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HYDROGEN INFRASTRUCTURE FOR TRANSPORT
HIT-2-CORRIDORS

WOIKOSKI

2015

Proposal for Implementation Plan Hydrogen as Alternative Fuel in Finland

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Content

1. Background

The Finnish hydrogen NIP is part of the Report Alternative fuels infrastructure — a proposal for a national framework until 2020/2030" published by Ministry of Transport and Communications of Finland (MINTC) in May, 2015. Hydrogen was chosen as one of the official alternative fuels in Finland. The official working group to prepare the official plan for the alternative fuels infrastructure of Finland was nominated by Ministry of Transport and Communication in October 2015 and the work began on 3rd December. The base for the work will be the proposal report mentioned above.

This report is a proposal for the national implementation plan for hydrogen as alternative fuel in transport based on past and new studies, reports, working group and roundtable discussions.

1.1 Early activities - Past studies, reports and programmes in 2007-2013

The strong background for hydrogen and fuel cell activities in Finland is based on the past **governmental funding programme** – Tekes Fuel Cells 2007-2013[1]. Tekes is Finnish Funding Agency for Technology and Innovation. More than 50 industrial companies and ten Finnish research organizations were developing their technologies, product concepts and infrastructure plans during the Programme. The total volume of the programme was more than 100 million €. The final report of the programme[2] and Results[3] were published at the end of the programme.

The first HRS in Finland was built 2013 by the gas company Oy Woikoski Ab. The project was funded by Tekes. The first HRS was part of a broad joint demonstration project Demo 2013 in Port of Helsinki, Vuosaari harbour.

During the Fuel Cell Programme **several studies and reports** were made to help Finnish companies to create future hydrogen and fuel cell business and to build infrastructure in Finland. Several ministries were involved in the programme such as Ministry of Employment and Economy (Energy department, Innovation department, Cleantech Program) and Ministry of Transport and Communication.

[1] http://www.tekes.fi/en/programmes-and-services/tekes-programmes/fuel-cell/

[2] http://www.tekes.fi/globalassets/global/ohjelmat-ja-palvelut/ohjelmat/polttokennot/aineistot/01_2014-polttokennot-ohjelman-loppuraportti.pdf

[3] http://www.tekes.fi/contentassets/28eba9f24d2d43dc8b83b08248d85dcd/301_13_fuel-cells_and_hydrogen-in-finland.pdf

The most relevant previous studies and reports related to hydrogen are: **Finnish Hydrogen Roadmap (VTT and several companies, 2013)**[4] and **Ensuring safety of fuel cell applications and hydrogen refuelling (in Finnish), VTT,2013**, of which a short translated English version "Demonstration of fuel cell applications at Vuosaari Harbour – review of legislation requirements", VTT 2013[5]. The safety, standard and legislation issues are discussed in Chapter 6.

The most active organizations to promote fuel cell and hydrogen industry in Finland is Fuel Cell Finland industrial grouping, part of Finnish Federation of Technology Industries, and a member of EHA, and the private gas company Oy Woikoski Ab. All of the important reports and publications can be found on FCF web site[6].

International co-operation is active. Finnish organizations have more than ten projects going on with funding of FCH JU. Five Finnish organizations are members in current FCH2 JU in Hydrogen Europe (earlier NEW IG) and NRGHY.

1.2 New reports, studies, and working groups in Finland

1.2.1 Plans and reports in 2014-2014

Finnish national implementation plan for the build up of hydrogen refuelling infrastructure is based on several reports, studies and past programmes related the hydrogen and fuel cell activities in Finland and abroad.

The main driver to the current proposal to the plan for Finnish alternative fuels infrastructure was the EU directive 2014/94/EU on the deployment of alternative fuels infrastructure. Finnish Ministry of Transport and Communications started to create a Finnish plan to answer the directive. A working group was formed. The result is the reoport **"Alternative fuels infrastructure — a proposal for a national framework until 2020/2030" published by Ministry of Transport and Comunications of Finland (MINTC)** in May, 2015[7]. Author is Expert group on alternative fuels infrastructure and the experts were from five ministries, several institutes, alternative fuels organizations and companies. The work was commissioned by Advisory Board for Environmental Affairs in Transport of Ministry of Transport and Communication. A summary of this report is in Chapter 3.2. The work was done during April 2014- February 2015. Five meetings and one joint workshop with scenario group were held.

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[4] Finnish hydrogen roadmap http://www.tekes.fi/globalassets/global/nyt/uutiset/vetytiekartta.pdf; http://www.fuelcelltoday.com/news-archive/2013/may/the-finnish-hydrogen-roadmap-hydrogen-to-join-electricity-in-ending-traffic-pollution

[5] http://www.vtt.fi/inf/pdf/technology/2013/T112.pdf
http://www.tekes.fi/globalassets/global/ohjelmat-ja-palvelut/ohjelmat/polttokennot/aineistot/vtt_r_04164_11.pdf

[6] http://new.teknologiateollisuus.fi/fi/ryhmat-ja-yhdistykset/tietolahteita-362.html ; http://new.teknologiateollisuus.fi/fi/ryhmat-ja-yhdistykset/polttokennot.html

[7] http://www.lvm.fi/docs/fi/3759144_DLFE-27022.pdf

1.2.2 Official implementation plan for alternative fuels will be done 2015-2016

An official plan will be made based on this proposal during 2015 -2016, kick-off in the beginning of December. An official working group has been nominated by Minister of Transport and Communication (many of the organizations and experts as in the proposal).

Scenarios for low carbon transport and traffic are developed in a study by VTT (States Technical Research Institute) and VATT (States research institute of economy). The study was funded by Ministry of Employment and Economy (Energy department, Energy in Transport). The scenarios were aligned with the work group for alternative fuels infrastructure (Ministry of Transport and Communications) and used in the report "Alternative fuels infrastructure". Scenarios for hydrogen are in Chapter 3.3.

Hydrogen was chosen as an alternative fuel in Finland

EU directive on deployment of alternative fuels infrastructure leaves hydrogen as a voluntary alternative for member states. **Hydrogen was chosen as one of the alternative fuels in Finland,** because there was already hydrogen refuelling infrastructure development and two stations in Finland in 2013-2014. Industrial companies were committed to continue building future HRS network and find new business opportunities in HRS technology.

1.3 Roundtable discussions, workshops, seminars and interviews

Totally more than 35 stakeholders were involved in the whole process.

The working group for Alternative fuels infrastructure had five workshop type meetings during April 2014 – January 2015.

A joint roundtable workshop was held in 22.10.2014. Participants consisted of two working groups: the organizations included **five ministries** (Ministry of Employment and Economy, Ministry of Transport and Communications, Ministry of Environment, Ministry of Forest and Agriculture, Ministry of Finance), VTT (States Technical Research Institute), VATT (States research institute of economy), representatives from biogas, LNG, electric vehicles, bioethanol, biofuel, and hydrogen organisations including companies and associations.

Fuel cell car manufacturers were interviewed separately.

A seminar "Climate panel studies" was arranged in 15.9.2015 by Ministry of Transport and Communications. Three studies and reports were introduced. More than 50 participants from the relevant organizations such as ministries, environmental agencies, research institutes, industrial associations and companies were discussing of the results.

The main result is the report (link in footnote 1). **Results are introduced in this report in Chapters 3.2 The proposal, 3.3 Scenarios and 4 Hydrogen, HRS and FCEV in Finland – a national implementation plan.**

A SWOT workshop was arranged internally in Oy Woikoski Ab in 27.8.2015. FCEV suppliers Hyundai and Toyota were interviewed separately. European stakeholders were interviewed in Brussels in 7.5.2015 including FCH JU managers, CEA, Daimler, consultant company Enovation, a BEV FC range extender supplier, gas company Airliquid and Hyundai Europe. They were asked to give suggestions to Finnish circumstances.

2 International view

2.1 The global and European status in 2014

The global status of the HRS in 2014 is in Figure 1 and European status in Figure 2. Both are based on LBST record (Ludwig-Bölkow-Systemtechnik GmbH).

Figure 1. The global status of HRS in 2014

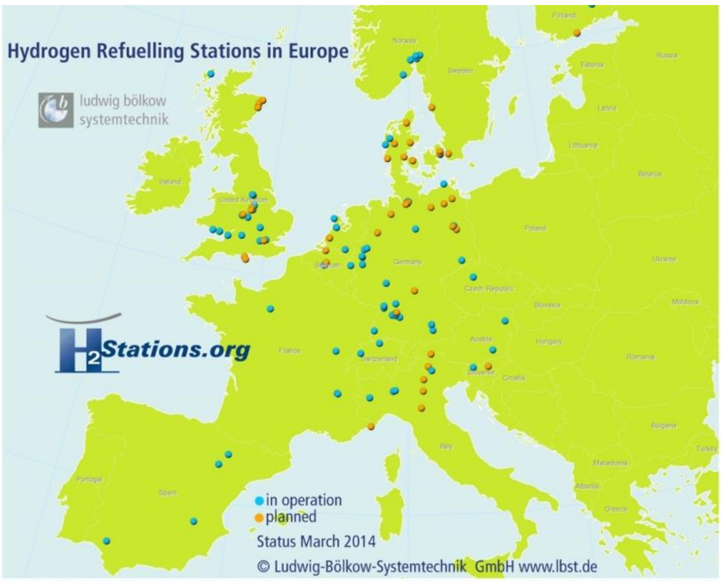


Figure 2. The current status of HRS in Europe (2014) is in Figure X by LBST

2.2 Scenarios in Europe

The future of hydrogen in transport is summarised below by New Energy World Industry Grouping (NEW-IG)

The example of transport

By 2015, existing national and European demonstration projects will have deployed approximately 70 Hydrogen Refuelling Stations (HRS) across Europe

France
France will have a small number of HRS which will centre around captive fleets

Germany
The clean energy partnership will have deployed **~50** HRS creating an initial nationwide German network

Netherlands
The Netherlands will start implementing their deployment plan with **2-4** HRS

Scandinavia
The Scandinavian network will comprise approximately **10** HRS

UK
The UK will have deployed **9** HRS of which 6 will be based in the London area

By 2018 the planned pan-European project will increase the refuelling network across these nations and start to create strategic links along TEN-T corridors

France
The French network will have expanded to ~20 HRS

Germany
The German network will have expanded to 100 HRS

Netherlands
The Dutch network will have expanded to 5-10 HRS

Scandinavia
The Scandinavian network will have expanded to 25 - 30 HRS

UK
The UK will have deployed at least 30 HRS

From 2020, the H2Mobility initiatives would allow nationwide driving in the first-mover countries and start to expand into neighbouring countries along TEN-T Corridors, taking learning from the early deployment centres

France
The French network will keep on expanding with **30-40** HRS by 2020 and **100** HRS by 2023

Germany
The German network will keep on expanding with **400** HRS in 2023

Netherlands
The Dutch network will keep on expanding with **20** HRS by 2020 and **40-50** HRS by 2023

Scandinavia
The Scandinavian network will keep on expanding with **35-40** HRS by 2020 and **50** HRS by 2023

UK
The UK network will keep on expanding with **60-70** HRS by 2020 and **100** HRS by 2023

National implementation plans have been done already in several European countries. Scenarios in some of these European coutries are summarized in Table 1.

