CMS Expert Guide to Hydrogen

The Promise of Hydrogen: An International Guide

Hydrogen in automotive sector

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In recent years, hydrogen technology has been at the forefront of environmental discussions in the attempt to meet increasingly tough climate protection goals and particularly low emissions targets in the transportation sector.

Whilst the current chapter will focus on the automotive sector, it is now a statement of the obvious that technological breakthroughs based on the use of hydrogen also happens in other areas of the transportation field. Trains, in particular, are now using the so called "Hydrails" technology. The world's first commercial hydrogen-powered passenger train in Germany, the Coradia iLint, was produced by the French railway manufacturer Alstom in 2016. [1] In Asia, East Japan Railway announced in the end of 2019 that it is investing ¥4 billion on the development of a hydrogen two-car trainset. [2] Also, in November 2019 Swiss rail manufacturer Stadler secured in the US a contract from San Bernardino County Transportation Authority to deliver the first hydrogen-powered train. [3] And the UK is fast catching up, too, introducing in 2020 "Hydroflex", the UK's first train to be powered by hydrogen. [4]

In the automotive sector, innovative hydrogen technology is pioneered as the most energy efficient alternative power source to engines, mandated as necessary to achieve a 60% to 80% reduction in greenhouse gases by 2050, according to the European Strategic Energy Technology Plan. [5]

Major automotive players in the EU and around the world are gearing up towards the hydrogen drive, already planning and implementing significant investments in the innovative technology of the future in car manufacturing, particularly hydrogen based fuel-cell electric vehicles ("**FCEVs**").

Hydrogen Technology in the Automotive Sector

Hydrogen fuel cell cars are powered by an electric motor and are therefore classified as e-cars.[6] As revealed by latest hydrogen technology deployed by car manufacturers (BMW, Toyota), the new technology can be integrated into existing models with minimal design changes, however at a significant cost.

Whilst it is widely acknowledged that hydrogen fuel cell technology is locally emission-free, the overall efficiency in the "power to vehicle drive" will ultimately depend on whether the hydrogen production has a neutral carbon footprint (i.e. if the electricity used in the process comes from renewable energy sources). [7] Still, the advantages remain unchallenged: compared to battery based electric cars, hydrogen technology provides fast refuelling, long range and less raw material consumption for batteries – significant incentives for future demand and for vehicle manufacturers to push ahead with this technology.

Pros and Cons of Hydrogen Technology

Hydrogen-powered vehicles have been praised for their positive effects on the environment. The hydrogen technology is believed to result in less pollution (compared to typical lithium-ion batteries from electric cars, which have a limited lifecycle and are hard to recycle) and reduce dependence on fossil fuels, while using a widely available resource – hydrogen. Moreover, compared to battery-powered electric cars, hydrogen e-cars are said to offer consumer benefits in terms of fast refuelling (estimated at 5 to 10 minutes) and longer range. [8]

Despite undoubted benefits, sceptics point towards the difficulties of turning hydrogen technology into large scale production, emphasizing the high costs associated with the manufacturing, operation and infrastructure of the technology (without public subsidies, models already available on the market cost around $80,000 for a mid- or upper-mid-range vehicle, almost twice as much as comparable fully electric or hybrid vehicles) and the dependence of large scale production on available fuelling infrastructure. [9] As detailed below, private and public funding is becoming increasingly available to mitigate this issue and make hydrogen e-cars more affordable.

Others also point out that hydrogen onboard a vehicle may pose a safety hazard, due to possible tank failures (e.g. leaks or ruptures) [10] and undesired chemical reactions. Both research studies and input from the car industry [11] address these concerns. Firstly, it is widely accepted that outdoor accidental releases of hydrogen from single vehicles will disperse quickly, and not lead to any significant explosion hazard, [12] contrary to gasoline which is also an extremely flammable fuel [13] which can leak out and pool beneath the damaged vehicle, creating a ready source of fuel for a prolonged burn. [14] Secondly, the risk of a leak and an explosion by a hydrogen tank is also nowadays lesser, since it is now made out of Kevlar, a material resistant to bullets, [15] thus confirming the high safety of the tanks storing the fuel (which has also been tested through numerous crash tests). Thirdly, this technology is not novel, as shown by trials and testing of hydrogen technology in other fields which confirm the secure use of this product (e.g. storage of hydrogen and operation of pipelines, processing of crude oil and the use of hydrogen as a process gas). Therefore, many industry experts opine that hydrogen fuel cell vehicles are safer than cars with internal combustion engines, [16] with only some concern for particular cases where safety becomes an issue, such as accidents in parking garages, workshops, or tunnels. [17]

Towards an Effective Framework for Hydrogen in the Automotive Sector in the EU and globally

In an effort to frame the transition towards a green energy strategy, in 2020 the European Commission launched a Hydrogen Strategy for Europe to be further implemented by the European Clean Hydrogen Alliance. [18] The European Commission aims to work within this frame to introduce common standards, terminology and further certification in an effort to make renewable or low-carbon hydrogen more competitive and easier to use as an alternative fuel resource.

