The hydrogen

Andy Pye was invited to attend an EU Brussels conference on hydrogen vehicles. Can hydrogen fuel cells hope to catch up with battery electric vehicles and become the dominant electric vehicle technology?

As more European countries move toward partial or complete bans on the sale of new petrol and diesel vehicles, hydrogen fuel-cell electric vehicles (FCEVs) are seen by some as a potential component of the future mix of vehicles on Europe's roads, alongside full battery electric vehicles (BEVs).

At the Hydrogen for Clean Transport Conference in Brussels last month, leaders of the automotive industry confirmed their commitment to expanding the deployment of FCEVs and a hydrogen refuelling infrastructure across Europe. FCEVs use the hydrogen and oxygen reaction to run electric motors.

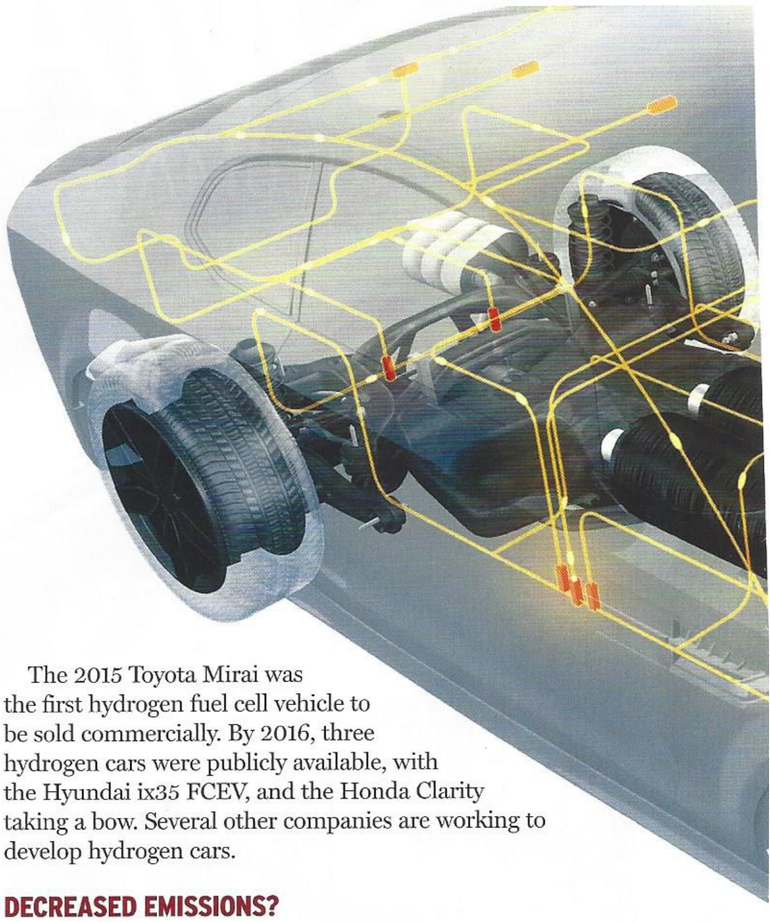
The Brussels conference, sponsored by the Fuel Cells & Hydrogen Joint Undertaking (FCH JU) and flagship hydrogen projects HyFIVE and H2ME, was a first for Europe's transport industry. Principal attendees were global vehicle manufacturers – including Audi, BMW, Daimler, Honda, Hyundai, Symbio and Toyota – as well as leading hydrogen refuelling infrastructure providers.

The idea is that hydrogen coupled with a fuel cell device will increasingly provide clean energy in the future. If pure hydrogen fuel is used, the only by-product of the process at the point of use is water. And excitingly, if the hydrogen itself is produced from a carbon-neutral source such as solar or wind power, there is the potential for carbon-neutral and emissions-free energy. The technology also addresses some of battery electric vehicles' main limitations – drain on the grid, limited range, long charging time and concerns over battery recycling.

FCEVs offer the same driving range as fossil-fuelled vehicles, typically between 385km and 700km (240 miles and 435 miles) to a tank, with a refuelling process similar to those of conventional petrol or diesel cars (around 3 to 5 minutes). FCEVs also offer the same quiet, smooth and refined performance as BEVs.