HRS	**Germany**	**United Kingdom**	**Nether lands**	**France**	**Denmark**	**Belgium**	**Sweden**	**Finland**	**Poland**
2015-2020	100	65	20	22*	15 - 50	25	15	6	1
2020-2025	400	300	80	355	100-200	75	25	20	5
2025-2030	900	1100	200	600	500 - 600	150	100	26	9

Table 1: Implementation scenario of HRS in European countries

*France: initial focus on range-extender vehicles for captive fleets

The total HRS penetration in these coutries is estimated following

- 2020: about 0,5 %
- 2025: about 2,5 % (exception Denmark with about 10%)

- 2030: bout 5,0 % (exception UK with about 13%)

Linked to the roll-out of HRS, estimations in many European counties have been made on the amount of hydrogen vehicles to be deployed in the timeframe 2015 – 2030 in Table 2.

FCEV	**Germany**	**United Kingdom**	**Nether lands**	**France**	**Denmark**	**Belgium**	**Sweden**	**Finland**
2015-2020	10.000	20.000	1.500	1.000	1.000	1000	n.a	10 – 20
2020-2025	100.000	300.000	15.000	100.000	100.000	7500	n.a	2000
2025-2030	1.800.000	1.600.000	150.000	800.000	300.000	30000	n.a	4000

Table 2: Implementation scenario of fuel cell electric vehicles in foreign countries

*France: initial focus on range-extender vehicles for captive fleets

2.3 TEN-T HIT Projects and national implementation plans

The maps of HIT-2 corridors hydrogen refueling stations and a synchronized map with all corridor HRS until 2020 are in Figures 3 and 4.

Figure 3. HIT-2 corridors new HRS

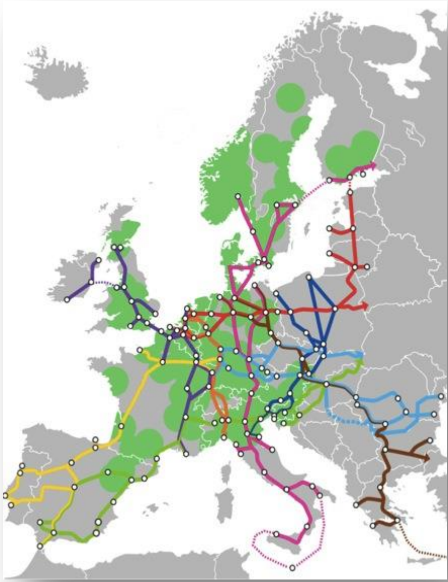


Figure 4. Sychronized map for hydrogen network for 2020

2.3.1 HIT-1 and national implementation plans for Sweden, Denmark, France and Netherland

During TEN-T HIT project four national implementation plans for Hydrogen was produced. A summary of national plans are in Figures 5 (the Netherlands and france) and 6 (Denmark and Sweden). The links for these plans can be found from the project web page http://www.hit-tent.eu/2014/12/hit-the-roads/.

Estimate for the **Netherlands 2015-20150**

	2015 – 2020 Market preparation	2020 – 2025 Early market intro	2025 – 2030 Full market intro	2030-2050 Mass market
Car fleet	few → 1,500	1,500 → 15,000	15,000 → 125,000	→ >2.5 mln
HRS network	4 → 20	20 → 75	75 → 200	→ ≥ 1,000
Bus fleet	→ 50 - 100	50 - 100 → 250 - 500	250 - 500 → 1,000	→ 2,000 - 3,500
HRS at depot	→ 5 – 7	5 - 7 → 10 - 25	10 - 25 → 25 - 50	→ ≥ 50

Estimate for **France 2015-2030**: FCEV/HRS 1200/22 (2020) – 130 000/340 (2025) – 760 000/ 590 (2030)

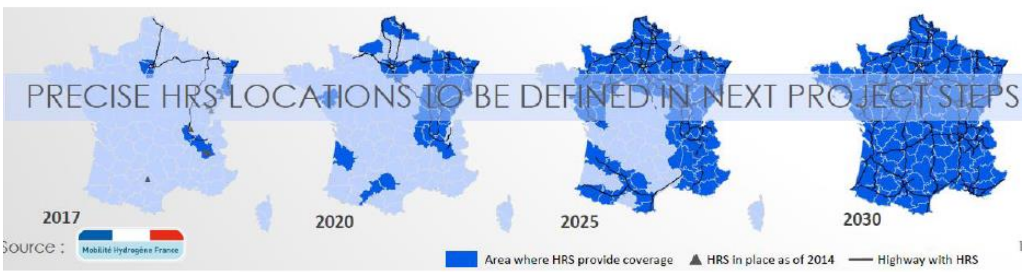


Figure 5. Estimaters for the Netherland and France until 2030/2050

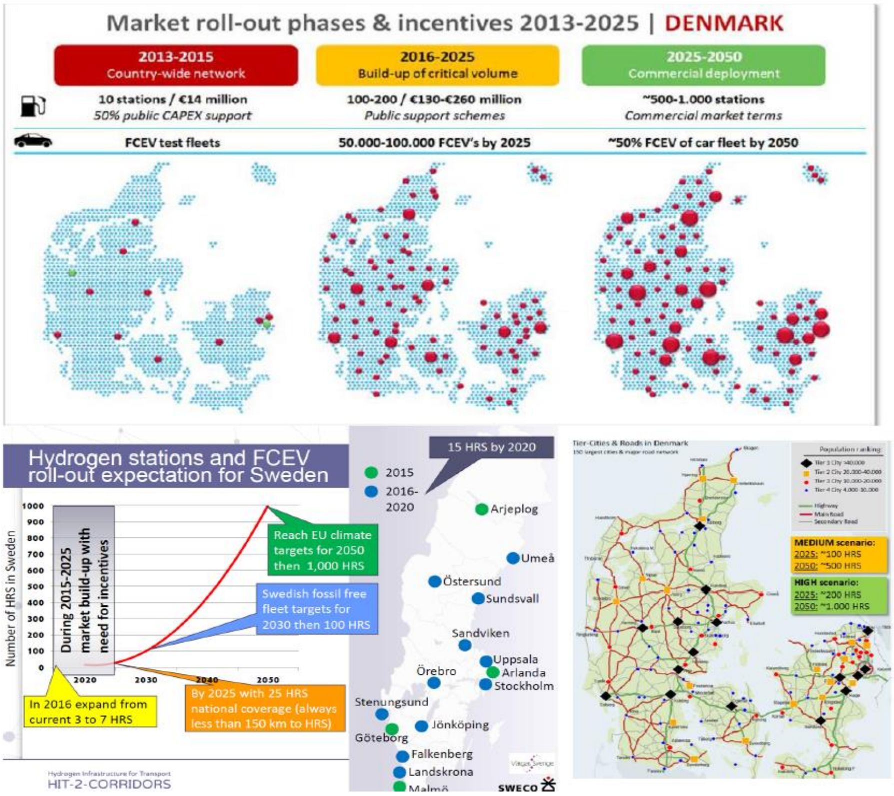


Figure 6. HRS estimates for Denmark and Sweden

2.3.2 HIT-2 Corridors and implementation plans for Belgium, Finland, Poland and Riga City

During HIT-2 project three more HRS were built and new national implementation plans were created in Finland, Belgium and Poland and a regional plan for Riga City. The summary of the national estimates are in Figure 7. Link to the project is http://hit-2-corridors.eu/

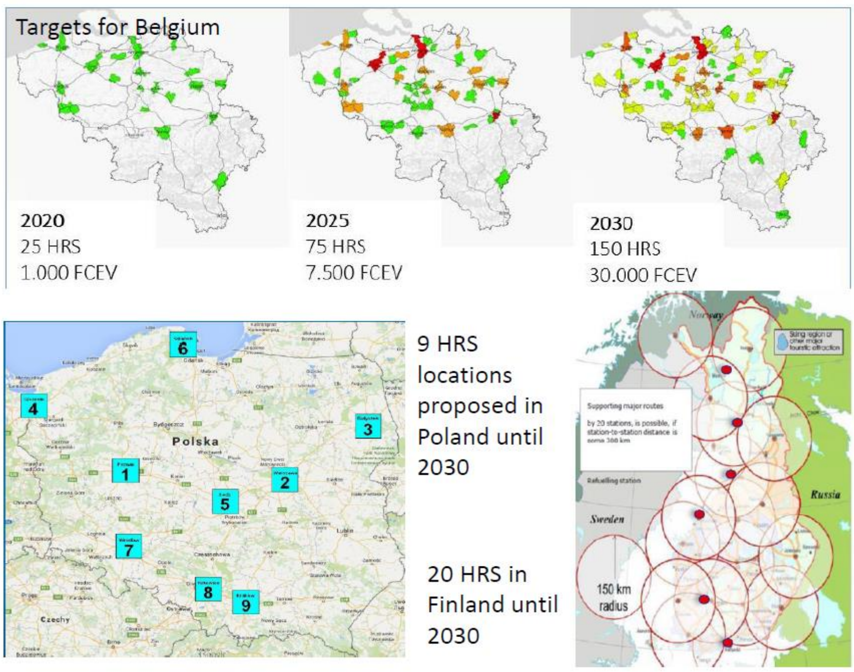


Figure 7. National estimates for Belgium, Finand and Poland until 2030

3. Infrastructure for alternative fuels

3.1 EU directive

The Directive on the deployment of alternative fuels infrastructure, 2014/94/EU, entered into force in October 2014. It obliges each Member State to adopt a national policy framework for the development of the market as regards alternative fuels in the transport sector and to deploy the relevant infrastructure by November 2016[8].

