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HYDROGEN

Stepping on the gas

Transport industry experts believe hydrogen fuel cell electric vehicles have a role to play in an industry-wide move towards zero emission transport. *Brian Davis* reports.

Hydrogen promises significant benefits for powering vehicles with zero emissions (as the exhaust pipe only emits water vapour), for heating homes and businesses, and balancing intermittent renewables if costs can be brought down and infrastructure built. Hydrogen fuel cell vehicles also offer advantages compared to full battery electric vehicles (EVs) since they can be refuelled in just three to six minutes and offer considerably higher ranges up to 500 km per tank.

Though it is still early days, industry leaders are committed to expanding deployment of fuel cell electric vehicles (FCEVs) and creating hydrogen refuelling infrastructure as part of the energy transition currently underway in Europe and beyond.

In mid-September 2017 global vehicle manufacturers Audi, BMW, Daimler, Honda, Hyundai, Symbio and Toyota, as well as hydrogen refuelling infrastructure providers, policymakers and other stakeholders, gathered in Brussels at the 'Hydrogen for Clean Transport' conference to discuss the latest developments in hydrogen-based solutions, working towards a zero emission transport sector in Europe by 2040.

The conference was sponsored by the Fuel Cells & Hydrogen Joint Undertaking (FCH JU) and flagship hydrogen projects HyFIVE and H2ME. The timing was particularly appropriate as more European countries press for partial or complete bans on the sale of new petrol or diesel vehicles. Although much publicity is given to the replacement of petrol and diesel transport by battery powered EVs, hydrogen fuel cell technologies are increasingly seen as a component of the future vehicle mix.

The major original equipment manufacturers (OEMs) were keen to show the latest models of their hydrogen fuelled vehicles, as a viable alternative and complement to full battery electric powertrains. Speakers at the Brussels conference stressed that many of the technology issues have been solved. The key challenge will be convincing consumers in the move from niche solutions to the mainstream and mass production.

According to Clara de la Torre, Director General Research & Transport (DG-RDT) in the European Commission (EC), major cities like Paris, Athens and Madrid have announced plans to ban most polluting cars from their city centres by 2025 to improve air quality. The Netherlands and UK intend to phase out diesel in 2030–2040, and the City of London is looking at greening its black cabs. 'Collectively, we must be prepared for a paradigm shift in the transport sector. However, for the hydrogen car to succeed there must be more models and customer education on issues like hydrogen safety,' she told conference delegates. 'We must "step on the gas" and spread the technology.'

Indeed, the EC is seeking to accelerate hydrogen fuel cell development and incentivise development and innovation through a number of well-funded programmes.

HyFIVE powers on

The HyFIVE programme has developed a hydrogen network with three clusters – London, Copenhagen and a southern area comprising Innsbruck, Munich, Stuttgart and Bolzano. Klaus Bonhof, Director of NOW, which coordinates the southern cluster HyFIVE learnings, is convinced 'we are at the edge of a real commercial roll-out of hydrogen fuel cell technology... as an important pillar of sustainable transport.'

Recently, new hydrogen fuel cell vehicles were introduced at the Frankfurt Motor Show. However, Bonhof stresses that batteries and fuel cells will need to satisfy future transport needs not only for passenger cars but also larger vehicles. 'Getting hydrogen as a fuel into mass markets will be a big challenge and will require motor industry and fuel infrastructure collaboration,' he says.

The overall vision is for vehicles, infrastructure and 'green' hydrogen sourced from renewables. At present, for example, 60% of hydrogen in Germany comes from green sources, where electrolysis is powered by solar or wind energy. Hyundai recently handed over 20 Mirai cars to the Clever Shuttle taxi service in Hamburg. Meanwhile, in the UK, Aberdeen Council runs 10 hydrogen powered buses and has ordered another 10.

Hydrogen refuelling infrastructure is being rolled out

OEMs were keen to showcase the latest models of their hydrogen fuelled vehicles at the 'Hydrogen for Clean Transport' conference in Brussels in September 2017
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▶ p18

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◀ p16

with 700 bar technology, but is being taken up with some reluctance by countries like Italy which prefer 350 bar. Some 51 hydrogen refuelling stations are in operation in Europe. A further five are being set up and 39 stations are at the planning stage.

Green electrolyser technology is key to transforming hydrogen as a fuel. The technology must be flexible and integrated in transport infrastructure with EVs, as a renewable power source. The next stage will be to develop 10, 20 and 50 MW electrolyser plants to generate hydrogen. 'But this will only happen with the right regulatory framework,' says Bonhof. 'Ultimately, we need to look at sustainable power, transport and heat collectively, rather than separately as at present.'

