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Hydrogenization of road transport in Poland – European Project HIT-2-Corridors

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Abstract

Two of the major international projects concerning hydrogenization of motor transport are in Europe: HyFIVE "Hydrogen For Innovative Vehicles" and "Hydrogen Mobility Europe" - creating the European visio for hydrogen transport project – H2ME. The hydrogenization of motor transport is the subject of many international research projects, e.g. „Clean Hydrogen In European Cities" – CHIC. Of special interest is the lecture regarding the plans of hydrogenisation of the British road transport prepared with E4tech project. As a result of verification, under Polish conditions (European Project HIT-2-Corridors), of the original method developed for determining the initial location of the hydrogen refueling station in Poland, in the pre-commercial phase (2020 - 2030), the said location has been indicated along with the order of investment, taking into account above all the freedom to move around Poland of cars powered by hydrogen visiting Poland and transiting our country between other EU countries.

Keywords: hydrogenization, road transport, TEN-T, FCEV

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1. Introduction

The advantages of hydrogen as an automotive fuel is the lack of pollutants emission from motor vehicles' engines, which is especially important in crowded city centers and with the possibilities of its local production. The use of hydrogen fuel in the road transport to a large degree brings about independence from the import of crude oil and crude oil derived fuels. In the case of producing hydrogen by water electrolysis using electricity from renewable energy sources, the result is the use of "clean" energy [4], [7].

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 of the Council 2014/94/EU of 22 October 2014 [1]. Under the provisions of the said Directive, it is recommended to EU countries to progressively ensure accessibility to hydrogen cars on their territories, and above all to ensure the possibility of driving hydrogen vehicles between the member States.

HyFIVE is an ambitious European project (total cost of EUR 39 million) including 15 partners who will deploy 185 fuel cell electric vehicles (FCEVs) from the five global automotive companies who are leading in their commercialisation (BMW, Daimler, Honda, Hyundai and Toyota). Refuelling stations configured in viable networks will be developed in three distinct clusters by deploying 6 new stations linked with 12 existing stations supplied by Air Products, Copenhagen Hydrogen Network, Linde, Danish Hydrogen Fuel AS etc. [5], [10].

One of the major international projects concerning hydrogenization of motor transport is the "Hydrogen Mobility Europe" creating the European visio for hydrogen transport project – H2ME [5], [9], [11]. The project has a budget of EUR 72 million.

Hydrogen Mobility Europe (H2ME) brings together Europe's 4 most ambitious national initiatives on hydrogen mobility (Germany, Scandinavia, France and the UK). The project will expand their developing networks of HRS and the fleets of fuel cell vehicles (FCEVs) operating on Europe's roads, to significantly expand the activities in each country and start the creation of a pan-European hydrogen fuelling station network. In creating a project of this scale, the FCH JU will create not only a physical but also a strategic link between the regions that are leading in the deployment of hydrogen. The project will also include 'observer countries' (Austria, Belgium and the Netherlands), who will use the learnings from this project to develop their own hydrogen mobility strategies. The project is the most ambitious coordinated hydrogen deployment project attempted in Europe. The scale of this deployment will allow the consortium to:

- trial a large fleet of FCEVs in diverse applications across Europe - 200 OEM FCEVs (Daimler and Hyundai) and 125 fuel cell range-extended vans (Symbio FCell collaborating with Renault) will be deployed,
- deploy 29 state of the art refuelling stations, using technology from the full breadth of Europe's hydrogen refuelling station providers. The scale will ensure that stations will be lower cost than in previous projects and the breadth will ensure that Europe's hydrogen station developers advance together,
- conduct a realworld test of 4 national hydrogen mobility strategies and share learnings to support other countries' strategy development,
- analyse the customer attitude to the FCEV proposition, with a focus on attitudes to the fuelling station networks as they evolve in each country,
- assess the performance of the refuelling stations and vehicles in order to provide data of a sufficient resolution to allow policy-makers, early adopters and the hydrogen mobility industry to validate the readiness of the technology for full commercial roll-out.

According to preliminary results of studies the level of costs per vehicle/km of a conventional vehicle (ICE) equal to 23 cents, a hydrogen vehicle may achieve at the price of 1kg of hydrogen of EUR 5 and if exempted from taxes.