The final Directive, as adopted by the European Parliament and the Council on 29 September 2014 following the inter-institutional negotiations[9]:

- Requires Member States to develop national policy frameworks for the market development of alternative fuels and their infrastructure;
- Foresees the use or common technical specifications for recharging and refuelling stations;
- Paves the way for setting up appropriate consumer information on alternative fuels, including a clear and sound price comparison methodology.

The required coverage and the timings by which this coverage must be put in place are as follows in Table 3 below:

	Coverage	Timings
Electricity in urban/suburban and other densely populated areas	Appropriate number of publically accessible points	by end 2020
CNG in urban/suburban and other densely populated areas	Appropriate number of points	by end 2020
CNG along the TEN-T core network	Appropriate number of points	by end 2025
Electricity at shore-side	Ports of the TEN-T core network and other ports	by end 2025
Hydrogen in the Member States who choose to develop it	**Appropriate number of points**	**by end 2025**
LNG at maritime ports	Ports of the TEN-T core network	by end 2025
LNG at inland ports	Ports of the TEN-T core network	by end 2030
LNG for heavy-duty vehicles	Appropriate number of points along the TEN-T core network	by end 2025

[8] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0094

[9] http://ec.europa.eu/transport/themes/urban/cpt/index_en.htm

3.2 Finnish proposal for a plan for alternative fuels infrastructure

Alternative fuels infrastructure — a proposal for a national framework until 2020/2030 was developed and written by Ministry of Transport and Communication and an expert group. The report is in Finnish but the abstract is in English.

In the transport sector a shift towards the use of alternative propulsions systems has started. There are many alternatives for conventional, oil-based, fossil fuels (petrol, diesel, kerosene, light and heavy fuel oil) that can be used for different transport modes. Therefore, all the most important alternative fuels should be developed with the focus on the special needs of each transport mode. In developing the markets for alternative fuels the aim in Finland is to decrease the dependence of transport on fossil oil, improve the security of supply, support economic growth, improve the competitiveness of the Finnish industry, decrease energy consumption in transport and reduce greenhouse gas emissions.

The Directive on the deployment of alternative fuels infrastructure, 2014/94/EU, entered into force in October 2014. The expert group on alternative fuels infrastructure for transport proposes that the fuel distribution network and the network of recharging points for electric vehicles be mainly built on market terms in Finland. *The most profitable areas will be built first, in other words major and medium-sized urban regions.*

Other regions and the related construction measures will be estimated by no later than 2020. When possible, *any existing EU and/or national aid can be used in the building process*.

According to the expert group, *the primary concern of the state* should be to *ensure that new technologies using alternative propulsion systems will be increasingly used in vehicles*. This way the distribution infrastructure of these technologies could be made profitable in the long term. It is not the state's duty to rank the alternatives so the steering methods must be sufficiently neutral in terms of technology. In addition to increasing the share of alternative technologies, attention must also be paid to the development of the so- called drop-in biofuel markets in Finland and the entire EU.

3.2.1 Targets for Finland

Finnish objective for transport sector:

- The use of imported oil will be cut in half during the 2020s
- The share of renewable transport fuels will be raised to 40 per cent by 2030

Targets in figures by Ministry of Transport and Communications are in Figure 8.

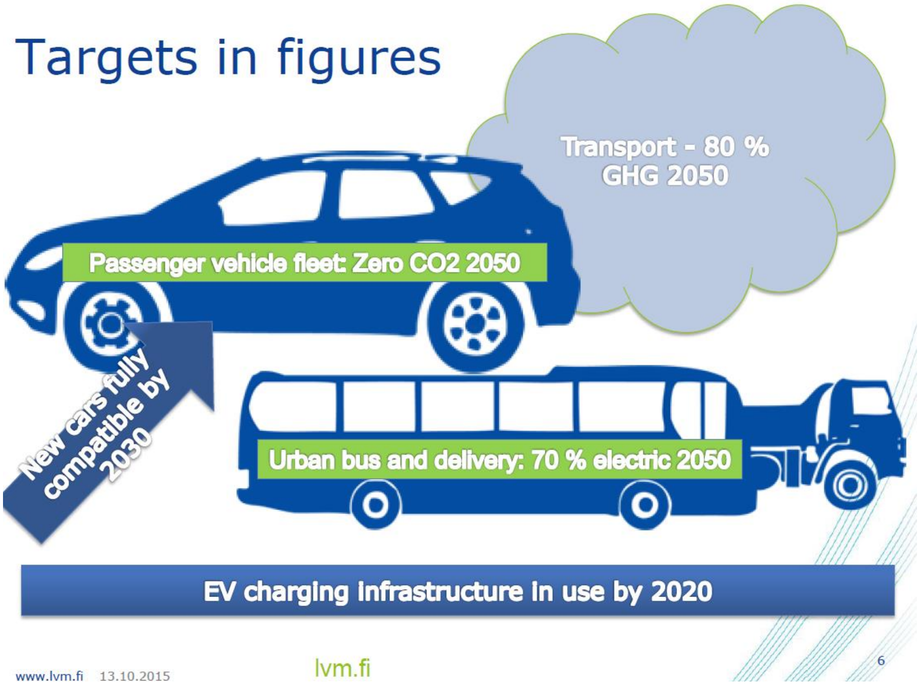


Figure 8. Targets in figures for Finand by by Ministry of Transport and Communications (source: MINTEC)

3.2.2 Curren status and targets for 2020 and 2025

The status of the infrastructure for alternative fuels and propulsion systems in Finland today and targets for 2020 and 2025 are summarized in Table 4 below:

Alternative fuel / propulsion system	Current situation	Target 2020	Target 2025
Electricity	150 public charging points, 900 EV	40 public, 3600 commercial, 40 000 private charging points	EU wide coverage (TEN-T corridors fully covered)
CNG, biogas	24 public stations (30 % biogas); 1900 cars	Population centres and main road network covered with stations for every 150 km	EU wide coverage (TEN-T corridors fully covered)
LNG in harbours	Tornio and Pori	TEN-T core network and other key harbours	TEN-T core network and other key harbours
Ground power in harbours and airports	Helsinki harbour	Places based on positive evaluation results	Central harbours and airports in TEN-T core network
LNG roads	-	Planning going on	Along TEN-T core network every 400 km
Hydrogen (refuelling station HRS, fuel cell vehicle FCEV)	2-3 HRS	6 HRS	12-15 HRS 2000 FCEV (2030: 20 HRS, 4000 FCEV, main roads covered with station-to-station distance 300 km).
Bioethanol E85	100 stations; 6000 cars	200 stations	Full coverage of the road network

3.3 Scenarios for alternative fuels in transportation in Finland

Several types of scenario work for emission reduction have been carried out in Finland. VTT's (Technical Research Centre of Finland)[10]. One of the basic scenario work for low-carbon transport is based on the spearhead programme "TransSmart" - Smart Mobility Integrated with Low-Carbon Energy. Their vision for 2030 and beyond is based on following principles:

- The Finnish transport system successfully pursues sustainability in societal, economic as well as environmental terms.
- **The transport system is mainly powered by biofuels, electricity and hydrogen**. Where conventional fuels and powertrains still apply, the efficiency of using energy and other resources has improved remarkably. Energy systems for transport are well integrated into other infrastructures in terms of production, storage and delivery.
- Transport and mobility needs of people and goods are fulfilled by a wide range of transport services, characterized by advanced technologies, functionality and efficiency.
- Development and production of **transport fuels, vehicles, mobile machinery, infrastructure and services generate business** and profit for the Finnish entrepreneurs in the domestic as well as global markets

Low-carbon options for transport in Finland

- Drop-in biofuels
  - Fully compatible with existing infrastructure and existing vehicles
  - Sustainable biomass feedstocks and new processing capacity needed
- Electric vehicles
  - The Finns are used to "plug and play"
  - Slow charging of EVs possible everywhere in Finland thanks to outlets for electric block heaters (minor modifications may be needed)
- Methane for transport (natural gas & biogas)
  - It took 20 years to get some 25 refuelling stations and some 1500 vehicles
- Hydrogen and fuel cell vehicles start from zero
  - It will be a tough task to bring FCEVs (cars) on the road in Finland
  - Maybe speciality vehicles would be the way to go (buses, mobile machinery etc.)

Electric vehicle assessment for the Ministry of Transports and Communication was done in 2011. A parallel could be drawn to **hydrogen and FCEVs as well**. The findings from EV assessment are summarized following:

- The market entry of electric vehicles has now probably started for real. The progress will at first be rather modest, though, and **EVs will not bring much contribution to fulfilling the 2020 targets in energy and climate policy**. On the other hand, there is no need to use EVs, and other technologies may allow more cost-effective solutions. However**, the situation will change markedly until 2030, and especially by 2050**.

