Hydrogen Fuel Cells: The Market in 2021

Whilst sales of vehicles powered by hydrogen lags behind battery-powered Electric Vehicles, the technology is fast developing. Here, we summarise where the global sector is, and outline some developments likely to be seen in the medium term.

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Hydrogen Fuel Cells (HFCs) have been known since 1842, when a Judge from Swansea, Sir William Robert Grove, designed a rudimentary version in his home laboratory. Since then, there have been many attempts to bring the technology to the point at which it is commercially viable for personal transport, although a bottleneck of sorts has been identified in its mass uptake. The underlying resource, hydrogen, is at a significant disadvantage to fossil fuels, with a number of factors – including both safety and lower power density – limiting the degree to which HFC-powered cars are visible on our streets.

The most abundant element in the universe

First, it may be enlightening to briefly outline the salient features of HFC technology. Commercialised Proton Exchange Membrane (PEM) fuel cells contain two electrodes, a positive cathode and a negative anode, which are separated by an electrolyte. Hydrogen is fed onto the anode and air is fed to the cathode. A platinum catalyst on the anode separates hydrogen molecules into protons and electrons which take different paths to the cathode, with the electrons going through a circuit, thereby creating electricity. At the cathode, hydrogen ions and electrons bond with oxygen in the air to form water vapour, the only other output from the process.[2]

The anode is treated with nanometre-sized particles of platinum that catalyse the reaction, separating protons and electrons. The quantity of platinum used in a fuel cell is small: between 10 and 20 grams per vehicle – greater than the 5 to 10 grams within an Internal Combustion Engine (ICE) catalytic converter, although efficiencies are expected to reduce the amount of platinum required over time.[3]

As mentioned, hydrogen as a power source does have key disadvantages – not least that the element is scarce in its pure form. Low-cost hydrogen is obtained from fossil deposits such as lignite, extracted through steam reform, becoming so-called ‘grey’ hydrogen. This process is patently unsustainable, given seven tons of carbon dioxide are produced for every ton of hydrogen generated. ‘Blue’ hydrogen, on the other hand, is the result of the same process, albeit with carbon capture technology (CCT) being utilised to somewhat reduce harmful emissions.

‘Green’ hydrogen, on the other hand, is produced in a far more sustainable manner, using electricity from solar or wind to power an electrolyser that breaks water down into its component parts, allowing hydrogen to be captured and stored for later use. Even the efficiency of green hydrogen power can be criticised, however, as hydrogen is primarily used as an energy storage medium, created by solar or wind electricity and then reconverted back into electrical power; this round-trip process means, in pure efficiency terms, it is currently preferable to create electricity from chemical reactions within batteries.[4]

Despite these challenges, it is becoming increasingly apparent that hydrogen can play a valuable role in providing sustainable power, particularly because of its compatibility with both new electric technologies and old power infrastructure systems. On top of this, a further consideration is the security and diversification of energy supply; countries such as China – which do not control the supply of materials used in batteries, primarily lithium, nickel and cobalt – are attracted to HFCs as they help reduce import dependencies and diversify onshore energy supply.[5]

Finally, with many countries announcing plans to rapidly accelerate their route to zero carbon emissions, hydrogen is attractive as an additional green power source complementing battery power.

Tumbling costs

Bloomberg New Energy Finance estimate the current cost of ‘grey’ hydrogen to be around $1.50 per kilo, blue to be between $1.50 - $3.00 and green $2.50-$5.00.[6] The Hydrogen Council expects hydrogen prices to fall rapidly as the scaling up of production, distribution and equipment manufacturing quickens pace, reducing costs by 50% over the next decade and making it possible that green hydrogen costs may fall to $0.60-$1.50 per kilo by 2050. Research by the Hydrogen Council found that for 22 hydrogen applications (accounting for around 15% of the world’s total energy consumption) such as commercial vehicles, trains, and domestic and industrial heating, the Total Cost of Ownership (TCO) by 2030 will be on a par with other low-carbon alternatives, while nine applications will be competitive with conventional energy, including heavy duty trucks, coaches and forklifts.[7]

Analysts at Bernstein estimate fuel cell production costs will fall by 20% in the next decade.[8] Deloitte, in conjunction with Ballard, a developer and manufacturer of fuel cells, estimate the TCO of FCEVs will achieve parity with Battery Electric Vehicles (BEVs) in Europe in 2023, US in 2027 and China in 2028. Parity will be achieved with ICE vehicles in Europe in 2024, US in 2026 and China in 2027.[9]

Working alongside battery power

The respective characteristics of hydrogen and battery power mean that hydrogen-powered vehicles have certain advantages over BEVs, including greater range before refueling, shorter refueling times, tolerance of low temperatures and consistent power output rates. This makes HFCEV performance superior to battery power for intensively used commercial vans, trucks, equipment such as forklift trucks and diggers, buses and trains.[10] The feasibility of use within shipping is also being assessed.