'Collectively, we must be prepared for a paradigm shift in the transport sector... We must "step on the gas" and spread the technology.'

Clara de la Torre, DG-RDT, European Commission

Energy security

The FCH JU was established by the EC to deliver energy security and boost EU competitiveness under the EU Climate and Energy Framework. Bart Biebuyck, Executive Director of the FCH JU, recognises that very severe targets have been set. In a nutshell, the EC is looking for 20% CO_2 reduction, 20% renewable energy sources and 20% energy efficiency by 2020; 40% CO_2 reduction, 27% renewable energy resources and 27% energy efficiency by 2030; and 80–95% CO_2 reduction and zero emissions by 2050.

The FCH JU is a public-private partnership with three main partners – Hydrogen Europe on the industry side (105 members); the EC, mostly in the DG-RDT; and the Hydrogen Europe research bureau (68 members). The FCH JU has been set five objectives by the EC – hydrogen storage grid balancing; green hydrogen production; clean transport, with lower fuel cell costs; heat and electricity production, with better cost efficiency; and minimal use of critical raw materials.

Currently, the FCH JU has 203 projects supported by €730mn from the EC and €782mn from private funding. There are 114 energy projects (€354mn), covering hydrogen production, storage and fuel cells for power and combined heat and power; 52 transport projects including HyFIVE (€337mn), for road vehicles, non-road vehicles, refuelling infrastructure, maritime, rail and aviation; and 34 cross-cutting projects, covering standards, safety, education, consumer awareness.

After three FCH JU research projects, BMW, Daimler, VW/Audi and Ford decided to industrialise their FCEV programmes. The aim is to create 30,000 fuel cell stacks per year under a €60mn German project. The stack can now provide about €90/kW but is still too expensive. 'We have to drive costs down and the target is to be competitive with a four-cylinder gasoline engine – about €15–€20/kW. So there is still a long way to go,' says Biebuyck.

The HyFIVE programme has a budget of €38.5mn, with €18mn contributed by the FCH JU. For the first time there have been large fleet deployments, with 185 hydrogen fuel cell cars on the road and five OEMs involved in the project. Meanwhile, the Hydrogen Mobility programme combines H2ME and H2ME2 in a €72mn programme which started in 2014.

Hyundai was first to introduce a hydrogen fuel cell car with the iX35 model, followed by Renault's HyKangoo, the Toyota Mirai and Honda Clarity. Daimler launched the GLC this year. Hyundai plans to introduce a new iX35 SUV, and a new Toyota Mirai and Lexus are due soon. BMW plans to launch a small series by 2021, with Audi/VW soon after, with many more models to follow after 2025. 'Most of the OEMs are working with the FCH JU,' notes Biebuyck, 'but we need to accelerate, especially on the infrastructure.'

Infrastructure build-up

At present 135 hydrogen refuelling stations (HRS) are deployed in Europe. The FCH JU has financed 20 of them. Though Europe initially had the lead in terms of the number of FCEVs and HRS on the market, the US and Japan recently overtook the EU. 'One important reason is policy,' says Biebuyck. Japan subsidises the FCV and the US has the ZEV mandate and subsidy from the Californian state government. Nevertheless, he looks forward to the EU Mobility Package, which is to be announced in November. 'This could give the Europeans a chance to catch up,' he hopes.

The US currently has 2,400 hydrogen vehicles on the road, Japan has 2,000 and Europe 900. The US has 35 refuelling stations, Japan 92 and Europe 90. 'As we look into the future, a serious gap is coming,' Biebuyck warns.

There are 206 hydrogen fuelled buses in Europe, with commitments to procure 919 buses by 2020. There are also opportunities for applications in material handling vehicles, maritime applications, aeroplanes, trains and trucks. Truck projects include the Symbio Renault initiative, Asko and Scania in Norway, VDL Group and Colruyt in Belgium and Esoro Group in Switzerland, as well as fuel cell range extenders using auxiliary power units (APUs) by Nikola Motor Company, Toyota Trucks and Kenworth Trucks.

Interestingly, David Hart, Director of E4Tech, which co-authored with Element Energy an authoritative report *Hydrogen and fuel cells: opportunities for growth*' as a roadmap for the UK, told *Petroleum Review* that the biggest user of hydrogen as a fuel today is forklifts. There are about 1,500 fuel cell forklifts mostly in the US, operated by Walmart, CocaCola and others. 'Hydrogen cell technology has moved forward significantly over the last decade, the big challenge is to move to meaningful scales in transport.'