With a price of hydrogen of 10 EUR/kg the cost per vehicle/km shall increase to 32 cents. The hydrogenization of motor transport is the subject of many international research projects, e.g. „Clean Hydrogen In European Cities" – CHIC where 23 partners of 8 countries invested EUR 81 million in HRS and 28 hydrogen buses (5 in Bologna, 8 in London, 5 in Oslo, 6 in Hamburg and 4 in Cologne) or „Hydrogen Acceptance In the Transition Phase – Public and Stakeholder Acceptance of Fuel Cell Electric Vehicle In Europe" – HYACINTH [2]. This project brings together 11 partners from 5 countries and a budget of EUR 1 million, of which EU funds total EUR 661 thousand [2].

The project comprised questionnaires among over 7 thousand residents of EU and interviews with 455 representatives of entities of potential hydrogen transport market players.

Of special interest is the lecture regarding the plans of hydrogenization of the British road transport prepared with E4tech [8].

The plan assumes that to 2020 the UK will have 30-65 hydrogen refuelling stations (HRS) and 50-100 hydrogen buses will be used and approx. 500 passenger cars. In 2025 the number of stations is expected to

expand to approx. 150 and the number of used hydrogen vehicles should be sever-al thousand. After year 2025 from 10 to 100 HRS, 100 buses and from 10 thousand to several thousand other vehicles with hydrogen drive should appear every year.
The HIT-2-Corridors European project provides the crucial next steps to market driven hydrogen infrastructure expansion and interconnectivity along core network corridors, in a way that is broader and more inclusive than ever before in the European context [3].
New national implementation plans for HRS was written for Belgium, Finland and Poland. For Riga (Latvia) was drafted implementation plan for hydrogen refuelling stations (HRS) for its region. These new plans was build upon experiences from developing similar plans for Sweden, Denmark, The Netherlands and France in the HIT project [6]. In this way, a collective learning process was deliver better and more harmonised plans for the future. The new plans was also gain experience from the Germany NOW program, the UK H2-Mobility program and the Norwegian HyNor program: all three already well advanced in national hydrogen network planning. In HIT-2-Corridors complementing business case studies was be drafted to propel further progress for first-mover regions among others in Sweden.
Three new HRS was deployed along two TEN-T core network corridors: Scandinavian-Mediterranean and North Sea-Baltic. All HRS have different characteristics and specific innovative elements. These new HRS fill essential missing links between the existing HRS along these two corridors. Germany, Denmark, Sweden, Norway and Finland was interlinked by two new HRS in Gothenburg and Stockholm. A new HRS in Finland was link Sweden and Finland to the Baltic States. The plans for HRS in Riga will extend the link via Finland towards Poland.
As a result of verification, under Polish conditions, of the original method developed for determining the initial location of the hydrogen refueling station in Poland, in the pre-commercial phase (2020 - 2030), the said location has been indicated along with the order of investment, taking into account above all the freedom to move around Poland of cars powered by hydrogen visiting Poland and transiting our country between other EU countries.
Despite the strategic importance of developing hydrogen filling stations infrastructure, in the available materials, including various national implementation programs for hydrogen propulsion technology developments, the explicitly formulated programming methodology for the development of these stations, has not been encountered.

2. Circumstances of the national plan for hydrogenization of road transport in Poland

National implementation plans are in place in a number of countries, e.g. Belgium, France, the Netherlands, Sweden, etc. In Poland, the methodology developed is of multi-stage character. Individual steps leading to the designation of the location of hydrogen refuelling stations in Poland (as the methodology alone seems to be of universal character) are as follows [3]:

- Stage I: Method allowing to identify regions in which the hydrogen refuelling stations should be located in the first place.
- Stage II: Method allowing to identify urban centres, in which should be located the said stations.
- Stage III: Method for determining the area of the station location.

In Table 1 is shown method allowing to identify regions (Stage I), urban centres (Stage II), area of the station location (Stage III).

