HYDROGEN

Can hydrogen fuel cells decarbonise freight transport?

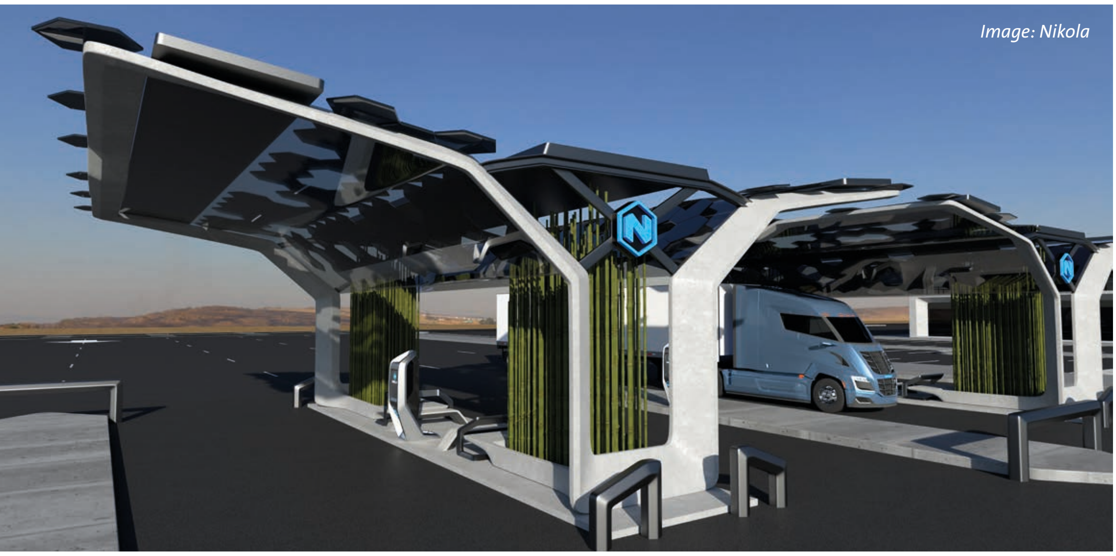

Image: Nikola

Hydrogen fuel cells show significant promise in sectors that might prove difficult to electrify with traditional batteries. *Jennifer Johnson* looks at whether technological ambition is matched by real progress in shipping and road freight.

Hydrogen has been dubbed the 'fuel of the future' for decades – and engineers have quietly recognised its merits for centuries. Some of the first internal combustion engine prototypes, including an 1807 design by Swiss inventor Francois Isaac de Rivaz, utilised hydrogen as a fuel. But ultimately, the engine designs that proved the most efficient and reliable would be powered by oil products.

Interest in hydrogen peaked briefly during the oil price hikes of the 1970s, though it faded once the crude market stabilised. An initial wave of environmental enthusiasm, combined with progress in fuel cell technologies, later led many major carmakers to show off hydrogen-powered vehicles at motor shows in the 1990s. However, low oil prices meant that commercial interest in these designs was limited. Now, with global calls to end fossil fuel use growing louder every day, hydrogen might finally have the chance to prove its mettle in global transport.

While it's both practical and easy to power a passenger car with lithium-ion batteries, the same cannot universally be said for larger vehicles. Batteries are ideal for driving short and predictable routes, though they're still plagued by lengthy recharging times. Given these factors, it's not surprising that long distance trucking firms are looking into using hydrogen fuel cells (HFCs) to decarbonise their operations.

Fuel cells are made up of individual cells, each containing an anode, a cathode and an electrolyte layer. When pressurised hydrogen enters the fuel cell 'stack', it reacts electrochemically with the oxygen already in the air to produce heat, water and an electrical current that drives a vehicle's motor. Unlike batteries, which have a fixed supply of energy to deploy after charging, HFCs can continue to generate electricity as long as they are supplied with hydrogen.

The hydrogen refuelling process itself takes a matter of minutes, which means that hydrogen-powered trucks would require shorter stop-offs than their plug-in counterparts. With so much of global trade relying on timely deliveries of goods, it's simply not practical for trucks to spend hours tethered to a charging station. HFCs also tend to boast longer driving ranges and lighter weights than lithium-ion batteries, making them theoretically suitable for oceangoing ships as well.

'Hydrogen can be stored as a gas in a tank and has similar storage properties to fossil fuels, although it is less energy dense, so it must be carried at very high pressures,' explains Jamie Speirs, a Research Fellow at the Sustainable Gas Institute at Imperial College. 'On the other hand, it's very hard to build small batteries that are light and energy dense. It's challenging to get ranges out of a battery system that is small enough not to reduce load carrying capabilities on a truck.'

Road freight

A growing number of companies are developing both battery and fuel cell trucks, among them EV giant Tesla and rival firm Nikola. The latter is hoping to revolutionise road freight by bringing hundreds of hydrogen-powered trucks to the roads of the US and Europe in the next few years. To date, Nikola has unveiled three HFC designs, with its flagship Nikola One expected to be available this year. The company has previously said it hopes to have 14,000 rigs on the road by 2028 and build a US-wide network of 700 hydrogen refuelling stations.

In May 2018, Anheuser-Busch, the maker of Budweiser beer, placed a significant bet on Nikola's HFC trucks – ordering 800 while offering to part finance 28 refuelling stations on routes connected to its breweries. While the order can be considered a vote of confidence for hydrogen trucks, Nikola still believes that there are also applications for batteries in the road freight sector. The firm announced earlier this year that it would introduce all-battery versions of its Nikola Two and Nikola Tre models for use on short haul, inner city routes where space and weight are not such a concern.

