ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1217196

FORECASTS FOR THE DEVELOPMENT OF HYDROGEN TECHNOLOGY IN THE ROAD TRANSPORT IN POLAND AGAINST THE BACKGROUND OF GLOBAL AND EUROPEAN TRENDS

Wojciech Gis, Edward Menes, Jerzy Waśkiewicz

Motor Transport Institute
Jagiellońska Street 80, 03-301 Warsaw, Poland
tel.: +48 22 4385400, fax: +48 22 4385401
e-mail: wojciech.gis@its.waw.pl, edward.menes@its.waw.pl
jerzy.waskiewicz@its.waw.pl

Abstract

The cars that use fuel cells are equipped with electric motors, batteries and brake energy recovery system. Traditional engines and liquid fuel tanks in conventional vehicles are replaced with fuel cells and hydrogen tanks. Duel cells produce energy in the oxidation reaction of hydrogen, and the vehicles powered by them emit only water vapour. The article concerns the current developments and prospects of the development of technology of fuel cell vehicles powered by hydrogen. Achievements of the leading car companies in this respect, the expected future sales volume of cars equipped with fuel cells, expectations of lowering production costs of such vehicles (affecting their price), forecasts of the quantitative development of FCV fleet in the world, in Europe, including selected countries as well as the expected development of a network of hydrogen car refuelling stations. Rationale for the development of the road transport hydrogenization in Poland, indicating the importance of initiating the construction in our country of hydrogen refuelling stations. Expert estimates of the quantitative development of the fuel cells cars fleet by the 2030 and 2050 against the forecasts electric cars fleet development in Poland. Future demand for hydrogen fuel by the road transport, including vehicles using the road infrastructure in Poland acc. to the type of road traffic participants (passenger cars operated in Poland, cars travelling in transit or to Poland, buses) by the 2050. Future importance of the hydrogen technology development in the road transport to the economy and the protection of the natural environment from the destructive influence of the automotive industry.

Keywords: *transport, road transport, vehicle, fuel cells, hydrogen technology, future development*

1. Introduction

Intensive work on the use of hydrogen in road transport was started yet back in the nineties of the last century. At around the half of the first decade of the twenty-first century, in the countries advanced in automotive technology, the development was started to a draft multi-annual work on the use of hydrogen in transport and new fuel cell technologies. The leaders in this were European countries such as the UK, Germany, etc., but the work was taken up also by the United States and Japan, and such countries such as South Korea. India, Canada. In Europe, the biggest current transport hydrogenization program with a budget of 1.4 billion Euro lead is run by Germany. The program entitled "National Innovation Programme Hydrogen and Fuel Cell Technology" is coordinated by the Nationale Organisation Wasserstoff – und Brennstoftzellentechnologie (NOW GmbH).

In view of many advantages (light weight, ease, speed of refuelling) and the absence of significant disadvantages associated with the technology of direct combustion of hydrogen in the engine compartment (pre-ignition, energy consumption storage of hydrogen in the liquid state, etc.), the technology being developed especially is one using hydrogen to create electricity in the fuel cells that is used by electric motors driving vehicles.

The cars with fuel cells, apart from the electric motors, are equipped with hydrogen tanks, batteries and brake energy regeneration system. In the fuel cells, the energy is generated in the

hydrogen oxidation reaction and the vehicles using this energy emit only water vapour. Unlike the electric cars using batteries, with a range of approximately 100-150 km and the need for a conventional charging for several hours (so-called, fast charging of several minutes lessens the durability of the batteries), the fuel cells vehicles can be filled with hydrogen in a few minutes, a full tank allows the range similar to vehicles powered by combustion engines. Refuelling of fuel cell buses takes up to 20 minutes. [13]. The expected range of the vehicles fuel cells equipped is 500-700 km (and even 900 km), which is on par with the range of the premium class electric passenger cars, i.e. Tesla S (approx. 400-500 km). The Hyundai ix35 vehicle equipped with fuel cells, which is on sale now, can be operated in the temperature of even –25°C [13].

The main barriers to the development of hydrogen drive technology were the costs and safety considerations throughout the distribution chain of hydrogen, from its place of production to the place of consumption in the car.