He points out that hydrogen is a tiny part of the fuel picture at present. 'There is no subsidy on the fuel, simply for the capital cost of the refuelling equipment. There is also discussion about how to classify "green" hydrogen for sustainability – which will mean using hydrogen from renewable sources rather than from some petroleum product; and how to tax it, as hydrogen has had an exemption from fuel duty for some time.'

Hydrogen Council

In a significant move in January 2017, 13 global industry leaders including Air Liquide, Alstom, BMW, Daimler, Anglo-American, Honda, Hyundai, Engie, Shell, Linde Group, Total, Toyota and Kawasaki launched the Hydrogen Council at the World Economic Forum at Davos to voice a united vision and long-term ambition to position hydrogen among key solutions of the energy transition. In September a further 11 companies, including Audi, Statoil, Plastic Omnium and Iwatani, added their names to the initiative.

Oliver Bishop, General Manager, Hydrogen, Shell, reports that the H2 Mobility joint venture in Germany plans to roll out 400 hydrogen refuelling stations by 2023. 'The technology has progressed tremendously over the last decade, costs have come down, and products are being commercialised across the whole value chain, but there is still a need for investment and costs to be driven down through scale up. Shell is convinced we can take 50% of the cost out on the hydrogen refueling side.'

Shell is also to partner with Honda and Toyota to roll out seven

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HRS in Northern California. The oil major is also reportedly planning to build its first 'no petrol' service station in London, to offer drivers hydrogen cell refuelling, biofuels and fast EV charging points.

Different flavours

There are different flavours of national infrastructure initiatives, according to Ben Madden, Director, Element Energy and H2ME Project Coordinator. In Germany a combination of industrial actors on the vehicle side and infrastructure players came together with policymakers to map out a commercial hydrogen infrastructure across the country in a sustainable way. The French initiative is based on captive fleets of vehicles, to justify hydrogen station deployments. Whereas Scandinavia is rolling out a nationwide infrastructure driven by differential sales taxes for hydrogen vehicles compared with diesel – aimed at transnational coverage by 2025. The UK initiative is driven by geographic clusters, which aim to create a network of 65 stations by 2020.

However, they all face the same problem when it comes to deploying hydrogen stations while vehicles are only coming on the market in 'dribs and drabs', says Madden. 'You don't have enough hydrogen vehicles to make an economic case for these stations without some form of state action to incentivise early deployment.'

'The FCH JU recognises the need for intervention as a large-scale funding body to help early stage catalysis of these interesting business models,' he continues. It also recognises the fragmented nature of these initiatives and has encouraged coalitions to draw up a concerted pan-European vision.

The Hydrogen Mobility Europe programme combines H2ME1 and H2ME2, and aims to deploy 47 HRS, over 1,400 hydrogen fuelled cars and vans, with a budget of €170mn. This is a pan-European effort – 20 stations will support 700 bar HRS in Germany; ten 700 bar HRS in Scandinavia, six 350 bar and 700 bar HTS in the UK; and one 700 bar HRS in the Netherlands. Madden estimates at least 130 HRS could be operating across Europe, including those stations that are already deployed by other actors.

Under the H2ME programme, there are plans to roll out 500 FCEVs in Europe and 900 fuel cell range-extended EV vans. Furthermore, the HyFive programme will deploy another 100 FCEVs to kickstart the commercialisation process. 'The ultimate aim is to put 1,100 FCEVs on the road at a more affordable price for customers by 2020,' says Madden.

Hydrogen fuel cell technology works and the first plausible hydrogen network is being set up across Europe, remarks Madden. 'We are starting to see attractive vehicle ownership models emerge for FCEV owners, as well as the first captive fleets with a zero emission commitment. There are early initiatives by the police and taxi operators, who both require long range and face problems recharging sufficient solely electric battery vehicles at speed.'

But there is still important work to do, in terms of building infrastructure due to lack of codes and regulatory standards, concerns about reliability in early refuelling stations and regulators who are risk averse.

Nevertheless, 'There is clear evidence we are going to see the end of the internal combustion engine due to air quality problems,' states Fabio Ferrari, CEO of Symbio. 'In future there will only be electro-powered mobility. From a technical viewpoint, everything is working. At the end of the road, we will earn money from the whole value chain from hydrogen production, fuel cell cars to refuelling stations. The only issue is how we reach this point.' ●