However, Nikola also emphasised that its hydrogen trucks are a full 2,270 kg lighter than the battery powered models. The company's CEO, Trevor Milton, has also been quoted as saying that his HFC trucks weigh some 2,270 kg less than Tesla's fully battery-powered trucks.

Meanwhile, automaker Hyundai has announced its own expansive hydrogen ambitions in Europe. This September, the company vowed to put 1,600 HFC trucks on the road in Switzerland over the course of the next five years, as well as selling them in other countries across the EU.

It's tempting when looking at the decarbonisation of shipping and freight to think of batteries and fuel cells as competing technologies. But in reality, some combination of the technologies could be used to optimally power zero emission vessels and vehicles. Even the Nikola One's fuel cell feeds a set of high density, 320 kWh batteries that power its fully electric drivetrain. According to Speirs, hybrid features will be essential to the commercialisation of hydrogen technologies.

'A hydrogen truck requires batteries anyway because you need somewhere to act as a buffer between energy production and energy demand,' he says. 'You don't want to run your fuel cell in transient mode, which means increasing and decreasing the load on that fuel stack dramatically. So you would have some level of battery storage on the vehicle and you would play with the balance between the batteries, the fuel and the fuel cell stack in order to get a hybrid system that could also be plugged into a wall.'

Hydrogen ships

Environmental imperatives are also pushing the shipping industry to take a closer look at hydrogen propulsion technologies. Last year, the International Maritime Organization adopted an initial strategy on reducing greenhouse gas use in the shipping industry, with member states agreeing to cut maritime emissions by at least 50% by 2050.

Though three decades might seem like ample time to figure out how to reach this goal, the average lifetime of a commercial vessel is 25 to 30 years. This means that investment decisions for low emission ships must be made soon – and hydrogen still remains relatively untested. The world's first hydrogen-powered ferry is expected to begin sailing in Norway from 2021, while an experimental hydrogen-fuelled catamaran called *Energy Observer* is currently on a six-year voyage around the world. The vessel utilises an onboard electrolyser to produce the hydrogen that it uses in its fuel cell.

The *Energy Observer* also features onboard solar panels to charge 126 kWh of batteries – with 100 kWh of this energy subsequently used to power the motors and the remainder diverted to crew comfort measures. As is the case with trucking, HFCs are likely to play a part in the decarbonisation of shipping without being the sole solution. Energy efficiency measures and auxiliary propulsion systems, such as kites and rotor sails, are also gaining popularity among shipping firms.

'Any option is going to require a combination of new fuels and new design across all of the elements of a ship,' Speirs predicts. 'This means improving the dynamics of ship hulls, adding low-resistance coatings below the surface, or installing wind and solar assistance measures.'

'Dirty' hydrogen

The availability of hydrogen distribution and refuelling infrastructure is one of the major hurdles that must be overcome to encourage widespread adoption in transport. Fortunately, the International Energy Agency (IEA) thinks it has found a way forward: turn busy ports into hubs where trucks and ships can stock up on the gas. In a report titled *The Future of Hydrogen*, published earlier this year, the IEA recommended that industrial ports are transformed into 'nerve centres' for the scaling-up of clean hydrogen production.

Today, much of the refining and chemicals production that uses hydrogen made from fossil fuels is concentrated in coastal industrial zones. 'These large sources of hydrogen supply can also fuel ships and trucks serving the ports and power other nearby industrial facilities like steel plants,' the report suggests. The majority of the hydrogen in use across the world today is produced via steam methane reforming. This process reacts the methane in natural gas with high-temperature steam in the presence of a catalyst to produce hydrogen and, more problematically, carbon dioxide.

'Hydrogen doesn't naturally exist, unlike natural gas which is found in pockets and can be extracted from a gas platform,' explains Professor Nigel Brandon, Director of Imperial's Sustainable Gas Institute. 'Because it's so reactive, hydrogen is found bonded to other things in molecules – tied to oxygen in water or carbon in methane – therefore you have to put in energy to make the hydrogen split off. These processes require energy, so the carbon footprint of hydrogen depends on where we get that energy from.'

Steam methane reforming powered by energy from the grid will ultimately produce hydrogen with poor environmental credentials, though it will still be zero emission at the point of use in a fuel cell. Hydrogen can also be produced from water using an electrolyser, which improves its emissions profile. It's better still if that electrolyser is powered using 100% renewable electricity. However, Brandon warns, it's still more expensive to make hydrogen through electrolysis than it is to make it from natural gas – and this is where policy interventions are needed.

'Instead of burning natural gas, we're going to use hydrogen, but that hydrogen is going to cost more because we've made it from natural gas in the first place,' he explains. 'It cannot cost less, so there has to be a market incentive to do this.'

The 'holy grail' of zero carbon hydrogen production may be approaching, though, as companies begin to trial projects that make use of wind-generated electricity that cannot find its way onto electricity grids for whatever reason, to make hydrogen. One example – covered in last month's issue of *Energy World* – is the Gigastack feasibility study by wind developer Ørsted, together with hydrogen company ITM Power and Element energy, to investigate zero carbon hydrogen production at offshore wind farms.

When it comes down to it, the story of hydrogen is the same as other promising low carbon solutions: scientists realise its potential and know how it can best be utilised, but policy incentives and physical infrastructure still lag behind. After more than 200 years on engineers' radars, there's still much work to be done before hydrogen reaches its full potential in transport. But the threat of climate change means there's no time like the present to get started. ●

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