[10] The scenario related text is based on a presentation of scenarios for alternative fuels by Nils-Olof Nylund, VTT, in HIT-2 Road Tour event in Helsinki, 14.10.2015

- Even if the EV market may still be modest**, it is due time to start taking into consideration e.g. the aspects of recharging systems in construction and building regulations**.
- From the point of view of transport policy and **cost-effectiveness it is not justified to immediately try to maximize the EV penetration**, because the price of electric vehicles is expected to get lower and overall performance to improve over time.
- **We need to launch demonstrations** that are so extensive that we can get statistically valid feedback information from EVs and their associated subsystems.

3.3.1 A study for 40% Reduction of CO_2 Emissions from Transport by 2030 - Propulsion Options and Their Impacts on National Economy

A joint study by VTT and VATT, the Government Institute for Economic Research was financed mainly by Ministry of Employment and the Economy. The objective was to evaluate which measures could deliver a 30 or 40 % reduction in CO_2 emissions in road transport by 2030 (reference year 2005). The execution was done by modelling the effects of biofuels and other alternative technologies on emissions and costs, costs also from the viewpoint of the national economy.

Scenarios and methodology for the impact on GDP

The methodology to calculate the impact of different scenarios of alternative fuels and related investments on GDP was developed by VTT and VATT . The method It is descibed in Figure 9 and the principle in Figure 10.

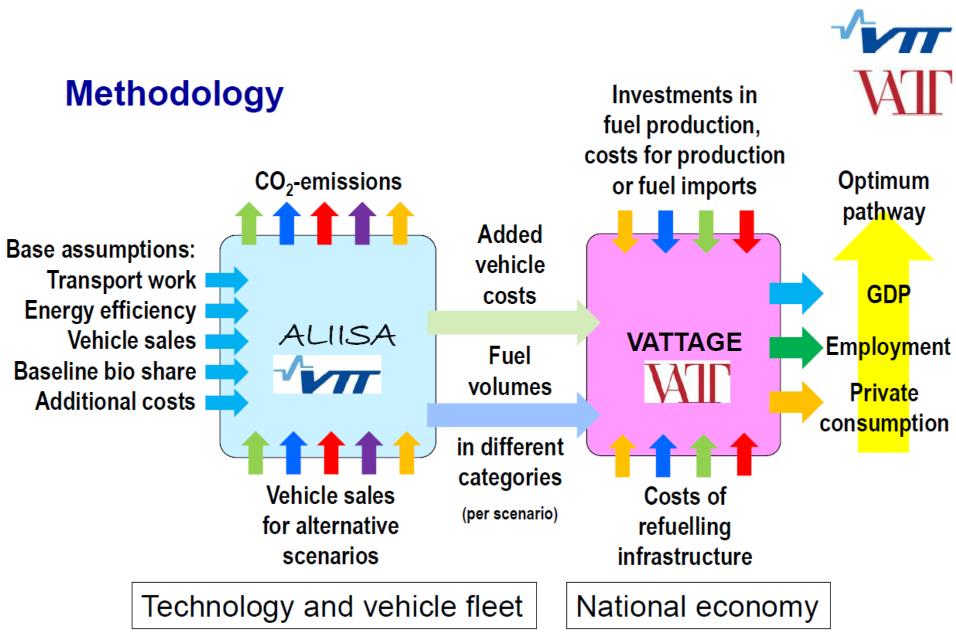


Figure 7. Methodology to the impact of different scenarios on .

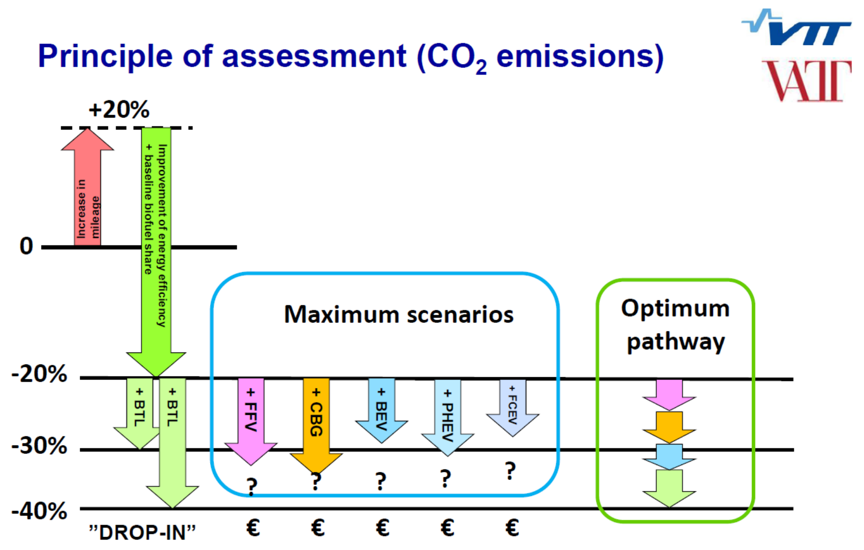


Figure 10. Princile of assessment of CO2 emissions using maximum scenarios.

The scenarios for the number of vehicles with different alternative propulsion options are listed in Table 5. The scenarios 2030 were developed based on the official statistics for milage and sales of new vehicles. A combination of the scenarios was further worked by VTT. Scenario figures were introduced and discussed in a joint roundtable meeting of the alternative fuel working groups of Ministry of Transport and Communications and Ministry of Emplyment and Economy.

Table 5. Volumes of vehicles in alternative scenarios. Each fuel was applied so that 40% reduction of CO2 emissions can be achieved.

Passanger cars
BE/DI Baseline: BE and DI continue s usual but BE include 10 % Ethanol, and Diesel decrease to 30 % in 2030. No alternatives, no new investments to the infrastructure. 2030 car volume divided 2,2 mill./1,1 million
FFV As baseline but FFV replaces BE in sales volume 100% in 2030, cumulative volume 1 100 000 in 2030
CNG/CBG volumes increase, replaces BE/DI in relation 70%/30%. Volume ca. 900 000 at 2030. Sales 10% in 2015 – 30% 2020 – 50% 2025-2030
FCEV/H2 share of sales of new cars increses to 10% until 2030, volume 160 000 at 2030. Ramp-up 0,5% - 3% - 5% - 7% - 10%
BEV 20% of BE cars in 2030, volume 186 000 cars. Share of the total sales 14%, ramp-up 0,5% - 3% - 5% - 9% - 14%
PHEV based on both BE and DI so that sales 50% in each category in 2030. Ramp-up 5-10-25-40-50%
Small delivery vans
Diesel continue, share of alternatives < 5%
CNG share of sales increases to 50% in 2030
PHEV share of sales increases to 25% in 2030
BEV share of sales increases to 25% in 2030
FCEV share of sales increases to 25% in 2030
City buses (total volume 3000, life cycle 15 years)
Diesel dominates, share of alternatives < 5%

LNG/CNG share of sales increases to 100% in 2030
ED95 share of sales increases to 25% in 2030
PHEV share of sales increases to 100% in 2030
FCEV share of sales increases to 50% in 2030
BEV share of sales increases to 100% in 2030

The impact of different alternative scenarios and related investments to GDP are compared with the baseline scenario in Figure 11 . FCEV and hydrogen option is not very favorable because the investments to the vehicles and the infrastructure are high starting from scratch. The current price of the vehicles are nearly double compared to the conventional car and there is no domestic car manufacturing. However, the fuel is domestic. When the price difference of the cars decrease – beyond 2030-2035 expected to be only 10 - 15 % higher – the situation will improve considerably. A feasibility study of hydrogen and FCEV as alternative propulsion option is in Chapter 4.

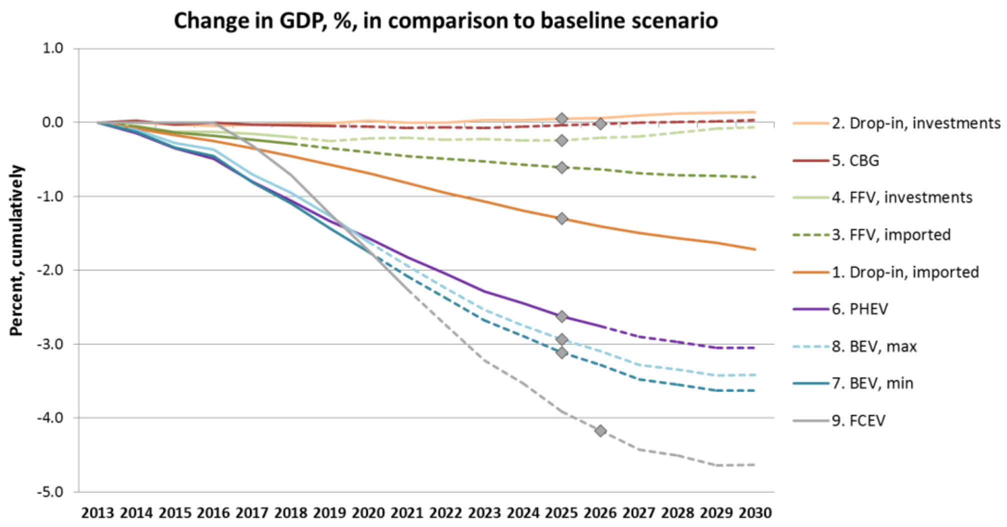


Figure 11. Impact of alternative scenarios on GDP.

3.3.2 Othe scenarios for volumes of the vehicles with alternative propulsion

Traffic reseach centret VERNE of Tampere University of Technology has created scenarios for reduction of emissions based on changens in behaviour. One scenario is “technolgy scenario” if behaviour will not change. In the technology based scenario hydrogen will be visible in vehicle volumes beyond 2030- 2035 (Figure 12).