Policy support

Japan was the first large country to introduce an outline of the path towards hydrogen uptake with its Basic Hydrogen Strategy in 2017, followed by the Strategic Road Map for Hydrogen and Fuel Cells in 2019. The country leads in the funding of research and development, investing $303m in HFC technology in 2019, with policies focused on promoting private hydrogen fuel cell electric vehicles (HFCEV) for passenger use, targeting 800,000 private automobiles and 900 refueling stations by 2030.[11]

China's investment in fuel cell development has increased significantly from US$19m in 2015, to US$129m in 2018. Subsidies for HFCEVs have been in existence since 2009, although adoption has been negligible with only 7,200 vehicles in use by July 2020. More promisingly, hydrogen power is now being recognised as a priority within the nation's 2021-2025 Five Year Plan; consumers purchasing HFC-powered vehicles will receive subsidies until 2025, even though support for battery-powered EVs is being phased out.[12] Central government is encouraging local authorities to develop and adopt HFC technology through policies such as designating municipalities as 'model cities'; Chongqing and Chengdu have been awarded CNY1.7bn to fund development and implementation over the next four years.[13] At present there is no comprehensive national subsidy system for refueling stations, although city authorities such as those in Foshan and Zhongshan have established their own schemes.[14]

The US Department of Energy's H2@Scale program launched in 2016 and has supported research and development in a number of areas including heavy duty trucks, electrolyser manufacture and hydrogen storage.[15] California has the highest level of commercialisation of hydrogen in the US, where the California Fuel Cell Partnership has set a target of 1m fuel cell electric vehicles by 2030. One area of higher HFCEV adoption in US is of forklift trucks, with 30,000 in use at companies such as Amazon and Walmart,[16] indicating that corporations have started to understand the benefit of using the technology for light vehicles not expected to venture far from the refilling infrastructure.

The 2020 EU Green Deal has set strategies to achieve zero carbon emissions by 2050 and further integrate Europe's energy systems. As part of this initiative, the Hydrogen Strategy for a Climate-Neutral Europe commits to grow electrolyser capacity to 40GW by 2030, with projected investment of up to €180bn by 2050.[17] Green hydrogen is a cornerstone of the EU's vision for decarbonisation, using energy from solar and wind farms; the EU Hydrogen Roadmap Europe targets 3.7m HFC passenger vehicles, 500,000 light commercial vehicles, 45,000 trucks and buses and 570 trains by 2030, supported by an infrastructure of 3,700 refueling stations.[18]

Putting fuel cells to work

The Japanese government's commitment to private passenger HFCEVs has enabled the country's automobile industry to establish global leadership in this area. Toyota launched its original Mirai model in 2014, with an updated version launched in 2020.[19] The company has recently announced a joint venture with a consortium of Chinese firms, including Dongfeng Motor to develop HFCEVs; its estimated China could have 2m HFCEVs by 2030, presenting around 5% of the country's total vehicles, with 1m operating in Beijing.

Chinese state support for HFCs is in part due to the country's abundance of solar and wind power; an estimated 150GW is wasted each year from plants that cannot be integrated into the grid. Hydrogen offers the opportunity to capture and store this power for later use.[20]

State policies recognise capability gaps faced in core technologies and production of key components encouraging Chinese firms to collaborate with market leaders. As a consequence, automobile manufacturer BYD started working with US Hybrid Corporation in 2020 operating HFC buses at Honolulu airport and Weichai Power, China's largest state-owned diesel engine maker, acquired a 20% stake in Ballard Power, a leading developer and manufacturer of fuel cells.[21]

An area where hydrogen can be used with existing infrastructure is within domestic heating systems. The UK's National Grid estimates that the gas-fired boilers which heat most British homes can cope with up to 20% hydrogen mixed in with existing natural gas; in the longer term, hydrogen-ready boilers can be installed which can burn either natural gas or hydrogen.[22] Green hydrogen presents a way to reduce emissions within carbon-intensive heavy manufacturing processes including steel, glass, and fertiliser production.

While China is presently the global leader in hydrogen production, Europe is at the forefront of hydrogen production from water using electrolysers, with capacity of 1.2GW in 2020. Capacity is expected to rapidly grow with projects such as Norway's NEL Hydrogen's plans for a 360MW plant, with scope to triple output over time.[23] Large-scale production enables stored hydrogen to be used to temporarily capture excess electricity for use at peak times.

Potential to transform both old and new energy

Hydrogen's flexibility along with its strengths compared to battery power make the two technologies highly complementary. Although hydrogen power is today either carbon intensive or relatively inefficient, significant investment and largescale subsidised use will scale up development, infrastructure and manufacture to reduce costs bringing them in line with both battery and combustion engines over the next decade.

Green hydrogen is highly sustainable, arguably with fewer environmental hazards than batteries, providing a simple mechanism for electricity storage mitigates one of the key weaknesses of solar and wind power.

These factors combined provide good reason for the Hydrogen Council to forecast hydrogen will provide up to a fifth of the world's energy by 2050.[24]

By Metal.Digital, January 2021

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Footnotes

1. American Physical Society
2. US Department of Energy
3. Deloitte and Ballard, 2020
4. Economist, July 2020
5. Financial Times, January 2019
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7. Hydrogen Council, January 2020
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