2. Development of the fuel cell vehicles technology

One of the first carmakers, who began intensive work on cars equipped with fuel cells, was Hyundai. Work began in 2000-2002, when it created prototypes of such cars as Santa Fe FCEV (75 kW) and Sportage (10 kW). In 2004-2005, there were constructed prototypes of such cars as Tucson FCEV (80 kW) and Sportage FCEV (80 kW).

According to Toyota in 2008, about 80% of the costs of the new generation car resulted from the fuel cells costs [9]. The price of the fuel cell car should continue to decrease, especially after 2026 years as a result of the development of mass production, mainly due to the multiple reduction of the fuel cells costs. A gradual decline in the cost of production of passenger cars with fuel cells is expected. These costs in 2010 averaged at 98.7 thousand Euros. Predictions are as follows: 2015 – 61.9 thousand Euro, 2020 – 25.2 thousand Euro, 2025 – 22.6 thousand Euro, 2030 – 20.0 thousand Euro, 2040 – 18.7 thousand Euro and 2050 – 18.0 thousand Euro [8].

At present, there are more than 60 models of cars powered by fuel cells in various stages of technical and market development, being prepared practically by all major automotive companies [3].

Currently, there is an intensive work under way by the consortia Daimler/Nissan/Ford as well as Toyota/BMW or Honda/GM and VW/Ballard, and the Hyundai company on the modern fuel cells with the power density in the order of 2.0 (2.5)-3.0 kW/dm^3. These consortia declare the production in the coming years, of hundreds of thousands of vehicles equipped with fuel cells [13].

3. Predictions of the hydrogen technology development in the road transport

The world's first hydrogen refuelling station was opened in Dearborn, USA. The following single hydrogen refuelling stations were opened as a rule, on major world events such as EXPO in Osaka in 2005, in Zaragoza in 2007, in Shanghai in 2010, the Olympic Games in Beijing in 2008, etc.

Dynamic development of the number of hydrogen refuelling stations occurred at the beginning of the second decade of the twenty-first century. For example, in 2012 there were 27 new hydrogen-refuelling stations launched in the world and in 2014, 17 stations. In July 2014, the Linde Company began mass production of hydrogen refuelling stations (28 already ordered by Japan).

As a result, in March 2015 there were 184 operational hydrogen filling stations in the world (82 in Europe, 63 in North America, 3 in South America, 38 in Asia) [7]. Only 40% of hydrogen refuelling stations (74 stations) was of the public character. Other frequently functioned within various research centres, industrial and energy units, or as private use stations.

According to available global forecasts, the number of hydrogen refuelling stations in the world should exceed 1000 in 2020 (at present the confirmed location have further 129 stations, of which 53 in Europe, including 24 in Germany), in 2025 – 2.5 thousand and in 2030 – 4 thousand [11].

This is probably underestimated number as only Japan assumes to have 5 thousand stations in 2030 (with 1000 in Germany and 500 in France or South Korea).

The current global fleet of hydrogen-powered – FCVs can be estimated at 2-3 thousand, while until recently it was assumed that only in Europe it would reach a level of 5 thousand passenger cars and 1,000 buses [1].

According to the forecast of 2010 the number of FCVs was in 2020 to reach 2.8 million and the production of 450 thousand in 2025, one million in 2027 and 2 million in 2030 [4].

According to various forecasts, the number of FCVs in 2020 has been set at about 600 thousand, including 500 thousand in EU countries.

In the year 2025 the FCVs' fleet, for example in France, would be 167,000 cars [6], in Denmark from 25 thousand to 100 thousand [10], in Japan – 2 million [9] and in 2030: 800 thousand vehicles in France, 10 thousand in the Netherlands [11], 1.5 million in the UK [12].

It seems that only real market data related to the launch of mass production and introduction of FCVs to the wide sale (Toyota Mirai, Hyundai ix35 Tucson, Honda FCV Concept) will allow verification of virtual, until now, forecasts of the growth of this segment of the automotive industry in the coming decades.

4. Predictions for the hydrogen technology development in Poland

The fuel cells electric cars' fleet development in Poland will be a prolonged process, depending primarily on the pace of the development of hydrogen refuelling infrastructure and the price affordability of such vehicles for the wealthy part of the society in our country. This second factor, due to the limited exclusive public interest in hydrogen cars will be less important, due to the existing already offers of hydrogen cars from such companies as Hyundai or Toyota, presented to potential clients in other EU countries. Also the care about the air cleanliness, e.g. in the city centres, may be a reason for the interest of municipal governments, together with the urban transport companies in the purchase and operation of fuel cell buses. A factor contributing to the development of hydrogen propulsion technology in Poland should be extra funding for research related to the development of the transport applications of this new energy carrier.