The current EU legal framework offers flexibility in terms of regulations applicable to deployment of hydrogen technology in the automotive sector, with limited rules that bear only an indirect impact (e.g. environmental rules on green-house-gas ("**GHG**") intensity of hydrogen, technical requirements to be followed by refuelling stations).[19]

At an international level, the United Nations Economic Commission for Europe ("**UN/ECE**") develops harmonized requirements under regulations which serve as the basis for the national regulatory standards for hydrogen vehicles and in particular FCEVs safety in North America (led by the United States), Japan, Korea, and the European Union. Regulation No 134 of the UN/ECE contains provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of hydrogen-fuelled vehicles [2019/795] is currently in force and recognised as being equivalent to the corresponding separate EU directives or regulations. [20]

Many of the barriers to hydrogen deployment are a result of regulatory gaps caused by a lack of harmonisation of rules and approaches, or by involuntary mismatches between rules imposed at national level rather than high legal and regulatory barriers imposed at EU level. [21]

Nevertheless, steady progress is being seen around the globe as countries take on initiatives to change national policies with the aim to decarbonise vehicle transport, with several countries pioneering concrete steps to invest in and develop hydrogen based vehicles in public and private transport (also including heavy-duty road vehicles, amongst others).

Hydrogen Vehicles around the World

Hydrogen infrastructure is available only in a limited number of cities and countries globally. Across Europe there are less than 200 hydrogen refuelling stations, and these are not spread equally geographically. [22] With a goal to operate 100 hydrogen stations in seven German metropolitan areas and along the connecting arterial roads and motorways in 2021, Germany is at the forefront of hydrogen technology in the EU, but other countries are catching up.

In transport, hydrogen is already seen as a promising option where electrification is more difficult - early adoption of hydrogen already occurs in captive uses, such as local city buses (as well as rail networks), where electrification is not feasible. For more detail on the role hydrogen plays in transport in individual countries, please see the relevant country-specific chapter of this guide.

Notable examples include:

- Belgium (for further information please refer here);
- Czech Republic (further information is available here);
- Denmark: In 2012, the Danish government was announcing a new Energy Plan 2020 that will establish a range of initiatives for a nationwide hydrogen infrastructure and fuel cell electric vehicles, with the overall aim of reaching 100% fossil fuel independence by 2050. [23] In 2019, Denmark was boasting the most dense network of stations for CO_2-free fuel, with Hyundai and Toyota as the main suppliers for the market; [24]
- France: [25] the world's first hydrogen-powered bus rapid transit ("**BRT"**) system has been deployed in the city of Pau in the south of France, with 8 buses built by Built by the Belgian manufacturer Van Hool in a project launched by French public transport operator, Keolis, in partnership with local transport operator Société de Transport de l'Agglomération Paloise (further information is available here);
- Germany: [26] in April 2020, the German Government funded WSW Mobil GmbH for the purchase of 10 fuel cell buses and refuelling infrastructure and the Obergische Verkehrsgesellschaft ("**OVAG"**) for the procurement of a hydrogen fuel cell bus and a hydrogen storage unit (further information information is available here);
- Italy (further information is available here);
- Netherlands: [27] in September 2019, Keolis won the largest electric bus contract in its history in what is claimed to be Europe's largest electric bus fleet, with 300 vehicles operating in the provinces of Overijssel, Flevoland and Gelderland from December 2020 onwards (further information is available here);
- Poland (further information is available here);
- Portugal (further information is available here);
- Slovakia (further information is available here);
- Spain (further information is available here);
- Sweden: in 2017, Sweden launched the Nordic Hydrogen Corridor, a partnership now including Hydrogen Sweden (Vätgas Sverige), Statkraft (Europe's largest producer of renewable energy), the green hydrogen fuel distributor Everfuel and the car producers Hyundai and Toyota. The total budget for implementing hydrogen road transport means in Sweden was approximately €20 million, the initiative being co-financed by the Connecting Europe Facility ("**CEF"**). Other Government supported initiates exist; [28]
- United Arab Emirates and Saudi Arabia (further information is available here);
- UK (further information is available here);

Despite significant costs, private companies in the automotive sector are seizing the potential and widening their portfolio to offer vehicles based on hydrogen technology.