Table 1. Method allowing to identify regions (stage I), urban centres (stage II), area of the station location (stage III) [3]

Stage I	Stage II	Stage III
Average GDP per capita	Average distance of the cities, over 250 thousand inhabitants, from the place of hydrogen manufacture (acquisition)	Results of locating the stations in question obtained in stage I and II, and relying on the results of the measurement of average traffic volume of passenger cars on the roads leading to these cities or on selected road junctions located near these cities
Average population density (inhab./km²)	Average distance of the cities, over 250 thousand inhabitants from the nearest hydrogen refuelling station located outside Poland	
The number of people living in the largest cities in the region, out of the cities with > 250 thousand inhabitants	Number of taxies in the city	Traffic flow intensity of passenger cars was included on the roads leading to the following cities: Warsaw, Poznan, Krakow, Wroclaw, Katowice (Upper Silesia conurbation),

Average traffic volume of passenger cars on the national roads of international significance running through the region (passenger cars/24 hours)	Number of municipal transport buses	Tri-City, Szczecin, Lodz, Bialystok

The average daily traffic of motor vehicles (SDR) in 2010 on the national road network was 9888 vehicles/24 hours [3]. On the international roads, the SDR in 2010 amounted to 16667 vehicles/24 hours, and at other national roads - 7097 vehicles/24 hours.
The average 24-hours traffic of passenger cars (SDR) in 2010 on the core network of national roads amounted to 11 167 vehicles/24 hours (all motor vehicles 16 667 vehicles/24 hours). The busiest roads belonging to the TEN-T in Poland were: section S1 and the E40 and E75, on which SDR of passenger cars amounted to over 14 thousand vehicles/24 hours, and in case of S1 over 20 thousand vehicles/24 hours. These traffic volumes are averages for the entire length of the road, while the SDR on individual sections of these roads was significantly differentiated.
Graphic illustration of the averaged daily traffic volume of passenger cars is shown in Fig.1.

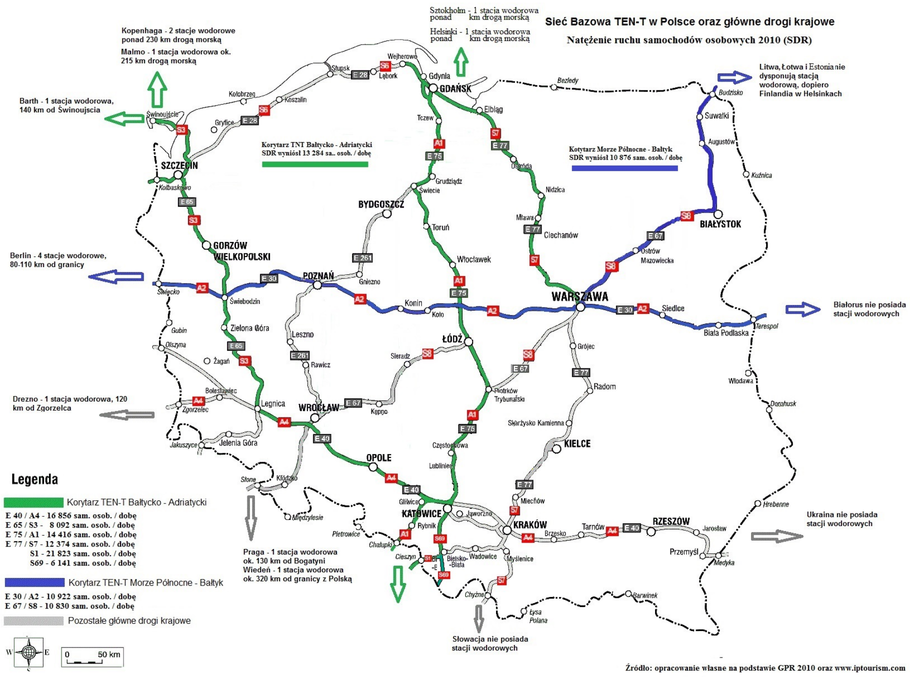

Fig.1. The SDR of passenger cars on the Core TEN-T network in Poland [Source: own compilation based on data from the GPR 2010, and www.iptourism.com]

For the TEN-T network in Poland, average traffic intensity on the roads in the Baltic - Adriatic corridor an amounted to 13 284 vehicles/24 hours (E40, E65, E75, E77, S1, S69), while of the roads in the North Sea - Baltic Sea corridor - 10 876 vehicles/24 hours (E30, E67) [3].
Additionally, while pre-indicating subsequent hydrogen station locations taken into consideration were:

- average passenger car traffic intensity and average traffic volume projected for 2020,
- development of hydrogen filling stations network in the country,
- development of hydrogen refuelling stations in areas with potentially high demand for hydrogen fuel also by fleets of buses and taxis.