It is assumed that a relatively dynamic development of the use of hydrogen in the road transport in Poland may take place only after the 2030. The period of the next few years will be devoted to, among the others, creating political and economic tools to promote hydrogen propulsion technology and the experiments related to the operation of electric vehicles equipped with fuel cells. The most important role in the quantitative development of hydrogen vehicles will be building hydrogen refuelling stations on the Polish territory.

The forecast number of electric cars in Poland until the 2030 was developed because of the research carried out as part of the European eMAP project [2]. Among the projected numbers of electric cars there are electric cars powered by electricity from fuel cells.

According to the optimistic scenario of the eMAP project, the forecast number of electric cars in Poland in 2030 may reach about 326 thousand. This is based on the used (VECTOR 21) forecasting model, developed by the German DLR institute, revised in this respect among the others for Germany and Finland.

As one can expect, the development of electromobility, including that using hydrogen to generate electricity in the fuel cells, will benefit from the use of all sorts of political and economic tools used by decision-making bodies participating in certain political principles and the reduction in prices, and therefore increase of the economic affordability of such vehicles.

The subject scenario assumes the sale of new electric cars in Poland in the years 2020-2025 of 50-60 thousand per year, including in the expert opinion: 100-300 of cars with fuel cells. It would allow reaching the level of about 1,000 hydrogen-powered cars in 2025 [5]. In 2030, the number of hydrogen-powered cars could rise to about 15 thousand, which would represent about 1.5% of the projected amount of electric cars.

After 2030, the experts expect in Poland increased sales of electric cars, including fuel cell cars. In the years 2030 – 2040, it is assumed that the average annual sales of electric cars on the Polish market will reach of 100 thousand, which would represent their level in 2040 of about 1.3 million (5-6% of total passenger cars). In 2040 in Poland, the cars with fuel cells would be 600 thousand. In the years 2040-2050, with the expert assumption of the average annual sales of new electric cars on the Polish market of 300 thousand, the number of such vehicles in 2050 would be around 4 million. Assuming that half of that number would represent fuel cell cars, the vehicles using hydrogen would be in Poland in 2050 about 2 million.

The share of fuel cells electric vehicles in the structure of the passenger cars fleet in Poland would represent only a fraction of a percent in 2030 and in 2050 would constitute 8-9% (Fig. 1).