Car pioneers include:

- Japanese companies such as Honda (with the Honda Clarity), Toyota (with its Toyota Mirai, one of the first hydrogen fuel cell vehicles to be sold commercially), Hyundai (with the Hyundai Nexo) and Kawasaki are currently at the forefront of hydrogen technology; [29]
- BMW recently announced that it has plans to invest in an X5 version powered by Toyota's fuel cells in a joint venture with the latter and that it will produce the I Hydrogen Next in small numbers from 2022; [30]
- a group formed by Ford, Daimler, and Nissan announced a collaboration on hydrogen technology development in 2013, but some of them later abandoned this cooperation (in 2020 Daimler's Mercedes-Benz gave up production of GLC F-Cell and limited its hydrogen programme to trucks and vans in association with Volvo); [31] and
- tested since 2014, Renault's hydrogen technology was developed in partnership with Symbio, a Michelin subsidiary. Renault presented its Kangoo Z.E. Hydrogen (a light vehicle) and Master Z.E. Hydrogen van at the end of. [32]

Heavy-duty vehicles also continue to thrive, with the following global players:

- in 2016 Nikola Motor Company introduced a hydrogen-powered electric semi-trailer Class 8 truck and in 2019 was already reported to have many orders for this truck; [33]
- United Parcel Service (UPS) began testing of a hydrogen powered delivery vehicle in 2017;[34]
- in 2017 US Hybrid (manufacturer of battery and fuel cell propulsion systems), Toyota, and Kenworth were announcing plans to test Class 8 hydrogen fuel cell trucks to move containers at the Ports of Los Angeles and Long Beach, expecting to build and deliver 1,200 of its fuel cell "engines" over the next 36 months; [35]
- Toyota Kenworth has a long track record of developing trucks using fuel cell technology and in 2019 it added 10 T680s to be used at the Port of Los Angeles and throughout Southern California; [36]
- in July 2020, the Hyundai was reported to be shipping the first 10 units of XCIENT Fuel Cell, the world's first fuel cell heavy-duty truck, to Switzerland, with plans to roll out 50 trucks in the same year and total of 1,600 units by 2025. In 2019, Hyundai formed, for its future development, Hyundai Hydrogen Mobility (HHM), a joint venture with Swiss company H2 Energy; [37]
- in 2017 Tesla was launching its Semi prototype truck based on hydrogen technology, however in 2019 was still reported to limit its use for its own internal operations, while continuing efforts to develop durable hydrogen technology for commercial trucking; [38] and
- The commercial vehicles manufacturer Faun (of the German Kirchhoff Group) will launch from 2021 the first hydrogen-powered refuse and sweeper vehicles in series production. [39]

Funding the Hydrogen Automotive Market

Around the world, states, organizations and private companies are making significant efforts to secure financial funding for hydrogen technology in the automotive sector.

At EU level, [40] the European Commission is funding two research projects (H2ME1 and H2ME2) that aim to see an additional 49 hydrogen filling stations and more than 1,400 cars, vans and trucks run on hydrogen within the EU by 2022. These projects have had budgets of €70 million and €100 million, respectively, with the EU's Horizon 2020 research program sinking €67 million in total into both, which run until May 2020 and June 2022, respectively. The research projects involve more than 40 partners from nine countries and from across the transport, hydrogen and energy industries, including Audi, BMW, Engie, H2 MOBILITY, Hyundai, Michelin, OMV and Renault. In the EU, the Fuel Cells and Hydrogen Joint Undertaking is the public-private partnership made up of the European Union, represented by the European Commission and the Industry and Research Grouping represented by "Hydrogen Europe", responsible for implementing the Fuel Cells and Hydrogen Joint Technology Initiative (**FCH JTI**), the political initiative proposing this public-private partnership in fuel cell and hydrogen technologies.

At national level, governments have already initiated incentive schemes for renewable and low-carbon hydrogen mobility, notable examples including, amongst others:

- Belgium (further information is available here);
- Czech Republic (further information is available here);
- Denmark: in 2019 alone a national reserve of more than €17 million for large-scale energy storage projects was implemented and the funding allocated to two P2X projects (Power-to-Product ("**P2X"**) refers to technologies that use (surplus) electricity, ideally from fluctuating renewable energy sources, to synthesize (gaseous) chemical products, like hydrogen or hydrocarbons.). With the private investments that follow the public funding nearly €67 million in total will be directed at industrial hydrogen production in Denmark; [41]
- France: remains committed to invest in hydrogen mobility, with call for projects launched in 2018 and in 2019 and continuing in 2020, which raised interest translating into over €450 million potential investment projects. [42] The most recent funding available in 2020 includes grants worth €80 million for projects selected in the "Hydrogen mobility ecosystems" call for proposals (further information is available here);
- Germany: in 2020, the State allocated €2.3 million in funding to WSW Mobil GmbH for the purchase of 10 fuel cell buses and refuelling infrastructure and an additional €1.08 million for the purchase of a storage unit to supply hydrogen to the fuel cell buses. Similarly, the Oberhessische Verkehrsgesellschaft ("**OVAG"**) will receive €1.23 million for the procurement of a hydrogen fuel cell bus and a hydrogen storage unit. [43] Moreover, as part of the plan to reboot the economy during the coronavirus pandemic, [44] the German government announced in June 2020 an investment of €7 billion over the coming two years [45] into the production of green hydrogen. [46] Additionally, €2 billion will be invested in fostering international partnerships. The southern state of Bavaria has set up a hydrogen research centre and has involved carmakers Audi and BMW, along with Siemens and energy supplier Bayernwerk [47] (further information is available here);
- Italy (further information is available here);
- Poland: R&D initiatives continue with the aid of public and private funding. Poland benefits by over €11 million in funds for research into development of new e-mobility technologies [48] (further information is available here);
- Portugal (further information is available here);
- UK: the Hydrogen for Transport Programme ('**HTP**") sets out the next steps to develop the UK hydrogen vehicle market, providing up to £23m of new grant funding until 2020 to support the growth of refuelling infrastructure alongside the deployment of new vehicles. The HTP was launched on 17 August 2017 by the Office for Low Emission Vehicles ("**OLEV**") to provide funding via open competition for both Hydrogen Refuelling Stations ("**HRS**") and hydrogen fuel cell electric vehicles ('**FCEVs"**) in two stages. Stage 2 commits almost £14 million funding to five projects which will serve to enhance and expand the UKs refuelling network and increase station utilisation with new vehicles [49] (further information is available here);
- Netherlands: in addition to the public funding for hydrogen technology deployed in public transport, the Dutch Government plans to allocate €35 million a year from 2021 to scale up projects. Support may also come from EU funds such as the Connecting Europe Facility, as well as the European Hydrogen Alliance initiated by the European Commission [50] (further information is available here);
- Japan was the first country to adopt a "Basic Hydrogen Strategy". To this end, in 2014 the government began investing in R&D. At present, almost all hydrogen and fuel cell technologies are highly dependent on public funding [51] (further information available here);
- United Arab Emirates and Saudi Arabia (further information is available here);

- USA: in 2019 Nikola Motors was awarded by the US Department of Energy a $1.7 million grant to help the startup advance its research into fuel cell membrane electrode assembly technology. [52] States are reported to allocate yearly significant funds for hydrogen technology – for example, Assembly Bill 8, enacted in 2013, includes a provision to fund at least 100 hydrogen stations with a commitment of up to $20 million per year and the Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program supplies funding for these hydrogen stations (further information is available here).

Undoubtedly, fuel cells are already changing the automotive landscape and hydrogen based technology is no longer a novelty for the future, but rather a current reality that stakeholders must be equipped to deal with. Although the road ahead may hold financial, regulatory and technical challenges, hydrogen technology in the automotive sector is an important alternative energy source. Thinking ahead, the sector will need to be prepared for everchanging economic and environmental realities.

Footnotes

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https://www.bbc.com/future/article/20200227-how-hydrogen-powered-trains-can-tackle-climate-chan
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2
https://www.bbc.com/future/article/20200227-how-hydrogen-powered-trains-can-tackle-climate-chan
Back to the text occurrence

3
https://www.bbc.com/future/article/20200227-how-hydrogen-powered-trains-can-tackle-climate-chan
Back to the text occurrence

4
https://www.bbc.com/future/article/20200227-how-hydrogen-powered-trains-can-tackle-climate-chan
Back to the text occurrence

5
https://ec.europa.eu/transport/themes/urban/vehicles/road/hydrogen_en
Back to the text occurrence

6
https://www.bmw.com/en/innovation/how-hydrogen-fuel-cell-cars-work.html
Back to the text occurrence

7 https://www.bmw.com/en/innovation/how-hydrogen-fuel-cell-cars-work.html#pwjt-3 and https://www.wardsauto.com/alternative-propulsion/europe-nurturing-hydrogen-vehicle-market
Back to the text occurrence

8
https://hydrogeneurope.eu/revolution-mobility
Back to the text occurrence

9
https://www.bmw.com/en/innovation/how-hydrogen-fuel-cell-cars-work.html
Back to the text occurrence