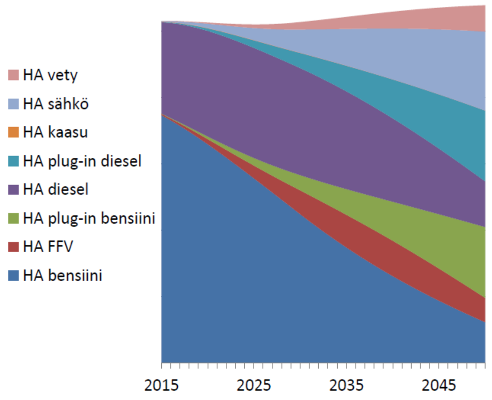


Figure 12. Technology scenarion by Tampere Unversity of Technoly. Hydrogen up with light orange colour, electricity light blue.

4. Hydrogen and HRS network in Finland –implementation plan and a feasibility study

4.1 Finnish hydrogen production and capacity

The major player in Finnis hydrogen production is a private company Oy Woioski Ab. Woikoski has produced hydrogen since 1913 and will continue investing in hydrogen technology.
The hydrogen in Finland comes

- As by-product hydrogen from sodium chlorate production
- Hydrogen produced by water electrolysis
- Steam reforming from natural or biogas

The by-product hydrogen is totally carbonfree. The current industrial sorces are locted western part of Finland and South-East near easter boarder. There is still much more by-product hydrogen available in Finland, for example in North Finland, in Oulu region. The future HRS network in North Finland may benefit of the short delivery distance.

Kokkola hydrogen and oxygen water electrolysis plant (acaline technology) opened in 2014. It is the largest hydrogen electrolysis plant in Europe. Capacity 1 400 000 kg/a high purity H_2. This high purity hydrogen could be very optimal to HRS use because the pressure is already high when it comes from the process. An attractive option is to transport hydrogen to the HRS by pipe.

Figure. Kokkola – the area of hydrogen production with electrolyser, hydrogen pipes

The total capacity of hydrogen for transport refueling in Finland is 2 000 000 kg/year and that means 10 000 cars or more than 830 busses.

Theoretically available hydrogen: 140 000 000 kg

- cars (20 000 km/a, 1 kg H_2/100 km) 700 000 pcs or
- busses (30 000 km/a, 8 kg H_2/100 km)58 000 pcs

Hydrogen is transported to the stations in cylinders, bundles, cylinder containers or in liquid hydrogen containers. Curently the most relevat ways for HRS with daily capacity og 50-100 kg are bundles or cylinder containers. Pipe from the electrolyser is an attractive future option.

4.2 HRS in Finland – current situation

There are three hydrogen refuelling stations (HRS) in Finland currently. Locations are in Helsinki/Vuosaari harbour and Voikoski. The third is movable and located in winter times in Lapland. They are based in international standard SAE J2061and refuelling pressures are 350 bar and 700 bar. The passenger cars use 700 bar today. The refueling time is targeted to 3–5 min. The range with one refueling is ca. 500–600 km; with one kg of hydrogen can be drived 100 km. 350 bar is used for buses and mobile working machines. Buses need a high-flow dispences.

All Finnish refueling stations are public. The global maps for the HRS locations are provided and updated by Ludvig-Bölkow-Systemtechnik GmbH with support TÜV SÜD. Finnish HRSs are also listed there (link www.h2stations.org). The location information in Finland is shared by Oy Woikoski Ab on their web site.

The current HRS map for European corridors is in Figure 13. Baltic and scandinavian corridors come to Finland from the south Europe.

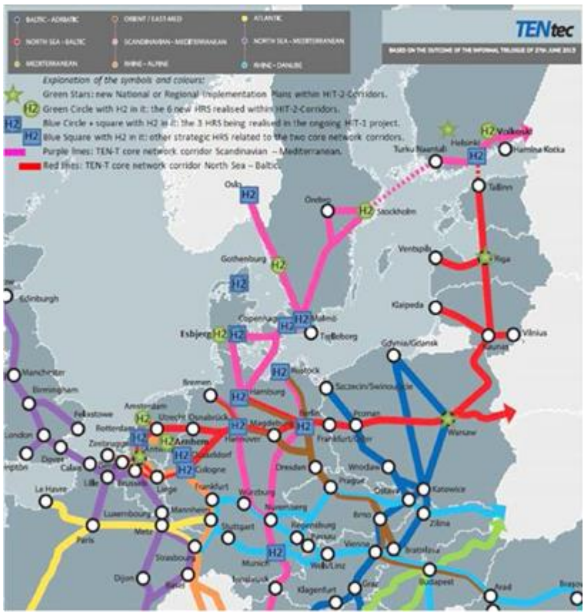


Figure 13. European hydrogen corridors

4.3 Future plan for HRS infrastructure 2020/2030

The plan to build the future HRS infrastructure in Finland until 2030 is shown in Figure 14. A drafted refueling station network for Finnish needs consists of 20 HRSs that can cover the whole country. The distance between the stations is ca. 300 km and the effective radius distance is 150 km. The stations cover all the most important cities in Finland.

The plan until 2020 is at least six stations in the biggist cities. The number of the HRSs is related to the fuel cell vehicle (FCEV) quantity so that one HRS serves 100 cars. In the areas with high car volumes more than one HRS may be allocated.

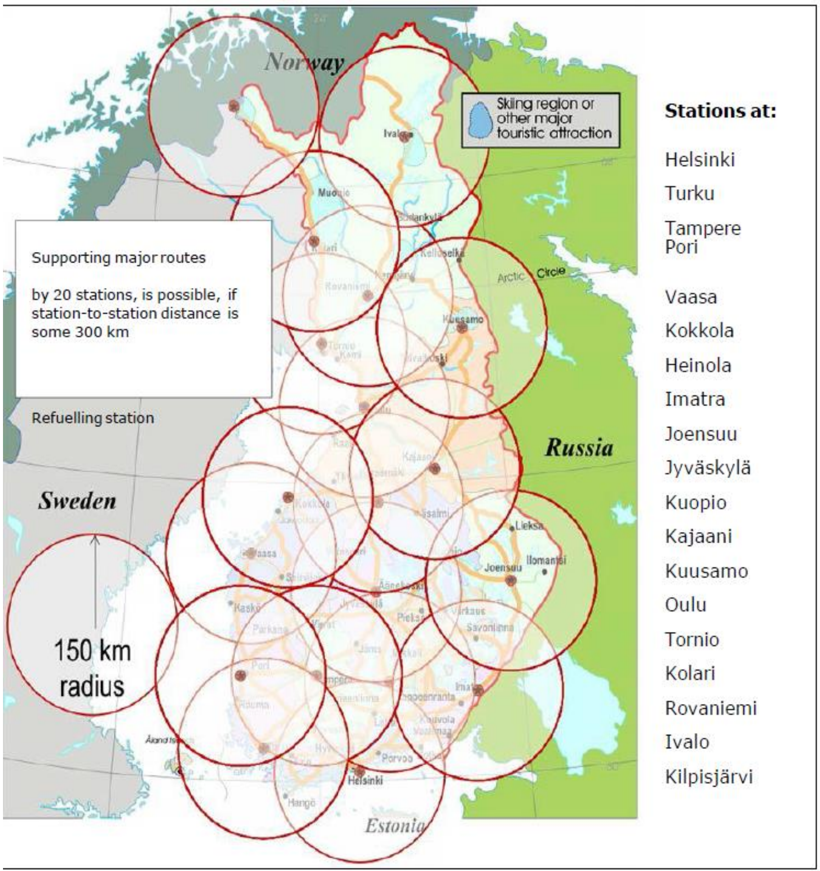


Figure 14. HRS network in Finland until 2030

4.4 Cost of hydrogen and HRS

Cost for a HRS depends on the type and size of HRS. In Finland the size will be rather small – 50 -100 kg/day because the long distances and few cars. Typical cost level will be 0,8 -1,5 M€. Cheapest solution is a mobile container type HRS. Other cost factors are related to the location. Multifuel station is an attractive solution in Finland. All alternative fuels and electricity could join forces and benefit of these. This is the only way to get addidional service to the stations.

The target cost for hydrogen is 10 €/kg at the moment but is xpected to be 6-8 €/kg until 2020-2023. EU target is 5 €/kg added with local tax.

4.5 FCEV volumes and cost

FCEV

The fuel cell cars (FCEV) will be launced in pre-commercial phase in 2013-2017. Hyundai, Toyota and Honda are the first. Hyundai and Toyota are the most active car manufacturers that promote FCEV in Finland. There is one Hyundai in Finland at the moment. Eight car manufacturers will bring their FCEV models on the market until 2017. The annual volumes will be tenths of thousands already in 2016. FCEV models are presented in Figure 15.

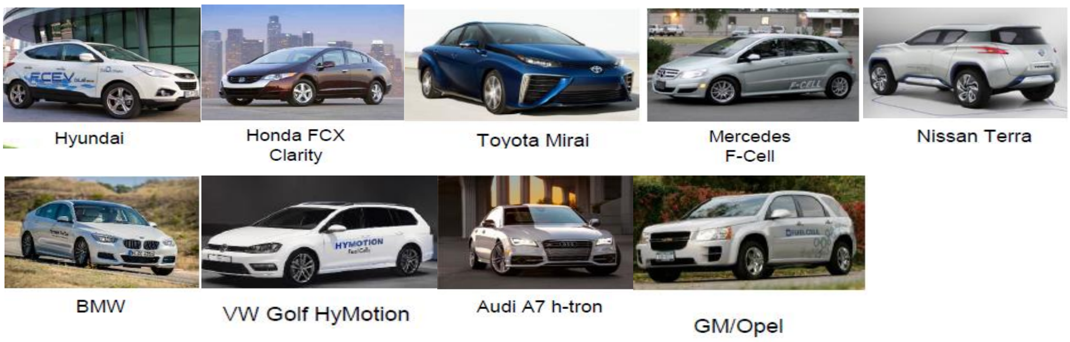


Figure 15. FCEV models will enter the market commercially in 2015-2017. Hyundai, Honda, Toyota, Mercedes and Nissan have had testing and pre-commercial models already severeral years.