But is fuelling vehicles using hydrogen just a pipedream? Due to recent dramatic cost reductions and range increases of BEVs, hydrogen-powered cars seem to be losing the race in the low emissions transport market. Investment bank UBS forecasts that the lifetime cost of BEVs could be similar to internal combustion engines by 2018, while cost of vehicles, fuelling cost and lack of fuel-delivery infrastructure are causing FCEVs to lag behind.

Hydrogen fuel cells are relatively expensive to produce, as their designs require rare substances such as platinum as a catalyst. But even so, sales of fuel cell vehicles are expected to take off (in the 2020 timescale), when sales of tens of thousands of vehicles a year are expected at an affordable cost to buyers.



The 2015 Toyota Mirai was the first hydrogen fuel cell vehicle to be sold commercially. By 2016, three hydrogen cars were publicly available, with the Hyundai ix35 FCEV, and the Honda Clarity taking a bow. Several other companies are working to develop hydrogen cars.

DECREASED EMISSIONS?

Hydrogen does not come as a pre-existing source of energy, like fossil fuels, but is first produced and then stored as a carrier or vector.

But when fuel cell vehicles are run on hydrogen reformed from natural gas, they do not provide significant environmental benefits because of greenhouse gas (GHG) emissions from the natural gas reformation process.

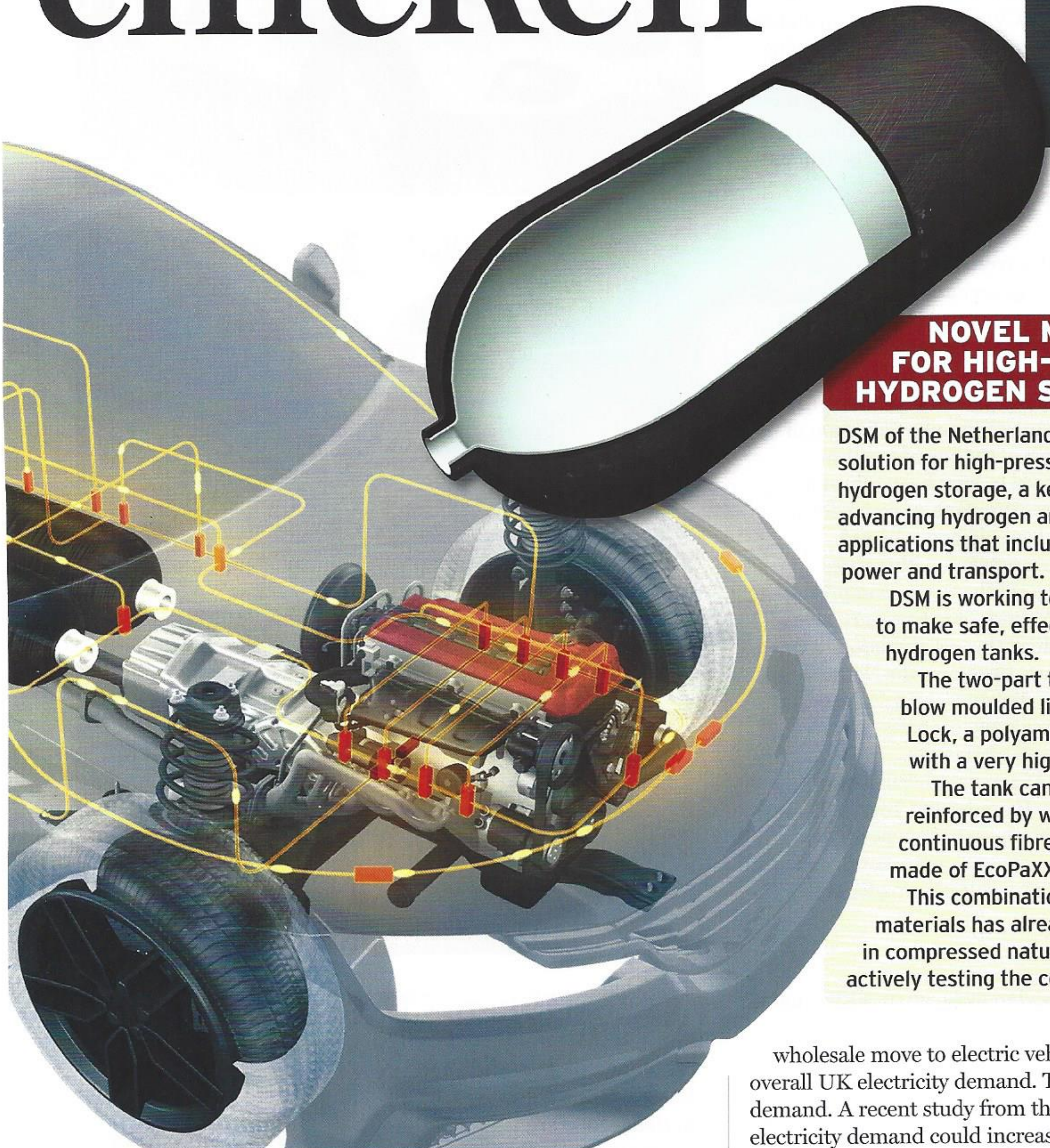
In 2014, 95 per cent of hydrogen was still made from natural gas, but once hydrogen is exclusively generated from renewable energy sources, then the balance of power swings in its favour. BEVs impose a direct demand on the grid which must be satisfied at times of peak loading, whereas hydrogen can be used to store surplus energy generated from renewable sources at times of high production (when the sun is shining or when the wind is blowing, for example).

