about 5% of the total engine operating time) fuelled with conventional fuel, until an adequate temperature is reached to protect the gas regulator from icing.

Table 6. Number of CNG tanks depending on the car segment the vehicle belongs to

Tabela 6. Liczba zbiorników CNG w zależności od autosegmentu, do którego należy pojazd

Car-segment	The smallest cars	Small cars	Lower middle class	Middle class	Vans	Small SUVs	Higher class	Large SUVs
Number of tanks	1	1	2	2	2	2	2	3

Source: own study.

In the case of LPG installation, the costs of operating the vehicle consist of:

- the cost of the technical inspection, which is carried out annually and is 69 PLN more expensive than the inspection of a vehicle without the installation,
- the cost of carrying out a leak test of the installation and fuel tanks, which is carried out every 10 years and amounts to 300 PLN per tank.

The cost value of installing a CNG system is influenced by parameters such as the number and capacity of fuel tanks and the type of engine and number of cylinders. Table 5 summarises the cost values for the installation of LPG systems. This data was obtained during consultations with car services specialising in the installation of LPG systems and from officially available price lists.

Based on the data in Table 7, triangular probability density distributions of the cost of purchasing and installing an LPG system were constructed for each variant of the number of cylinders in the engine.

Based on an analysis of an article by Łyko et al. (2014), it was assumed that 20% of vehicle owners would choose not to install a CNG system even though it would make economic sense to do so. This is due to the discomfort that may be associated with the use of CNG vehicles caused by, among other things, limited boot space and a limited number of refuelling stations.

The model made it possible to indicate whether it made sense (from an economic point of view) to install a CNG system in a vehicle. For each of the hypothetical vehicles, the cost of

Table 7. Costs of installing LNG facilities

Tabela 7. Koszty montażu instalacji LNG

Specification	Unit	Values				
Engine displacement from	dm^3	0.6	0.8	1.0	2.5	4.0
Engine displacement up to	dm^3	1.0	1.4	3.0	5.0	4.2
Number of cylinders	pieces	2	3	4	6	8
Maximum cost of installation including assembly	PLN	2,465	3,081	3,081	4,062	4,788
Average cost of installation including assembly	PLN	2,465	3,081	3,081	4,062	4,788
Minimum cost of installation including assembly	PLN	1,600	2,000	2,000	2,800	3,500

Source: own study.

fitting a CNG system and operating the vehicle on natural gas for its entire life was determined. Similarly, costs were calculated for the installation of an LPG system and the operation of an autogas vehicle over its lifetime. These values, discounted at a five per cent discount rate, are compared with each other. If the value of the sum of the discounted operating costs of a CNG vehicle is the lowest (i.e. lower than the value of the sum of the discounted operating costs of a vehicle with an engine that burns liquid fuel or LPG), the annual natural gas consumption of that vehicle is determined. The sum of CNG consumption determined as described above for a set of hypothetical vehicles has to be increased a thousand times. As a result, the annual potential for CNG consumption by passenger cars in Poland powered by conventional fuels is obtained. In order to obtain the value of the total potential, the value of natural gas consumption by vehicles that are currently already running on CNG was added to the value calculated above.

The number of passenger cars in which a CNG system can be installed is approximately 17.618 million units (CEPIK).

The Monte Carlo simulation was performed using Oracle software called Crystal Ball version 11.

2. Results and discussion

On the basis of simulation studies, the potential for natural gas use in passenger cars in Poland was estimated. The value of this potential depends on the price of CNG and the price of LPG – the most important competitor for CNG. Table 8 shows the potential demand for CNG to power passenger cars depending on the number of fuel prices.

On average, in 4% of the smallest cars it makes economic sense to install a CNG system. In other car-segments, this would be, respectively: small cars – 12%, lower mid-range car – 20%, mid-range cars – 29%, wans – 31%, small strokes – 39%, upper-range cars – 46% and large strokes – 45%. Gasoline-powered spark-ignition cars dominate, generating almost 82% of the annual natural gas use potential.

Figure 1 shows the dependence of CNG demand potential for passenger cars on LPG prices. In this figure it can be seen that as LPG prices increase, the potential for CNG increases, but the rate of increase decreases until the market is saturated at an LPG price of 6.00 PLN.

Figure 2 shows the dependence of the demand potential for CNG to power passenger cars on CNG prices. An increase in CNG prices causes a decrease in the potential for CNG. The rate of change of the potential for CNG depends on the LPG price: at high LPG prices (5.50 PLN), the rate of change is relatively constant throughout the analysed range; at low LPG prices (3.00 PLN), the rate of change of the CNG potential decreases.

The analysis showed that an increase in the LPG price by a unit leads to an increase in the value of the CNG demand potential for passenger cars by an average of 1,296.86 m^3/year. Conversely, an increase in the price of LPG by a unit leads to a decrease in the value of CNG demand potential to fuel passenger cars by an average of 1,541.05 million m^3/year.