The order of investment: while taking into account the initial hydrogen refuelling stations locations (Stages I-III), in the first place included were:

- existing hydrogen refuelling capabilities in the neighbouring countries,
- the assumed future hydrogen refuelling stations locations in the Baltic Sea countries,
- new stations at the distances up to approx. 300 kilometers away from the existing stations or sequentially from the newly-opened stations.

3. Results

With the above criteria, the order the construction of a hydrogen refuelling stations in Poland, in order of their creation, along the TEN-T corridors are: 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 (Fig.2).

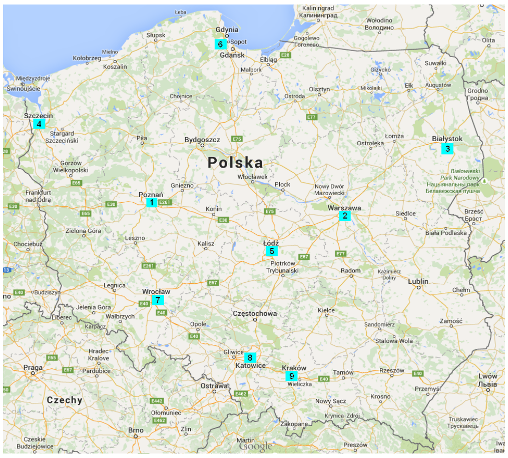

Fig.2. Map of Poland with marked sites of the proposed public hydrogen refuelling station locations [3]

On the Fig. 3 is shown the movement area of cars using fuel cells based on 1 hydrogen refueling station situated on the national TEN-T road network by the 2020.

Fig.3. Penetration area of cars using fuel cells based on 1 hydrogen refuelling station situated on the national TEN-T road network by the 2020 [3]
a) when driving in one direction (diameter of large circles - to approx. 600 km),
b) when driving there and back (diameter of small, shaded circles - to approx. 300 km)

On the Fig. 4 is shown the movement area of cars using fuel cells based on 5 hydrogen refueling stations situated on the national TEN-T road network by the 2025.

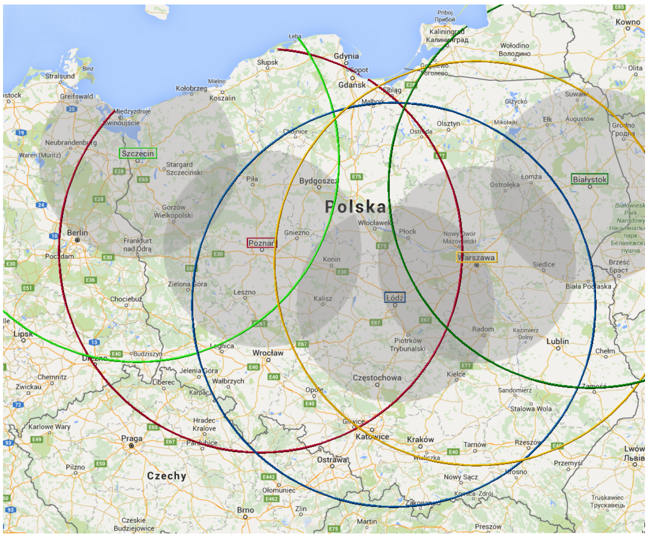

Fig. 4. Penetration area of cars using fuel cells based on 5 hydrogen refuelling stations situated on the national TEN-T road network by the 2025 [3]
a) when driving in one direction (diameter of large circles - to approx. 600 km),
b) when driving there and back (diameter of small, shaded circles - to approx. 300 km)

On the Fig. 5 shown the movement area of cars using fuel cells based on 9 hydrogen refueling stations situated on the national TEN-T road network by the 2030.