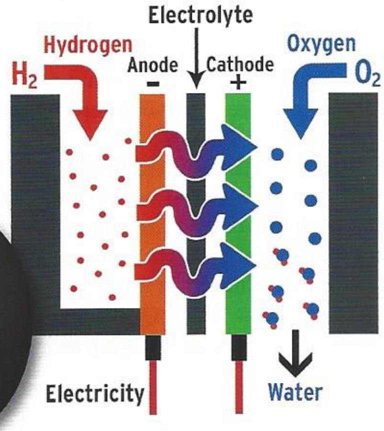
Hydrogen technology may be especially attractive in certain niche markets:

- So-called captive fleets, such as that of the police in London who cannot afford the time to plug a vehicle in for 30 minutes to recharge; taxis with a long daily range; and heavier vehicles, such as buses and delivery vehicles, especially those which travel within a limited geographical area where a single recharging station (such

›› Schematic showing the possible chassis positioning of high-pressure hydrogen storage tanks (below left) similar to those developed by DSM (below centre); and the chemical process that generates electricity using hydrogen and oxygen (below right)

chicken





NOVEL MATERIALS FOR HIGH-PRESSURE HYDROGEN STORAGE

DSM of the Netherlands has introduced a material solution for high-pressure composite tanks for hydrogen storage, a key enabling technology for advancing hydrogen and fuel cell technology in applications that include stationary power, portable power and transport.

DSM is working to apply its materials expertise to make safe, effective and very lightweight hydrogen tanks.

The two-part tank design features a proven, blow moulded liner made from Akulon Fuel Lock, a polyamide 6-based engineering plastic with a very high barrier to hydrocarbons.

The tank can then potentially be further reinforced by wrapping it in unidirectional continuous fibre-reinforced thermoplastic tapes made of EcoPaXX polyamide 410.

This combination of commercially available materials has already proven to be very effective in compressed natural gas tanks, and DSM is now actively testing the concept in hydrogen tanks.

as in a bus garage) could be accessed.

- Private sales in high tax countries, where the sales tax would be waived for hydrogen vehicles to give price parity.

HERE ALREADY

The UK National Grid estimates that there could be 9 million electric cars on the road by 2030, up from just over 100,000 in 2017. The limited driving range (120-460km) causes anxiety. And while most commutes are well within the range, such a car is poorly suited to longer distance use.

To use electricity instead of fossil fuels to power cars, we are going to need to generate more electricity, though less than at first sight: electric vehicles are much more efficient than conventional cars, so they don't need as much power of any kind to work.

Recent analysis from Cambridge Econometrics shows that a wholesale move to electric vehicles would add just 10 per cent to overall UK electricity demand. The real issue is the change in peak demand. A recent study from the National Grid showed peak electricity demand could increase by 6-18GW by 2050, depending on a range of factors. Peak demand today is about 60GW.

