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HYDROGENIZATION OF ROAD TRANSPORT ON THE EXAMPLE OF SWEDEN, POLAND AND JAPAN

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Abstract

The article analyses the activities within the EU and national (Sweden, Poland) concerning the introduction of hydrogen fuel in road transport. The advantages and disadvantages of this drive were addressed. A directional program of hydrogen propulsion technology motion was presented on the example of Sweden and Poland. The most recent activities in Sweden regard the so-called Nordic Hydrogen Corridor European Project. The location of basic hydrogen refuelling stations in Poland until 2030 was proposed (HIT-2-Corridors European Project). These stations should be located in both TEN-T corridors running through Poland, i.e. in 1 – Poznan, 2 – Warsaw, 3 – Bialystok, 4 – Szczecin, 5 – the Lodz region, 6 – the Tri-City region, 7 – Wroclaw, 8 – the Katowice region, 9 – Krakow, to ensure the possibility of passing vehicles equipped with fuel cells (FCEV – Fuel Cell Electric Vehicle) among others between Western Europe and Scandinavia. For comparison, the article discusses FCEV development and initial hydrogen market creation in Japan. In the article is presented reasons for hydrogen society in Japan. The reasons are as follows: hydrogen is CO_2 *free; hydrogen can be produced from various sources, energy security – local production and consumption of energy, energy security – compensating for fluctuations in renewable energy production. In the article is presented Hydrogen/FCEV strategy Roadmap in Japan in context Hydrogen/FCEV Roadmap in China.*

Keywords: *road transport, hydrogenization, combustion engines, environmental protection*

1. Introduction

With 125 operational hydrogen, refuelling station (HRS) Europe has currently (September 2017 status) the largest network in the world. The network will expand to 350 hydrogen stations (already planned and financed) by 2020 [1].

These stations require a basic demand for hydrogen from fuel cell electric vehicles (FCEV) to cover their operational costs and on longer term get a return on investment. The current fleet of about 500 fuel cell electric cars and 125 fuel cell buses is far too small to cover the operational cost of the existing 125 stations. Each station needs at least 100 fuel cell cars to cover running costs.

The Connecting Europe Facility (CEF) programme has co-financed 10 projects, which together deploy 77 hydrogen stations. The 10 projects represent an investment of 166 million Euro in hydrogen mobility.

Together with private, national, and other European funding the CEF, financing has been instrumental to setup a first hydrogen infrastructure in this transition phase in which substantial demand from fuel cell electric vehicles is not yet place. Once tens of thousands of fuel cell electric vehicles are deployed in Europe hydrogen mobility can enter a more commercial scale up of the rollout.

As stated in the Europe 2020 strategy, recalled in the Commission's "Clean Power for Transport (CPT): A European alternative fuels strategy" (COM (2013) 17 final, 24 January 2013), union aid shall support studies addressing technologies that reduce external costs, including mitigation and adaptation to climate change in the areas of freight and/or passenger transport [2].

A specific objective shall be the development of the necessary TEN-T infrastructure and facilities that will support the use of alternative fuels and propulsion replacing fossil fuels, including, electric propulsion of any type, hydrogen and methane.

The European Directive 2014/94/EU on the deployment of alternative fuels infrastructure (AFID), is the result of the CPT strategy [3]. It required Member States to develop national policy frameworks for the market development of alternative fuels and their infrastructure by November 2016. Hydrogen is mentioned as an option for realising zero-emission transport, especially for the longer distances, and then hydrogen infrastructure coverage of appropriate number of fuelling points by 2025 is set as an important condition.

For example, the Nordic Hydrogen Corridor European Project corresponds to linked EU-directives and strategies [4]. As part of a larger package of measures to mitigate climate change, the EC has indicated the need to reduce CO_2 emissions in the transport sector by 60% in 2050 compared to the level in 1990. In order to meet these decarbonisation targets of transport, new technologies will be needed, which at the same time stimulates a shift towards cleaner and more sustainable transport in urban areas (EU Urban mobility package, 17 December 2013), which is a solution for cities to ban polluting vehicles (Air Quality Directive (2008/50/EC)) [5] and support the Fuel Quality Directive (2009/30/EC) [6] that strives to lower carbon intensity of fuels and the Renewable Energy Directive (2009/28/EC) [7] that wants to accelerate implementation of renewable energy in fuel. The new National Emissions Ceilings (NEC) Directive that entered into force 31 December 2016 [8]; the main implementing measure is the National Air Pollution Control Programme, which the Member States must produce by 31 March 2019 [8]. The NEC Directive sets maximum emission ceilings for each country per year for fine particulate matter (PM2.5), SO_2, NO_x, NH_3 and non-methane volatile organic compounds.