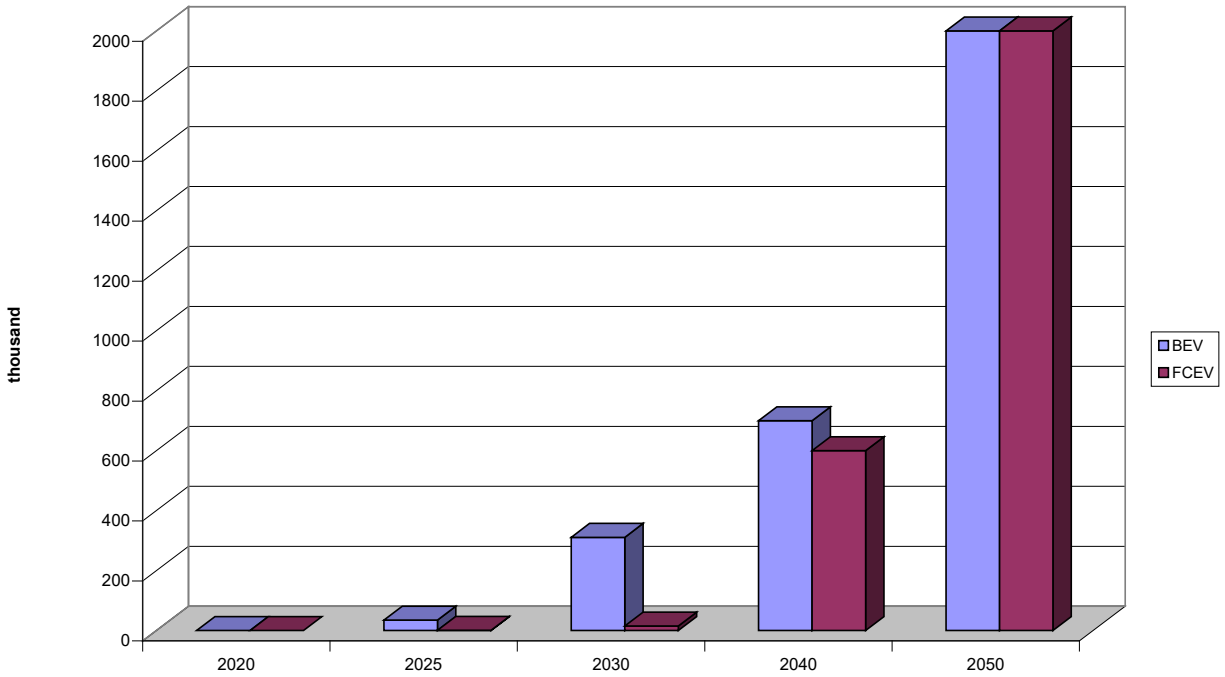

Fig. 1. Estimated number of electric BEV and FCEV cars in Poland [in thousands]

In the case of the fuel cells electric buses fleet (mostly urban) in 2020 the experimental operation of such vehicles may take place. In 2030, their share in the structure of the bus fleet in Poland would be the order of 0.2% (1-2% in the structure of city buses). In the 2050, this share would rise to 1% and 8-10% respectively.

It is expected that in connection with the anticipated construction of the hydrogen refuelling infrastructure and the gradual expansion of Poland's areas penetrated by the cars requiring this type of fuel, the consumers of hydrogen will also be the users of fuel cells electric vehicles from other countries (in the initial period mainly from Western Europe and the North) heading for Poland or driving through Poland. It is assumed that in the case of building the first hydrogen refuelling station, the number of cars coming to the Poland may amount in 2020 to about 1 thousand. With the further development of hydrogen refuelling network in Poland, the number of such cars may rise to about 60 thousand in 2030 and about 300 thousand in 2050. The structure of the projected demand for hydrogen fuel for the road transport in the years 2025 and 2050 is shown in the Fig. 2 and 3.

In 2050, the hydrogen fuel consumers will be dominated by the operated in Poland cars equipped with fuel cells (Fig. 4).

Under the adopted assumptions scenario for the hydrogen propulsion technology development of motor vehicles in Poland, the demand for hydrogen in 2020 would amount to about 20 Mg, in 2025 about 400 Mg, in 2030 about 3.6 Gg, in 2040 about 95 Gg, and in 2050 about 310 Gg.

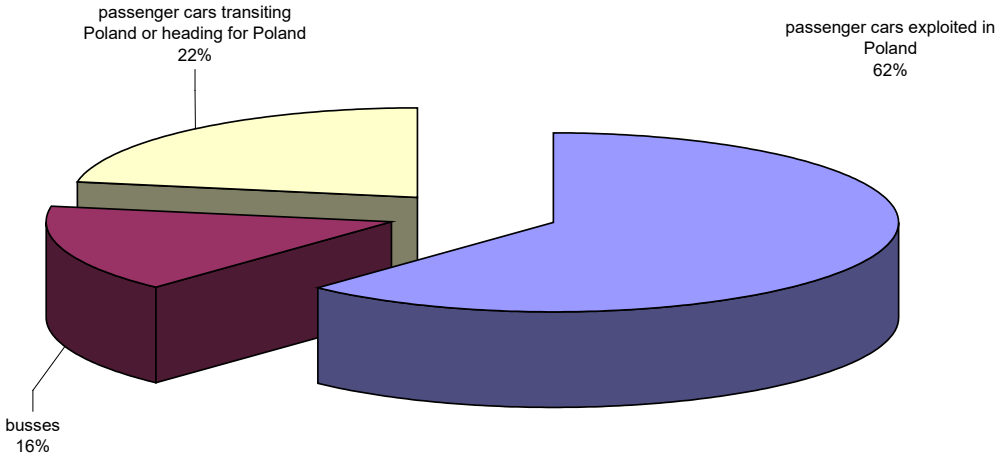

Fig. 2. Projected structure of the demand for hydrogen by the vehicles equipped with fuel cells in Poland in 2025, according to the user groups