Statistics of cars in Finland

The total number of cars in Finland in 2014 was:

Passenger cars	Delivery vans	Trucks	Buses	Other	Total
3 172 735	400 396	137 285	16 202	11 923	3 738 541

The challenge in Finland is to accelerate the renewal of the the vehicles and tha target is to increase the share of cars with alternative propulsions. The target is 160 000 low emission cars with alternative fuels until 2020 and 490 000 cars until 2025.

Estimated FCEV volumes in Finland

VTT (States Technology Research Institute) has made an realistic estimate for the FCEV volumes in the report Finnish Hydrogen Roadmap 2013: the estimate is **2000–4 000 fuel cell cars in 2025–2030.**

One scenario discussed in Chapter 3.3.1 is **FCEV maximizing** scenario expecting that FCEV share will rise to 10% of all new cars until 2030 ramping up 0,5%, 3%, 5%, 7%, 10%. Based on this scenario the number of FCEV will be 160 000 in 2030. This is not realistic. The cost of cars and the investments to the infrastructure in so short run will still be too high. More realistic is that the high volumes of cars will become beyond 2030 when the gap of cost compared to the conventional cars becomes small.

Cost of FCEV

The cost of cars will be ca. 50 000 - 55 000 plus tax in 2015-2017. In Finland the tax for zero emission car is 5% plus VAT. The current 2015 price for FCEV including tax is ca 70 000 €. This is afordable to early market pioneers.

The price (excl. tax and VAT) is expected to be ca. 30 000 € until 2023. Threre is no plan to set a 0 % tax to zero emission cars in Finalnd at the moment. The current tax 5 % will remain.

The cost reduction of FCEV can be seen in Toyota's picture in Figure 16. According to Toyota FCVs will become mainstream technology around 2035.

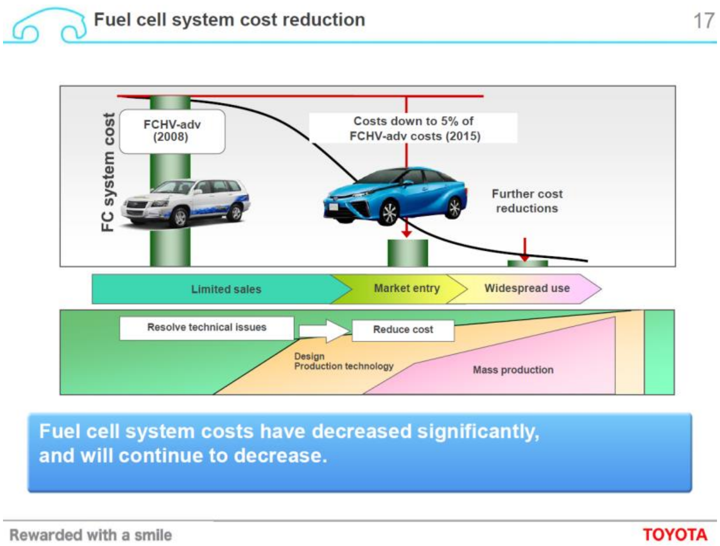


Figure 16. Toyota's FCEV cost reduction model.

Battery electric vehicles with fuel cell range extender

A battery electric vehicle with fuel cell range extender is an interesting option to Finland. At least Renault, Nissan and Daimler have developed these concepts and some European organizations develop these cars as well. French Post has demonstarted Renault range extender in logistics successfully (Picture 17)

Picture17. Renault hydrogen range extender in the project "LaPoste"

The advantages for hydrogen FC range extender include:

- Zero emission
- Fits in any electric vehicle such as passenger car, logictic vehicles, trucks and bus
- Automotive certified
- Extends range of an BEV up to 500 km's

- Long life time, low maintenance cost
- Lower price than FCEV, better availability than FCEV
- Both electric charging and HRS network can be used

4.7 HRS strategies for Finland

4.7.1 SWOT

SWOT analysis was done in an internal workshop in Woikoski and by interviewing FC car manufacturers , range extender manufacturers and some European organizations such as FCHJU and CEA (France)

Strengths	Opportunities
- Hydrogen from by-product industry is emission free and FCEV is emission free. - Much by-product hydrogen n Finland - Hydrogen is domestic fuel - There are HRS and other refueling station manufacturers in Finland - Finnish consumers are technology oriented: much early adopters in EV and hybrid cars indicate that FCEV can be accepted as well - Enough wealthy people to buy FCEV - Finnish HRS manufacturer has the whole concept in-house: gas, transport, delivery, technology, HRS	Climate challenges and emission reduction targets encourages zero emission solutions Finland is dependent of foreign energy sources in traffic and transport - hydrogen is a domestic option There is still a lot of unutilized by-product hydrogen in Finland. General to multifuel stations → join forces for cheaper stations with service BEV with FC range extender →cheaper option with better availability Logistics vehicles, delivery vans and working machines with FC or range extender Buses and taxis, snow scooters Big companies, that have high need for clean and efficient logistic vehicles, trucks, forklifts Cities with terminals and gas pipe, need for trucs and forklifts and mobile working machines and public city transport and service traffic Cities with active environmental programmes and emission reduction targets
Weaknesses	**Threats**
General: FCEV cars are delayed in the market Expensive vehicles Finland is a long country. Distances are long. Population is small and rare outside the capital area. Car base renewal is slow No car manufacturing in Finland	FCEVs are too expensive Tax issues are not clear yet Delay in market roll-out: FCEV manufacturers fail to bring the cars to the market - FCEV not available in high volumes

Turning weaknesses to opportunities

A Finnish weakness is that there is no domestic car manufacturing. This is a fact that affects to GDP negatively. An opportunity to Finnish industry and innovative start-ups might be to create new business by starting to develop and manufacture specialty vehicles using fuel cells as range extenders. Domestic vehicle manufacturing could affect positively to the GDP and incentives and support.

BEV with FC range extenders could enter the market quicker than FCEVs. They are also cheaper. Cheaper vehicles could create opportunities to build a flexible HRS network with small HRSs.

4.7.2 Strategies for Finland

Special features of Finland are that the country and distances are long (the lengt of the country 1600 km) and population is small (5,5 million people) and the number of cars is small (ca. 3,7 million vehicles totally of which 3,1 million passenger cars and 0,4 million delivery vans). The renewal of the cars is slow. Population is rare outside the capital area.

Big cities are the first target to buid HRS network. Taxis are an interesting target group. A suitable area to get started might be the airport and a harbour because there is much traffic and the refueling station is always in the sufficient distance. Buses for public transport in city area or between the near cities should be demonstrated. Cities need to be committed to clean traffic and choose hydrogen to one alternative to public transport or for public services. Finnish cities should be encouraged to join European bus funding projects as partners.

Small and mobile HRSs are a recommended solution to keep the HRS investment cost low in the rare populated areas and small cities. Mobile unit means that the HRS can be moved to a better place if needed because it is not easy to estimate the best traffic places beforehand.

Fuel cell delivery vans, trucks, buses and forklifts could be a proper way to get more use for HRS. A suitable model is that one HRS serves both private logistic companies and public transport and public logistics such as post and city service transport. Cheaper range extender-type electric/fuel cell vehicles could be an option. This model has been demonstrated in Lion in France (LaPoste/Ikea). The model could be suitable also for Finland and fits well to small cities.

North Finland is rarely populated and the number of cars is low. It is a challenge to build hydrogen infrastructure to rural areas. In North Finland and Lapland tourism is an important business. Snow scooter safaries are popular. Emission free and silent snow scooters are very attractive. There is also snow scooter manufacturing in Finland. A small flexible HRS is a good solution to the biggest tourism cnters.

4.7.3 Business model and value chain

The business model includes all operations in the value chain. The key players are vehicle suppliers (FCEV) and end-users, HRS suppliers, HRS operators, maintenance and service suppliers, and hydrogen suppliers (industry). Cities and municipalities are offering the platform. Related to the public transport the bus operators are also key players in the value chain.

A gas company can outsource the HRS building and make partner agreements with the refuelling operators. The most relevant role in the value chain for a gas company is the production, purification and delivery of hydrogen to the refuelling stations. Because a gas company is a specialist in handling hydrogen the maintenance of HRS might fit also to the role of the gas company. For the refuelling station operators a multifuel refuelling station concept is a good option to offer services to all consumers of alternative fuels. The service of the hydrogen refuelling stations is part of the value chain and offer business opportunities as well.

The cooperation between gas company and vehicle suppliers is crucial because of the chicken-and-egg problem. A joint promotion will be needed. Financing the business is a critical question. A positive business case and realistic funding needs should be assessed. Dutch ministry of infrastructure and environment (RWS) has developed an integrated model and a tool for assess and evaluate the financing needs. This is discussed in Chapter 4.8.2 and Figure 18.

4.8 Funding and subsidies

4.8.1 Funding, subsidies and incentives in Finland

European, national, regional and local funding and subsidies will be needed.

The electric vehicles including FCEV can get support to monthly leasing fees from Ministry of Emplyment and Economy (Energy department) until 2017. The maximum period for support is four years. The support can be received only for leased cars. The monthly support is 500-700 € depending on the type of the vehicle. New support programmes may be developed when the corrent programme ends.