2. Deployment of hydrogen infrastructure and FCEV

In Europe, Germany is leading the way with the Clean Energy Partnership and the industry "H2 Mobility Deutschland" initiative, aiming to have 100 HRS in operation in Germany by 2017 and 400 HRS by 2023. The UK-H2Mobility partnership plans to have 65 HRS ready by 2017. The AFHYPAC association is working on an HRS network in France. The Scandinavian Hydrogen Highway Partnership (SHHP) is developing HRS networks in Denmark, Sweden and Norway, but only five stations are operational in Sweden now and one more will open early 2017. The Nordic Hydrogen Corridor Project will lift Sweden to the same level as neighbour countries Norway, Denmark and Germany, thereby effectively connect the HRS networks in the region, and expand hydrogen electromobility in Europe. That interconnected European network will put Europe ahead of the HRS networks in Japan and USA, which are competing for leadership on FCEV, HRS and hydrogen production.

Such a "transnational European HRS network" can be used by politicians of different Member States to openly support stronger incentives to facilitate the introduction of FCEVs in their own MS and across Europe. The expansion of the European network and stronger political support and incentives in MSs are essential prerequisites for the European vehicle production sector to earlier shift of their production to FCEVs (instead of fossil fuel vehicles) and to put priority on delivering FCEV fleets to the MSs with HRS networks. European car manufacturers produce and sell cars across the world and need active support from multiple MSs to be able to prioritise deployment in Europe [9].

3. Hydrogen mobility in Sweden

Following years of studies and experiments, the first Swedish public hydrogen refuelling station was launched in 2014 in Malmö. In 2015, the next two hydrogen-refuelling stations were opened under the HIT-2 Corridors project – in Stockholm and Goteborg. Those stations serve a fleet of over a dozen or so of hydrogen-fuelled vehicles, mostly Hyundai ix35 and Toyota Mirai.

By 2020 further 14 hydrogen filling stations will be built – among others in Sandviken, Sundsvall, Östersund, Arjeplog, Umea, Pitea (allowing for a hydrogen corridor with Finland) and Örebro, Marcestad, Jönköping, Falkenberg, Stenungsund providing service for the most populated areas in Sweden and also for trans-European routes to Denmark, Germany and the UK [10].

In 2030 Sweden should have some 130-140 hydrogen refuelling stations to serve from 50 to 100,000 vehicles and approx. 50-100 hydrogen-fuelled buses [10].

According to forecasts for year 2050, the number of Swedish hydrogen refuelling stations should total approx. 100 objects serving roughly 2 million hydrogen-fuelled vehicles [10].

End 2017 some 35 FCEVs were registered and in use in Sweden.

Nordic Hydrogen Corridor European Project is a real-life trial of 8-10 new hydrogen refuelling stations (HRS), hydrogen production units (electrolysers) and 100-150 fuel cell electric vehicles (FCEV) along the TEN-T Scandinavian-Mediterranean core network corridor in Sweden during the period 2017-2020. It can be seen as the puzzle piece that interconnects the existing HRS networks in Norway, Denmark, Sweden and Finland. The project will create one Nordic HRS network in the most populated parts of these countries connecting the capitals Oslo, Stockholm, Helsinki and Copenhagen enabling hydrogen mobility for 18 million people across borders. Furthermore, it will facilitate hydrogen-based transport in a larger part of Europe, via the HRS networks in Germany and the Baltic states. FCEV have now reached such a technological maturity that they are ready for commercialization. Market development rather than technology development is currently the main barrier for FCEV market introduction.

4. Hydrogen mobility in Japan

Works on the use of hydrogen as a source of energy, which began in Japan in the last years of the 20th century, initially focused on the needs of living, for example heating of flats. Studies on the use of hydrogen as a means of transport began in 2002, when a multi-year, phased research and demonstration project "Japan Hydrogen & Fuel Cell Demonstration Project" was launched, consisting of two parts: "Fuel Cell Vehicle and Demonstration" and "Hydrogen Infrastructure demonstration".