10
https://www.sciencedirect.com/science/article/abs/pii/S036031990900202X
Back to the text occurrence

11
https://www.sciencedirect.com/science/article/abs/pii/S036031990900202X
Back to the text occurrence

12
https://www.sciencedirect.com/science/article/abs/pii/S036031990900202X
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14
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15
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16
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Back to the text occurrence

17
https://www.sciencedirect.com/science/article/abs/pii/S036031990900202X
Back to the text occurrence

18
https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf and
https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en
Back to the text occurrence

19 This includes (amongst others): Commission Delegated Regulation (EU) 2019/1745 of 13 August 2019 su amending Directive 2014/94/EU of the European Parliament and of the Council as regards recharging p motor vehicles, shore-side electricity supply for inland waterway vessels, hydrogen supply for road tra supply for road and waterborne transport and repealing Commission Delegated Regulation (EU) 2018/ Renewable Energy Directive (Directive (EU) 2018/2001 (RED II) on the promotion of the use of energy fr (RED); Alternative Fuels Infrastructure Directive 2014/94/EU (AFID). Source: https://www.hylaw.eu/sites 02/D4.4%20-
%20EU%20regulations%20and%20directives%20which%20impact%20the%20deployment%20of%20FC
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20 Regulation 134 (published in the OJ L 129, 17.5.2019, p. 43–89) is available at: https://eur-lex.europa.eu uri=uriserv:OJ.L_.2019.129.01.0043.01.ENG For example, Directive 2007/46 establishes a framework for motor vehicles classes M (passenger cars and busses), N (trucks), O (trailers), and of systems and comp such vehicles. Specific technical requirements concerning the construction and functioning of vehicles subsequent regulatory acts, the exhaustive list of which is set out in Annex IV. The UNECE Regulations IV are recognized as being equivalent to the corresponding separate directives or regulations in as mu same scope and subject matter.
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21
https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c1628
Back to the text occurrence

22
https://h2.live/en
Back to the text occurrence

23
https://www.dw.com/en/driving-a-hydrogen-powered-car-in-denmark/a-49172769
Back to the text occurrence

24
https://www.dw.com/en/driving-a-hydrogen-powered-car-in-denmark/a-49172769
Back to the text occurrence

25
Back to the text occurrence

26
Back to the text occurrence

27
Back to the text occurrence

28
http://www.scandinavianhydrogen.org/nhc/
Back to the text occurrence

29
https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
Back to the text occurrence

30
https://www.cnet.com/roadshow/news/bmw-hydrogen-fuel-cell-x5-production-toyota/
Back to the text occurrence

31 https://electrek.co/2020/04/22/daimler-ends-hydrogen-car-development-because-its-too-costly/ and https://www.autocar.co.uk/car-news/motor-shows-frankfurt-motor-show/bmw-i-hydrogen-next-conce range
Back to the text occurrence

32
https://autovistagroup.com/news-and-insights/renault-introduce-hydrogen-commercial-vehicles-year-
Back to the text occurrence

33 https://www.teslarati.com/tesla-semi-rival-nikola-get-1-million-us-department-of-energy-fuel-cell-rese https://www.foxnews.com/auto/nikola-hydrogen-powered-semi-truck-revealed
Back to the text occurrence

34
https://www.cnet.com/roadshow/news/ups-begins-testing-hydrogen-fuel-cell-delivery-truck
Back to the text occurrence

35 https://www.ballard.com/about-ballard/newsroom/market-updates/ballard-and-kenworth-fuel-cell-tru moves-to-next-stage and https://www.trucks.com/2017/05/04/us-hybrid-hydrogen-fuel-cell-truck/
Back to the text occurrence

36
https://energypost.eu/hydrogen-fuel-cell-trucks-can-decarbonise-heavy-transport/
Back to the text occurrence

37
https://hyundai-hm.com/en/2020/07/08/worlds-first-fuel-cell-heavy-duty-truck-hyundai-xcient-fuel-cel commercial-use/
Back to the text occurrence

38 https://www.teslarati.com/tesla-semi-rival-nikola-get-1-million-us-department-of-energy-fuel-cell-rese https://www.teslarati.com/tesla-semi-dublin-supercharger-sighting-lathrop-fremont-factory/
Back to the text occurrence

39
https://fuelcellsworks.com/news/the-kirchhoff-group-starts-manufacturing-the-worlds-first-refuse-and hydrogen-fuel-cells/
Back to the text occurrence

40
Back to the text occurrence

41
https://hydrogeneurope.eu/sites/default/files/Press%20release%20-%20Hydrogen%20and%20P2X%20on%20the%20rise%20in%20Denmark.pdf
Back to the text occurrence

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