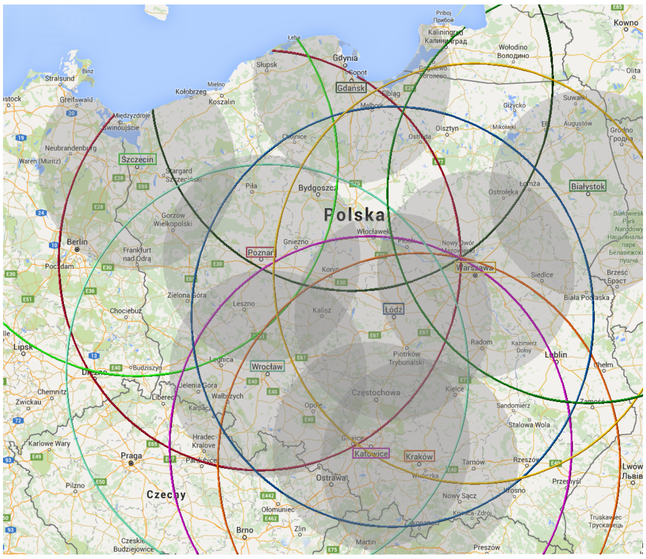

Fig. 5. Penetration area of cars using fuel cells based on 9 hydrogen refuelling stations situated on the national TEN-T road network by the 2030 [3]
a) when driving in one direction (diameter of large circles –
to approx. 600 km),
b) when driving there and back (diameter of small, shaded circles - to approx. 300 km)

Full commercialization of hydrogen technology in Poland (the years 2040 – 2050): Respectively: 200 - 600 hydrogen refueling stations, Financial expenditures for the construction of hydrogen refueling infrastructure in the order of 155-190 million €.
The assumptions: 600 thousand respectively - 2 million passenger cars, 500 - 1000 buses, 100 - 300 thousand cars transiting Poland annually.
On the Fig.6 is shown forecast of demand for hydrogen by the vehicles equipped with fuel cells in Poland by the 2050.

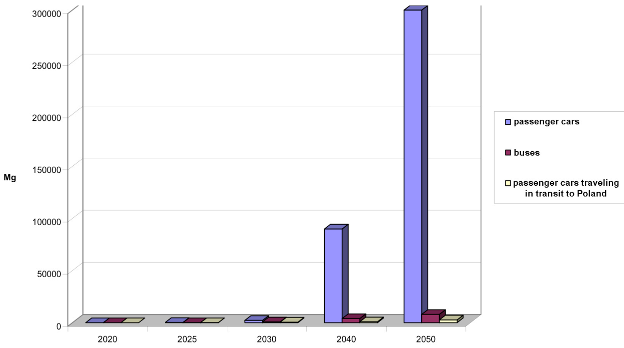

Fig. 6. Forecast of demand for hydrogen by the vehicles equipped with fuel cells in Poland by the 2050 Mg [3]

4. Summary

In summary, it can be stated that [3]:

- the advancement of hydrogen technology supplied with fuel cells technology is significant (for example Toyota launched the production of FCEV in the autumn 2014),
- hydrogen as an automotive fuel is the lack of pollutants emission from motor vehicles'engines, which is especially important in crowded city centres and with the producing electrical energy used by automobile engines offers a real opportunity for the global automotive industry,
- the advantages of possibilities of its local production,
- the use of hydrogen fuel in the road transport to a large degree brings about independence from the import of crude oil and crude oil derived fuels,
- in the case of producing hydrogen by water electrolysis using electricity from renewable energy sources, the result is the use of "clean" energy (0,97 $CO_{2eqv.}$/1 kg H_2),
- the territorial accessibility for hydrogen vehicles is determined by the availability of hydrogen refuelling infrastructure (in Germany will be in 2020 about 100 HRS, the same situation will be in this year in Japan), in the first place in Europe along the TEN-T network,
- as a consequence, the study assumed that pre-commercial phase of the development of hydrogen technology in Poland will take place in the years 2020 - 2030, and its full commercialization will be possible only in the years 2040-2050,
- the places where it is proposed to built hydrogen refuelling stations should be in years 2020 – 2030 (in order of their creation, along the TEN-T corridors): 1 - Poznan 2 - Warsaw, 3 - Bialystok, 4 - Szczecin, 5 - Lodz region, 6 - Tri-City area, 7 - Wroclaw, 8 - Katowice region, 9 - Krakow.

5. References

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