As part of the project, inter alia, 43 prototypes of hydrogen-powered passenger cars and 5 prototypes of hydrogen-powered buses and the first 14 hydrogen filling stations in Japan were launched.

The draft assumes that in 2020, there will be approximately 1,000 hydrogen-refuelling stations in Japan, and about 50,000 will be placed on the market hydrogen cars annually.

In 2030, the number of hydrogen refuelling stations would increase to 5,000, and annual deliveries to the hydrogen car market would exceed one million vehicles.

The implementation of the results of the conducted studies was carried out by the "Fuel Cell Commercialisation Conference of Japan" established in 2001, which includes 114 entities, primarily automotive and energy, but also research and development such as Japan Automobile Research Institute or Engineering Advancement Association of Japan.

The developed scenario assumed four phases of hydrogen technology development.

The first phase, covering the years 2010-2011, apart from testing the technical solutions developed during the second stage of the Japan Hydrogen & Fuel Cell Demonstration Project, was devoted to the analysis of socio-economic aspects related to the new technology and the elaboration of the necessary legal and technical regulations. In the second phase, planned for 2015, demonstrational marketization of both hydrogen vehicles and the accompanying technical infrastructure was established. In the third phase, covering the years 2016-2025, the initial commercialization of hydrogen propulsion technology was assumed, progressing along with the gradual reduction of unit costs of construction and operation of hydrogen filling station and prices of hydrogen itself, as well as the development and production of hydrogen vehicles.

The full commercialization of hydrogen propulsion technology in Japan was established in phase four, which would start in 2026, when in Japan there should be more than 1,000 hydrogen filling stations serving a fleet of 2 million hydrogen vehicles.

In 2014, there were 31 hydrogen-refuelling stations in Japan, concentrated in the areas of the largest agglomerations (16 in the Tokyo area, 8 in the Nagoya region, 4 in the Fukuoka area, and 3 in the Osaka region). This means a significant delay compared to the 80-100 hydrogen filling stations assumed in the scenario operating in 2015. The delay in the implementation of the assumed plan for the development of the hydrogen network (despite 50% financing of the costs of their construction by the Ministry of Economy, Trade and Industry) is due to a lower than assumed dynamics of the development of the Japanese hydrogen vehicle park.

The dynamization of development of the hydrogen propulsion technology will probably bring about the organization of the Tokyo Olympics in 2020. The city plans to build up to this year, at a cost of nearly USD 400 million, 35 consecutive hydrogen-refuelling stations that would service 6,000 hydrogen cars.

According to the latest available data, Japanese sources assume that there are currently 92 HRS and 2321 FCEVs (as of Dec. 31, 2017), in 2020 the country will have 160 hydrogen refuelling stations and 40,000 hydrogen cars, in 2025 320 stations and 200 thousand cars, and in 2030 – 320 stations and 800 thousand hydrogen cars [11].

According to the Japanese hydrogen is CO_2 free, can be produced from various sources, energy security – local production and consumption of energy, energy security – compensating for fluctuations in renewable energy production. They are the reasons that Japan is entering the path of being hydrogen civilization.

For comparison Hydrogen/ FCEV Roadmap in China is as follows (2016.10): in 2020 – 100 HRS (5,000 FCEV cars), 2025 – 350 HRS (50,000 FCEV cars), 2030 – 1000 HRS (1,000,000 FCEV cars [12].

5. Hydrogen mobility in Poland

An essential element and direction for the development of road transport based on hydrogen-powered fuel cells is to create an alternative hydrogen-refuelling infrastructure.

Despite the strategic importance of developing HRS network, the explicitly formulated programming methodology for the development of these stations, has not been encountered.

The methodology developed is of multi-stage character. Individual steps leading to the designation of the location of HRS in Poland (as the methodology alone seems to be of universal character) are as follows [13]:

Stage I: Method allowing identifying regions in which the hydrogen refuelling stations should be located in the first place.
Stage II: Method allowing identifying urban centres, in which should be located the said stations.
Stage III: Method for determining the area of the station location.
Stage IV: Method used to indicate a specific location of hydrogen refuelling station.
Stage V: Method indicating the preferred order of building investments in creating future network of hydrogen filling stations on the Polish territory.