There are no major incentives to the zero-emission vehicles at the moment. The tax is lower for low-emission cars. All alternative propulsons are in equal position and building the infrastructure for each is market based. The responssibility of State is to find the ways to accelerate the renewal of the cars and affect to the volume increase of the low-emission cars with alternative propulsions to reach the targets. Cities are encouraged to favor low-emission tranport and arrange oppottunities to build infrasturucture to alternative fuels in a consistent way through the country starting from big cities.

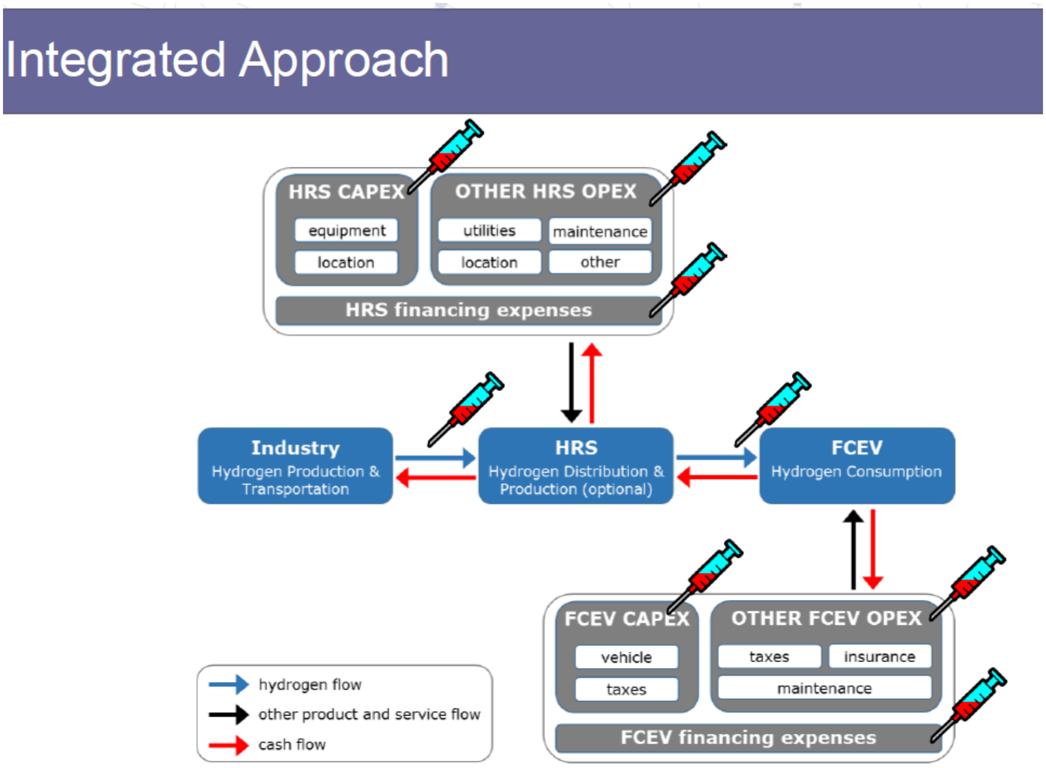
Experiences and models in other Euroan countries will be analysed to find the best practises for Finland. One suggested option might be to reduce tax for the zero-emission company cars to increase the car base.

For building and developing hydrogen infrastructure the most relevant European funding options are FCH JU and TEN-T/CEF. FCH JU (Fuel Cell and Hydrogen Joint Undertaking) is the most important funding organization besides CEF /TEN-T. However, FCH JU funding is based on multi annual working plan and focused mainly to large refueling stations targeting to big cities and high volumes of FCEV and buses.

Other suitable EU funding instruments to Finnish SMEs might be Horizon 2020 SME and Fast Track for Innovation funding. Also funding for cities and partner organizations will be needed.

4.8.2 A tool for evaluating the business case and need of subsidies and funding

As part of HIT-2 project Dutch ministry of infrastructure and environment (RWS) created a tool for national, regional and municipality decision-makers to evaluate the business opportunities and need of funding and support. The tool HIBIT is available for public and private organizations, municipalities and regions[11]. The draft of the integrated approach and tool are in Figure 18.



[11] More information from Floris Mulder floris.mulder@rws.nl

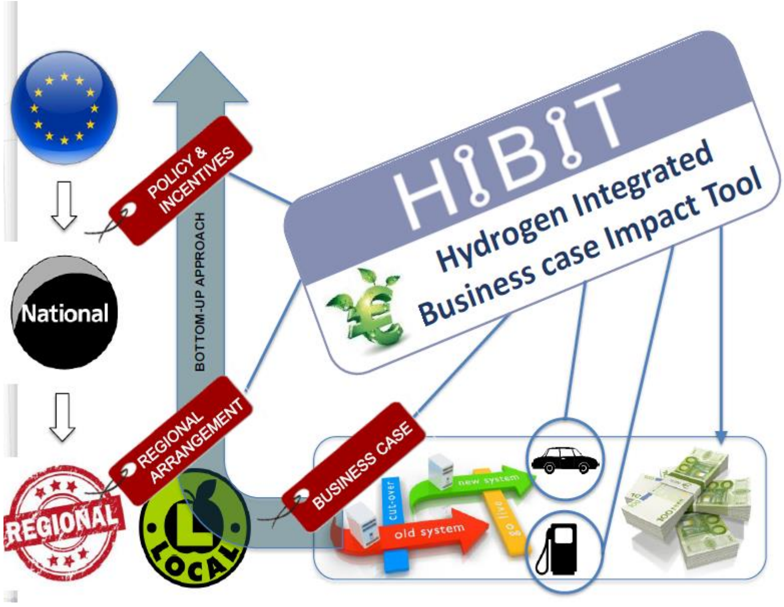


Figure 18. The draft of the integrated approach and tool HIBIS by RWS.

5. Hydrogen safety, standards and legislation

Safety aspects, standards and legislation of hydrogen vehicles and refueling stations were reviewed in a study of VTT and several companies: **Ensuring safety of fuel cell applications and hydrogen refuelling, VTT, 2013.** The report is in Finnish and all instructions can be found in the web page of Fuel Cell Finland. The report helps the companies and research organizations to build hydrogen business and infrastructure. Also authorities benefit of the report. The anbstract of the study is translated in English and a shortened document reklated to the demonstration project Demo2013 is in English. A list of standards and relevant legislation is also listed below.

Abstract:

Fuel cell technology is considered a promising alternative in terms of viable energy systems. The advantages of fuel cell systems include a good efficiency rate and the lack of harmful environmental emissions. Factors which may slow down the commercialisation of fuel cell technology, e.g. fuel cell vehicles, include the high price of hydrogen and the insufficiency of the infrastructure required for the distri- bution of hydrogen. A large proportion of major car manufacturers are committed to introducing fuel cell cars to the market by 2014–2016. In order to ensure a successful market introduction of fuel cell vehicles, this has to be aligned with the development of the necessary hydrogen infrastructure.

In the early commercialisation stages of a new technology, it is important to give the public correct, justified and understandable information on the safety of the fuel cell applications, and also on the measures taken to ensure the safety of applications. A lack of necessary information, inaccurate perceptions and prejudices can have an adverse effect on the public acceptance of fuel cell applications.

Hazards and potential accidents related to fuel cell systems are mainly associated with the flammable substances (e.g. hydrogen, methane) used as fuel, the high pressure of hydrogen, electrical hazards, and dangers concerning technical systems in general. The fuel cell applications reviewed in this publication are transport applications and stationary applications and the refuelling system of gaseous hydrogen. The publication concentrates on fuel cells using hydrogen as fuel.

The publication gives an overview of how EU-legislation (mainly various directives) and Finnish legislation applies to fuel cell systems and applications, and what kind of safety requirements the legislation sets. In addition, a brief overview of safety standards concerning fuel cell systems and hydrogen refuelling is presented.

List of relevat standards for hydrogen and HRS:

International Organization for Standardization (ISO)
• ISO/TS 15869 (2009): Gaseous hydrogen and hydrogen blends – Land vehicle fuel tanks • ISO/TR 15916 (2004): Basic considerations for the safety of hydrogen systems • ISO 17268 (2012): Compressed hydrogen surface vehicle refueling connection devices • ISO/TS 20100 (2008): Gaseous hydrogen – Fueling stations • ISO 23273-1 (2006): Fuel cell road vehicles – Safety specifications – Part 1: Vehicle functional safety* • ISO 23273-2 (2006): Fuel cell road vehicles – Safety specifications – Part 2: Protection against hydrogen hazards for vehicles fueled with compressed hydrogen • ISO 23273-3 (2006): Fuel cell road vehicles – Safety specifications – Part 3: Protection of persons against electric shock* • * not valid and updated (2015)
International Electrotechnical Commission (IEC)
• IEC/TS 62282-1 ed. 2.0 (2010): Fuel cell technologies – Part 1: Terminology • IEC 62282-2 ed. 2 (2012):Fuel cell technologies – Part 2: Fuel cell modules • IEC 62282-3-100 ed. 1 (2012): Fuel cell technologies – Part 3-100: Stationary fuel cell power systems – Safety • IEC 62282-4-101 Ed. 1.0: Fuel cell technologies – Part 4-101: Fuel cell power systems for propulsion other than road vehicles and
Society of Automotive Engineers (SAE)
• SAE J2574 (2011): Fuel Cell Electric Vehicle Terminology • SAE J2578 (2009): Recommended Practice for General Fuel Cell Vehicle Safety • SAE J2579 (2013): Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles • SAE J2600 (2012): Compressed Hydrogen Surface Vehicle Refueling Connection Devices • SAE J2601 (2010): Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles • SAE J2760 (2011): Pressure Terminology Used in Fuel Cells and Other Hydrogen Vehicle Applications • SAE J2799 (2007): 70 MPa Compressed Hydrogen Surface Vehicle Fuelling Connection Device and Optional Vehicle to Station Communications • SAE J2990/1 (going on): Gaseous Hydrogen and Fuel Cell Vehicle First and Second Responder
European Industrial Gas Association (EIGA)
• IGC Document 15/06: Gaseous Hydrogen Stations • IGC Document 75/07: Determination of Safety Distances

Information in Finnish:

ISO/TR 15916 (2004): Basic considerations for the safety of hydrogen systems (61 sivua)

- Dokumentti (Technical report) käsittelee yleisesti vetyjärjestelmien turvallisuusnäkö- kohtia ja siinä on ohjeita niin kaasumaisen kuin nestemäisen vedyn turvalliselle käytölle.
- Raportti ei keskity mihinkään tiettyyn sovellukseen tai vedyn käyttökohteeseen, vaan siinä tarkastellaan vedyn aineominaisuuksista ja tyypillisistä käyttöolosuhteista aiheutuvia vaaratekijöitä (syttyminen ja palaminen, räjähtäminen, lämpötila, paine, materiaalien vetyhaurastuminen, terveysvaikutukset) ja näihin liittyvien riskien hallintaa.
- Liitteenä on tietoja vedyn aineominaisuuksista, palamis- ja räjähdysominaisuuksista sekä vetylaitteistojen materiaalivalinnoissa huomioon otettavista seikoista.
- ISO/TR 15916 uudistus on käynnissä.