TABLE 8. CNG demand potential to fuel passenger cars for option 26 CNG refueling stations [million m^3/year]

TABELA 8. Potencjał zapotrzebowania CNG do zasilania samochodów osobowych dla wariantu 26 stacji tankowania CNG [mln m^3/rok]

		CNG price [PLN]										
		3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50
LPG pric [PLN]	3.00	1,401.67	828.89	621.96	446.37	264.07	113.91	12.63	0.00	0.00	0.00	0.00
	3.25	2,367.56	1,528.18	824.85	527.73	362.61	185.71	63.74	5.08	0.00	0.00	0.00
	3.50	3,322.87	2,482.22	1,644.23	894.91	450.40	269.07	128.15	30.10	0.00	0.00	0.00
	3.75	4,150.09	3,391.17	2,613.20	1,756.96	954.01	393.93	178.21	89.10	6.66	0.00	0.00
	4.00	4,752.68	4,162.06	3,477.95	2,697.88	1,869.96	1,055.38	392.66	110.25	32.47	3.50	0.00
	4.25	5,209.33	4,694.34	4,144.61	3,481.04	2,733.37	1,955.45	1,167.09	458.23	74.97	6.66	0.00
	4.50	5,537.40	5,103.47	4,617.16	4,068.44	3,453.72	2,752.28	2,031.49	1,277.03	557.64	86.57	1.15
	4.75	5,752.83	5,358.65	4,957.52	4,458.97	3,903.13	3,332.84	2,708.27	2,047.11	1,359.83	698.48	185.71
	5.00	5,890.75	5,505.67	5,127.61	4,698.00	4,182.32	3,632.45	3,086.51	2,519.18	1,905.82	1,318.10	758.87
	5.25	5,928.89	5,548.88	5,159.45	4,739.75	4,241.58	3,704.90	3,159.41	2,600.76	2,011.58	1,437.39	895.54
	5.50	5,928.89	5,548.88	5,159.45	4,739.75	4,241.58	3,704.90	3,159.41	2,600.76	2,011.58	1,437.39	895.54

Source: own study.

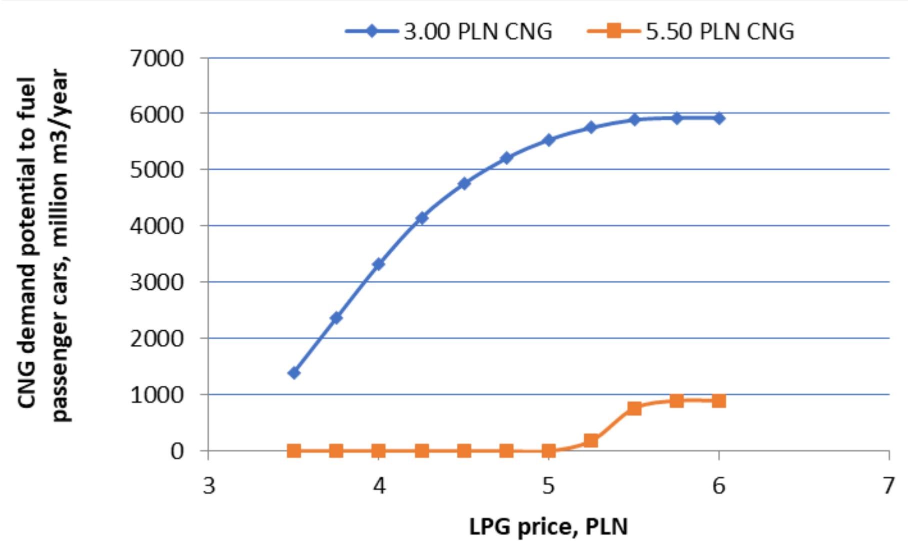

Fig. 1. CNG demand potential to fuel passenger cars depending on LPG prices [million m^3/year]
Source: own elaboration

Rys. 1. Potencjał zapotrzebowania na CNG dla samochodów osobowych w zależności od cen LPG [mln m^3/rok]