In any of the said stages the group of 3-5 basic characteristics was adopted that determine, according to the experts, the potential future demand for hydrogen fuel, whose likely impact strength was determined by giving them the appropriate rank on a scale of 1 to 5 [13]. Detailed assumptions, acting procedures, numerical information, etc. contained by the task No. 5 entitled "The selection criteria for the location of HRS on the Polish TEN-T network" [13].

According to the guidelines of the HIT-2-Corridors project, as the indications of development of the network of HRS on the territory Polish, was the assumption taking into account firstly the possibility of refuelling with hydrogen connecting the areas between the Polish western border and the Baltic countries and next e.g. via ferry – with Finland**.** This idea is adhered to by enabling the safe use of hydrogen cars by their owners crossing the northern border of Poland (via ferry). This would provide, in the first place, opportunity for maintaining continuity of the passage of hydrogen cars along the transport corridors in these international directions within the EU.

Pointing to the proposed order of investments in the construction of HRS in Poland and taking into account the above-mentioned reasons, the preliminary aspect of locations in the cities or urban areas selected according to the rankings stages I to III, was considered.

In the first place taken into account were:

– already existing refuelling opportunities in the neighbouring countries,
– the expected future HRS locations in the Baltic countries,
– gradually increasing the area available for hydrogen-powered cars as a result of the subsequent location of new stations at distances up to 300 km from the existing or sequentially from the newly-opened ones.

In addition, while pre-indicating another HRS locations, taken into account were:

– a size of average passenger car traffic intensity along the selected national roads according to available data, the average traffic volume projected for 2020,
– development of HRS network ensuring gradually increasing the area of accessibility of other Polish regions by hydrogen cars,
– development of HRS in areas with potentially high demand for hydrogen fuel also by the fleet of city buses and taxis.

With the above criteria, the order of preliminary proposals to build HRS in Poland are as follows: 1 – Poznan, 2 – Warsaw, 3 – Bialystok, 4 – Szczecin, 5 – Lodz area, 6 – Tri-City area, 7 – Wroclaw, 8 – Katowice region, 9 – Krakow (Fig. 1).

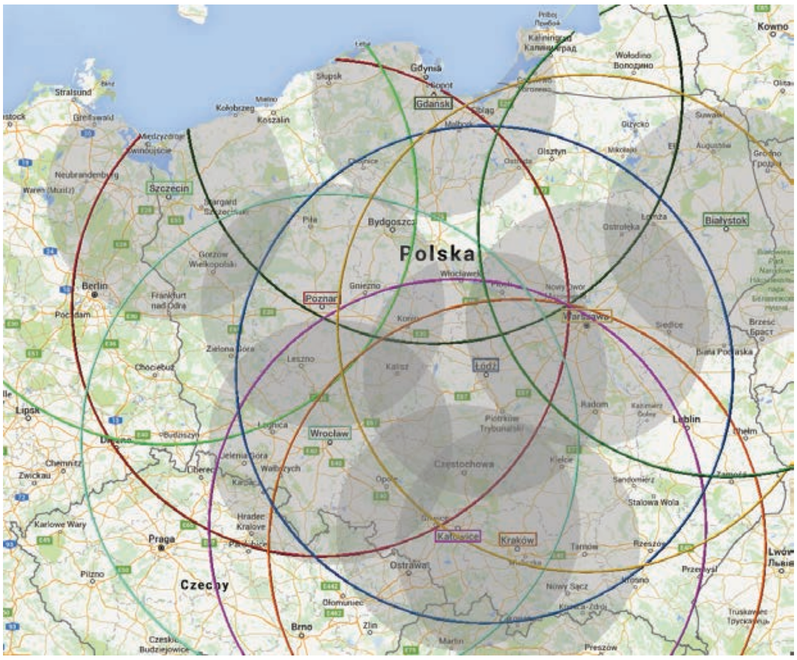

Fig. 1. The movement area of cars using fuel cells based on 9 hydrogen refuelling stations situated on the national TEN-T road network by the 2030 [4]: a) when driving in one direction (large circles – to approx. 600 km) b) when driving there and back (small circles – to approx. 300 km)

6. Summary

The development of hydrogen civilizations is progressing. The fastest is in Japan. It also takes place in China. In Europe, it is intense in Sweden. However, the fastest one is in Germany. In Poland, in Motor Transport Institute has been develop circumstances of the national plan for hydrogenization of road transport.

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