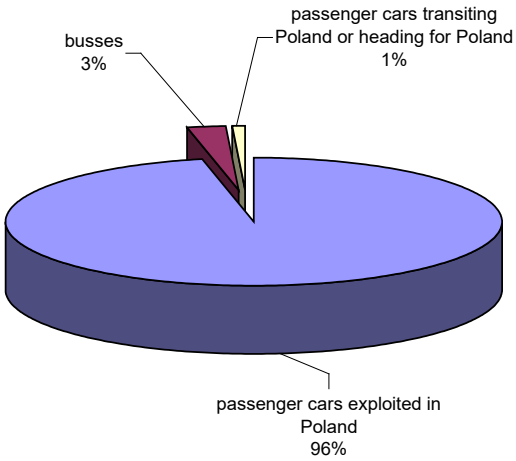

Fig. 3. Projected structure of the demand for hydrogen by the vehicles equipped with fuel cells in Poland in 2050, according to the user groups

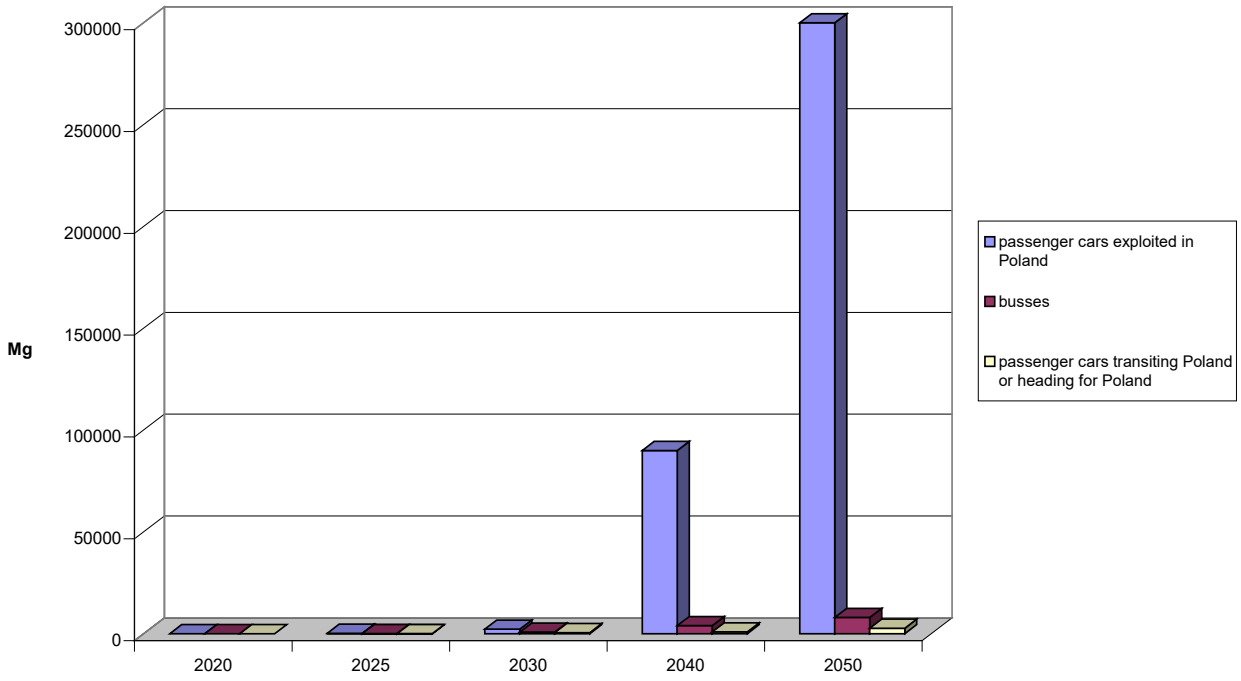

Fig. 4. Projected demand for hydrogen by the vehicles equipped with fuel cells in Poland by the 2050 [Mg]