IEC/TS 62282-1 ed. 2.0 (2010): Fuel cell technologies – Part 1: Terminology (72 sivua)

- Teknisessä spesifikaatiossa esitetään polttokennoteknologiaan liittyvää terminologiaa ja polttokennosovellusten yhteydessä käytettäviä määritelmiä.
- Dokumentissa on periaatekaaviot stationääriseen sähköntuotantoon tarkoitetusta polttokennosovelluksesta, kannettavasta ja mikroluokan polttokennosovelluksesta sekä polttokennoajoneuvosta.

IEC 62282-2 ed. 2 (2012): Fuel cell technologies – Part 2: Fuel cell modules (82

- Standardi esittää sekä korotetussa paineessa, että lähellä normaalipainetta toimivien polttokennomoduulien turvallisuuden ja toiminnan vähimmäisvaatimukset. Soveltamis- alaan kuuluvat eri polttokennotyypit (PEM, PAFC, AFC, MCFC, SOFC).
- Standardi koskee sellaisten vaarojen torjuntaa, jotka voivat aiheuttaa vahinkoa polttokennomoduulin ulkopuolella.
- Standardissa on polttokennomoduuleja koskevat yleiset turvallisuuden varmistamisen ja suunnittelun periaatteet. Suunnitteluun liittyen standardissa on vaatimuksia koskien mm. vuotojen sekä syttymisen ja räjähtämisen estämistä, turvajärjestelmiä, putkistoja ja liitoksia, sähköisiä komponentteja ja järjestelmiä. Lisäksi standardi käsittelee poltto-kennomoduulien testausta, merkintää ja dokumentointia.

SAE J2574 (2011): Fuel Cell Electric Vehicle Terminology (12 sivua)

- Dokumentti (Information report) sisältää vetyä käyttäviä polttokennoajoneuvoja koskevaa terminologiaa ja määritelmiä. Se on tarkoitettu tueksi tahoille, jotka laativat vetyä käyttäviä polttokennoajoneuvoja koskevia standardeja ja muuta aineistoa esimerkiksi hyviä käytäntöjä kuvaavia ohjeita.

SAE J2760 (2011): Pressure Terminology Used in Fuel Cells and Other Hydrogen Vehicle Applications (10 sivua)

- Dokumentti määrittelee polttokennoajoneuvojen ja muiden vetyä käyttävien ajoneuvojen paineistettujen järjestelmien ja säiliöiden yhteydessä käytettävän terminologian.

SAE J2990/1 (laadinta käynnissä): Gaseous Hydrogen and Fuel Cell Vehicle First and Second Responder Recommended Practice

- Polttokennoajoneuvojen aiheuttamat vaarat onnettomuustilanteita hoitavalle pelastus- henkilöstölle ja vaurioituneiden polttokennoajoneuvojen korjaajille poikkeavat perinteisiä polttonesteitä käyttävien ajoneuvojen aiheuttamista vaaroista. Polttokennoajoneuvojen kohdalla tulee varautua ajoneuvon sisältämän vedyn ja myös sähköjännitteen aiheuttamiin vaaroihin.
- Sähköajoneuvoihin liittyviä vaaroja on käsitelty dokumentissa SAE J2990 Hybrid and EV First and Second Responder Recommended Practice, mutta polttokennoajoneuvot eivät kuulu sen soveltamisalaan.

ISO/TS 15869 (2009): Gaseous hydrogen and hydrogen blends – Land vehicle fuel tanks (41 sivua)

- Dokumentti (Technical specification) määrittelee vaatimukset ajoneuvojen korkeapai- neisen kaasumaisen vedyn kevytrakenteisille (light-weight) polttoainesäiliöille. Standardi koskee ainoastaan kaasumaisen vedyn tai vetyseosten polttoainesäiliöitä.
- Vaatimuksia sovelletaan teräksestä, ruostumattomasta teräksestä, alumiinista ja ei-metallisista materiaalista valmistetuille polttoainesäiliöille, joiden suunnittelu ja valmistustapa soveltuu standardissa määriteltyyn tarkoitukseen.

ISO 23273-1 (2006): Fuel cell road vehicles – Safety specifications – Part 1: Vehicle functional safety

- Standardi on kumottu 3.7.2012, saatavilla ei ole tietoa standardin päivittämisestä http://www.is o.org/is o/home/store/c atalogue_ics.htm
- Standardi määritteli polttokennoajoneuvoja koskevat henkilöiden ja ympäristön suojaamista koskevat olennaiset turvallisuusvaatimukset, jotka liittyvät polttokennojärjestelmään ja sen toimintaan.

ISO/TS 20100 (2008): Gaseous hydrogen – Fuelling stations (47 sivua)

- Dokumentti (Technical specification) määrittelee ulkotiloihin sijoitettaville, ajoneuvojen käyttöön tarkoitetuille kaasumaisen vedyn tankkausasemille asetettavat vaatimukset. Asuin- ja kotikäyttöön tarkoitetut kaasumaisen vedyn tankkaussovellukset eivät kuulu soveltamisalaan.
- Dokumentti käsittelee mm. tankkausaseman suunnittelun turvallisuusvaatimuksia, vedyn toimitustapoja, tankkausaseman päälaitteita ja toiminnan valvontaa, tankkaus- aseman lay-out-suunnittelua ja turvaetäisyyksiä, palo- ja räjähdysvaaran torjuntaa sekä tarvittavia hälytys- ja turvajärjestelmiä.

ISO 17268 (2012): Compressed hydrogen surface vehicle refuelling connection devices (35 sivua)

- Standardi koskee kaasumaista vetyä käyttävän ajoneuvon tankkausliitännän suunnittelua sekä turvallisuutta ja toimintaa koskevia ominaisuuksia. Tankkausliitännällä tarkoitetaan yhteyttä, joka muodostuu ajoneuvon vetysäiliön ja tankkausaseman annostelusuuttimen välille.
- Standardia sovelletaan seuraaviin tankkausliitäntöihin:
  - H11: 11 MPa ja 15 °C
  - H25: 25 MPa ja 15 °C
  - H35: 35 MPa ja 15 °C
  - H35HF: 35 MPa ja 15 °C (high flow)
  - H70: 70 MPa ja 15 °C.

SAE J2600 (2012): Compressed Hydrogen Surface Vehicle Refuelling Connection Devices

- Dokumentti koskee kaasumaista vetyä käyttävän ajoneuvon tankkausliitännän ja -suuttimen sekä vetysäiliön suunnittelua ja testausta. Sitä sovelletaan seuraaviin tankkausliitäntöihin:
  - H11: 11 MPa ja 15°C,
  - H25: 25 MPa ja 15°C,
  - H35: 35 MPa ja 15°C,
  - H70: 70 MPa ja15°C.
- Tankkausyhteiden ja -suuttimien sekä vetysäiliöiden on täytettävä kaikki SAE J2600 vaatimukset ja testit ollakseen SAE J2600 yhteensopiva.
- Vrt. ISO standardi ISO 17268 (2012).
- Dokumentin piirrosta koskevaa päivitystä on ehdotettu. http://www.fuelc ellstandards.c om/2.1.7.2.htm

SAE J2601 (2010): Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles (54 sivua)

- Dokumentti asettaa turvarajat ja suorituskykyvaatimukset kaasumaisen vedyn tankkaukselle. Dokumentissa on kriteerit vedyn korkeimmalle sallitulle lämpötilalle annostelusuuttimessa, maksimivirtausmäärälle, suurimalle sallitulle paineennousunopeudelle ja muille toimintasuureille, jotka liittyvät tankkausasemalla olevaan vedyn jäähdytys- kapasiteettiin.
- Dokumentissa käsitellään sekä tiedonsiirrolla varustettu tankkaus (communication fueling) että ilman tiedonsiirtoa oleva tankkaus (non-communication fueling). Näistä ensimmäisessä tankattava ajoneuvo lähettää tankkauksen kannalta merkityksellistä tietoa vedyn annostelujärjestelmälle. Dokumentti määrittelee tiedonsiirron, jonka avulla tankkaustapahtuma optimoidaan.
- Uudistus on käynnissä. Osa standardin SAE J2799 (2007) sisällöstä sulautetaan päivitettyyn version (ks. alla SAE J2799).

SAE J2799 (2007): 70 MPa Compressed Hydrogen Surface Vehicle Fuelling Connection Device and Optional Vehicle to Station

- Standardin sisältö sulautetaan dokumentteihin SAE J2600 ja SAE J2601, minkä jälkeen standardi kumotaan vuonna 2013. Lähde: http://www.fuelc ellstandards.c om/2.1.7.2.htm