Further developments in batteries will solve much of this problem – higher range and different electrolytes, so that within a few years BEVs will have longer range than conventional vehicles. The result will soon be charging only at source for most people and only at source and destination for others. For those with off-street parking, many electric cars can also be charged at home overnight, meaning that we won't need quite the same coverage as we have with present day fossil fuel stations.

SMART CHARGING

The National Grid's Future Energy Scenarios (FES) included examples which estimated the additional system-wide peak electricity demand from electric vehicles (EVs) would range from 6-18GW in 2050.

Electric Nation is investigating the benefits which smart

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charging – tying vehicle recharging to off-peak times – could provide for local electricity networks, where additional demand from local clusters of EVs could require reinforcement of these networks. More than 40 different makes and models of EVs are taking part in the trial.

Electric Nation's initial findings, which were presented at the recent UK low carbon vehicle event LCV2017, are based on almost 70,000 hours of charging data, and show that 48 per cent of plug-in events begin between 5pm and midnight. On average, these vehicles are plugged in for 12 hours but are only charging for just over two hours. This suggests that there is likely to be sufficient flexibility to manage charging away from peak electricity demand periods.

CHICKEN-AND-EGG

For FCEVs to challenge BEVs a viable recharging network is required. Here lies the chicken-and-egg scenario: without enough vehicles on the road it is not economically justifiable to invest in the recharging network, while from the car manufacturers' point of view, without the recharging network it is hard to justify investing in vehicle production. This, of course, is where central funding plays a vital role. For widespread commercialisation of hydrogen FCEVs to be a realistic part of the electric vehicle picture, the remaining challenges need to have been solved by 2025 at the latest. And the cost of FCEVs needs to come down considerably, in the way that BEVs have already achieved.

HyFIVE has developed a hydrogen network within three clusters: London, Copenhagen and a southern area comprising the three German cities of Innsbruck, Munich, and Stuttgart, along with Bolzano in Italy. H2ME expanded this collaboration to 12 European countries – the UK, France, Germany, the Netherlands, Norway, Sweden, Denmark, Iceland, Belgium, Austria, Italy and Luxembourg – to give FCEV drivers access to a nascent pan-European network of hydrogen refuelling stations.

HyFIVE has deployed 185 FCEVs from five global automotive companies: BMW, Daimler, Honda, Hyundai and Toyota. These vehicles have different maturity levels, from prototype up to commercial production, with performance characteristics and cost reduction targets that have led to a plausible offering for early-adopting customers.

WHERE NOW?

Hydrogen FCEVs have a lot of ground to make up on BEVs, and it seems clear that hydrogen is inferior to battery technology as a storage of energy for vehicles. Perhaps by 2025 the last hold-outs should likely be retiring their fuel cell dreams. Or will they?

There are benefits to be gained in overall energy management if they can make up the ground. As we move to 100 per cent of electricity generated from renewable energy, there is a need for a storage mechanism for energy created during periods of low consumption. Having hydrogen plants located close to the energy generation facilities is an attractive way of storing the energy. An approach taking into account the entire energy cycle seems the most likely way that hydrogen vehicles can become a serious contender, which will require central support and significant research and development funding. It is perhaps more likely to succeed in mainland Europe. The UK is largely committing to BEVs, while the EU is adopting the more ambivalent approach of the technologies as being complementary in a mixed future. EE

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» The Toyota Mirai (below centre) in 2015 was the first commercially sold hydrogen fuel cell car. It was joined a year later by the Hyundai ix35 FCEV (below top) and Honda's Clarity (below bottom)

HYDROGEN-POWERED STREET SWEEPER

Roads in the northern Netherlands village of Hoogezand are being cleaned with half the noise and zero pollution since a new hydrogen-powered street sweeper entered service.

Formerly diesel-powered, the machine was converted to run on a hydrogen fuel cell by Netherlands firm Holthausen, in cooperation with the municipality of Groningen. Finnish manufacturer Visedo supplied its expertise to electrify the vehicle's drive system.

The end result is a street-cleaning vehicle that can run for 1.5 days on a single hydrogen charge and emits nothing except water.