5. Recapitulation

1. The advancement of technology to supply hydrogen to fuel cells, which produce electricity that is used by automotive motors, creates a real opportunity for the global automotive industry.
2. The advantages of hydrogen as an automotive fuel for the vehicles with fuel cells, is the lack of emissions from the engines of these vehicles and their low noise emission, which is especially important in crowded city centres.
3. The use of hydrogen fuel in the road transport frees the economy from oil imports and imports of fuel oil derivatives.
4. The source of obtaining hydrogen can be processes in the chemical industry, where this gas is, among the others, a by-product or autonomous processes for producing hydrogen e.g. by the water electrolysis, methane reforming, or bioprocesses.
5. In the case of hydrogen production by water electrolysis using electricity from renewable energy sources, the effect is the use of "clean" energy.
6. Efficient use of electricity produced during periods of excess energy production (excluding peak demand of electricity) can rely on its retention in the form of hydrogen, then later used for various purposes, e.g. to power electric vehicles equipped with fuel cells.
7. The territorial accessibility to hydrogen vehicles is determined by the availability of hydrogen refuelling infrastructure first of all along the TEN-T network.
8. Due to the innovativeness of the introduction of hydrogen technology in transport, it is expected that the economic effectiveness of the actions taken will appear only at the stage of full commercialization of the technology.
9. The development of hydrogen propulsion technology will represent an important component of the growth of innovativeness and competitiveness of the Polish economy.
10. The pre-commercial phase of the hydrogen technology development will require the use of various instruments to implement the assumed political strategy. They can be varied instruments of economic and administrative character, addressed to both the users of electric vehicles with fuel cells, and the users of vehicles with conventional engines.
11. Implementation and dissemination of hydrogen technology in the Polish transport requires proper lobbying, including the development of multi-stage information-education program.
12. The development of hydrogen technology in the road transport in the EU countries is recommended, among the others, in the Directive of the European Parliament and the Council 2014/94/EU [21] of 22 October 2014. Under the provisions of the said Directive, it is recommended that the EU countries gradually ensure accessibility to the hydrogen cars on their territory; and above all to ensure the possibility of driving hydrogen vehicles between the Member States.

References

[1] *Assessment of Implementation of European alternative fuels strategy and possible supportive proposals*, Project Move/l/1497/-1-2011, Energia, Energy and Environment Consultants, sierpień 2012.
[2] Gis, W., et al., *Elektromobilność – rynkowe scenariusze potencjalnego rozwoju rynku oraz polityczne wyzwania; (electromobility – scenerio based Market potential, Assessment and Policy options): eMAP*, Praca finansowana ze środków NCBiR w ramach programu Electromobility +, Warszawa, maj 2015.
[3] *European Union Hydrogen Highway*, http://www.hydrogencaronow.com/eu-hydrogen-highway.htm.
[4] *Fuel Cell Vehicles*, Navigant Research. http://www.greencarcongress.com/2013/05/fcvs-20130527.html.

[5] Gis, W., et al., *Przesłanki narodowego planu wodoryzacji transportu samochodowego w Polsce. Synteza*, Raport przygotowany w ITS w ramach projektu HIT-2-Corridors, 2015.
[6] H2 *Mobilite France. Study for a Fuel Cells Electric Vehicle national deployment plan*, Mobilite Hydrogene France, www.afhypac.org/images/h2_mobilitat_france.
[7] *H2stations.org* – strona Web prowadzona przez Ludwig-Bolkow-Systemtechnik.gmbh.
[8] Harrison, P., et al., *Fuelling Europe's Future*, wyd. Clepa, Eurelectric, Eurobat, European Klimat Fundation, Nissan, SSE, Transport and Environment, Cambridge Econometrics, Ricardo AEA, Element Energy, 2013.
[9] Hirose, K., *Toyota's approach to sustainability mobility and fuel cell vehicle development*, Toyota Motor Corporation and Hanley, S., Japan spending Big on Hydrogen Fuel Ahead of Olimpic, http://gas2org/2015/01/25/japan-spending, 2013.
[10] HIT NIP Denmark*, National Implementation Plan for Hydrogen Refuelling Infrastructure*, 3, wyd. 06.2014.
[11] NIP-NL*, Energy Research Centre of the Netherlands*, LE Petten, June 2014.
[12] *UK HFCA welcomes government plans for multi million pounds founding for hydrogen infrastructure and fuel cell electric vehicle*, and UK Plans on 1.5 million Hydrogen Car by 2030, www.cnh2.es/.../uk-plans-on-1-5-million-hydrogen-cars, 2014.
[13] Wallmark, C., Schaap, G., *Infrastruktura wodorowa dla transportu, Fakty i plan koncepcyjny dla Szwecji 2014-2020*, 31.12.2014.