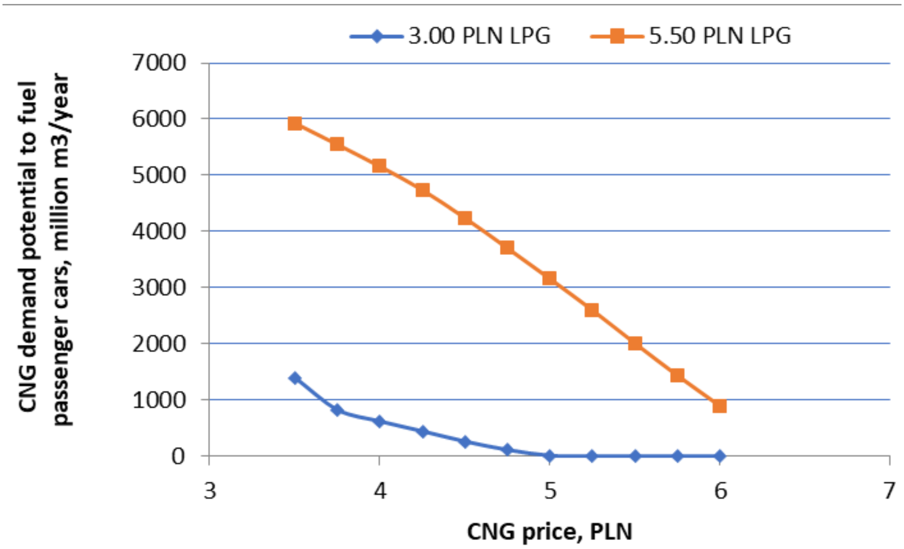

Fig. 2. CNG demand potential to fuel passenger cars depending on CNG prices [million m^3/year]
Source: own elaboration

Rys. 2. Potencjał zapotrzebowania na CNG do zasilania samochodów osobowych w zależności od cen CNG [mln m^3/rok]

Conclusions

The European Union's policy is directed towards the application of pro-environmental solutions The introduction of the so-called 3 x 20 package and emission reduction guidelines obliges member states to seek pro-environmental solutions in every sector of the economy, One of the sectors with high emissions and in which there are a number of opportunities to reduce pollution is the road transport sector.

The research carried out allows a number of conclusions to be drawn:

1. The simulation carried out concluded that the price ratio of CNG relative to other fuels is of key importance for the economic viability of converting passenger cars to CNG fuel. At the current CNG fuel price of over 9.50 PLN/m^3 , the installation of a CNG system in passenger cars in Poland is not economically viable. Taking into account current fuel prices, the installation of a CNG system will start to be economically efficient for a small number of vehicles when the CNG price is 4 PLN/m^3 lower than the current price.
2. The low share of CNG-installed vehicles in the passenger car structure in Poland may be due to the high price of natural gas and comfort concerns arising from the limited range, the small number of charging stations and the high initial costs associated with vehicle conversion.
3. Conversion most often has a positive economic effect when it takes place in cars with a petrol-fuelled engine characterised by high fuel consumption and an average annual mileage of more than 20,000 kilometers. It makes particular sense to convert the power supply of a large SUV and upper class passenger car.
4. As a result of using CNG as a vehicle fuel instead of conventional fuels such as petrol and diesel, there will be a reduction in carbon dioxide emissions of 19 to 22% and particulate emissions of more than 90% by each vehicle.

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Ocena potencjału wykorzystania CNG do zasilania samochodów osobowych w Polsce

Streszczenie

Artykuł prezentuje wyniki oceny potencjału wykorzystania CNG w Polsce jako paliwa do zasilania samochodów osobowych napędzanych silnikiem spalinowym zasilanym beznyną lub olejem napędowym. Podstawą do oceny potencjału była analiza efektywności ekonomicznej konwersji samochodu osobowego zasilanego benzyną lub olejem napędowym na pojazd dwupaliwowy polegający na montażu instalcji CNG. Na podstawie dostępnych danych literaturowych scharakteryzowano strukturę pojazdów za pomocą następujących kryteriów: wiek pojazdu, pojemność silnika, autosegment, rodzaj stosowanego paliwa, masa własna. Średnie zużycie paliwa (benzyny lub oleju napędowego) przez pojazd przed konwersją zostało określone na podstawie specjalnie opracowanych modeli statystycznych. Koszty konwersji i eksploatacji pojazdu zasilanego paliwem konwencjonalnym oraz instalacja CNG (po konwersji pojazdu) oszacowano na podstawie stochastycznego modelu symulacyjnego wykorzystującego rozkłady gęstości prawdopodobieństwa parametrów pojazdów oraz metodę Monte Carlo. Parametry pojazdów estymowano tak, aby otrzymany zbiór pojazdów odzwierciedlał rzeczywistą strukturę samochodów osobowych w Polsce. Oszacowane koszty konwersji pojazdu (zakup i montaż instalacji CNG) oraz jego późniejszej koszty eksploatacji umożliwiły ocenę efektywności ekonomicznej procesu konwersji samochodu. Potencjał wykorzystania CNG jako paliwa dla samochodów spalinowych został oszacowany poprzez porównanie kosztów eksploatacji pojazdu przed konwersją i kosztów eksploatacji pojazdu po konwersji z uwzględnieniem kosztów jej przeprowadzenia. Analogiczne obliczenia prrzeprowadzono dla wariantu konwersji pojazdu na napęd zasilany LPG to jest paliwa będącego najważniejszym konkurentem dla CNG.

Słowa kluczowe: efektywność ekonomiczna, Monte Carlo, LPG, CNG, ICE