Hydrogen and its ever inventive technologies

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04/01/2021

Hydrogen is to the energy and infra world what a black turtleneck is to struggling artists, or truffle oil to a moderately-regarded London restaurant. It provides an answer to everything, we just don't really understand how yet.

Hydrogen is heralded these days as the panacea for many energy woes… and it's clean.

It lends hope to many energy importing countries that one day they can make the switch to exporting, while also being touted as a solution to grid intermittency issues caused by renewable energy, and even re-purposes oil and gas majors.

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Hydrogen has been given as a one-word answer to many of the questions posed about what the energy make-up will look in 2050.

Yet despite the blind trust the industry seems now to have in the most abundant element in the universe, what technologies exist this time around to make the hydrogen revolution any different to what it was expected to be two decades ago?

While the motivation to lower emissions and curb global warming has increased in urgency, has the efficiency of technology advanced with it?

This question is all the more pressing given that hydrogen is now considered along every step of energy usage. From its production to its use in households, new hydrogen technologies are emerging to fill gaps left by CO2 emitting combustion technologies.

Bridging the storage gap

With many developers planning to attach an electrolyser onto large renewable projects, on paper the hydrogen produced can have numerous applications.

Countries have begun injecting hydrogen directly into the grid and combining it with carbon dioxide to create other liquid fuels. The most commonly discussed technology is storing the hydrogen to use in place of a battery solution and converting it back to energy, without combustion, through an electrochemical process. This is storing energy in fuel cells.

However, in these cases end-to-end efficiency of electrolysis-based hydrogen energy storage is typically half that achieved by a lithium ion battery.

Technology being developed by HyTech in Redmond, Washington, is attempting to close the gap. It has built its Scaleable Energy Storage product to compete with big batteries and fuel resources. The technology is being retrofitted to different modes of transport but can also be used in homes and businesses and even grid-scale storage systems.

The Scaleable Energy Storage (SES) system stores hydrogen weakly bonded to metals as hydrides in an inert, non-pressurized liquid solution. In order to store this solution the bond must be weak enough to be broken without extra energy when energy is needed and the energy density of the resulting fluid must be increased.

The solution HyTech has identified is increasing the power-to-weight ratio high enough to beat lithium-ion batteries and make the hydride bond weak enough so that it can be broken using only the redirected waste heat from the engine with no added heat or pressure required.

SES lasts longer than a battery through more than 10,000 charge-and-discharge cycles – compared with around 1,000 for a lithium-ion battery – making its lifespan closer to that of a typical solar panel. It can be fully charged or discharged unlike a battery for fear of degradation and once it is worn out, SES is entirely recyclable. The metals are melted down, reground, and reused; the water is redistilled.

Lastly, the hydride solution can be stored indefinitely without maintenance or loss of potential, making it a great candidate for long-term energy storage.

While some are calling for complete electrification and others are hellbent on turning everything into hydrogen fuel cells, there is a number of lobby groups calling for hydrogen and batteries to work in tandem.

A New Zealand energy advisory firms believes that electric vehicles should be used in towns and city centers for short distance transport applications, while hydrogen fuel cells have an important role in long distance transport, like freight trains, lorry driving and airplanes.

Hydrogen fuel cells could also be brought in to extend the life of carbon emitting industrial regions, allowing them to stay open with little to no emissions or waste.

Decarbonising industrial clusters

In many OECD countries, energy utilities and other industrial groups are deploying capital to decarbonise industrial clusters by building offshore CO2 transport and storage infrastructure.

The Northern Endurance Partnership in the UK is hoping to secure funding to build the infrastructure around the Net Zero Teesside and Zero Carbon Humber projects, while the Netherlands is looking to decarbonise Groningen.

Meanwhile, the Tomokomai test site in Japan has shown unusual promise in CCS by burying CO2 emissions below the seabed off Hokkaido Island. The project is owned by Japan CCS – a consortium of Japan Petroleum Exploration, Mitsubishi Corp, JXTG Holdings and 30 other companies – which claims to have cut energy costs by two thirds at the plant.

At Tomokomai, the captured by-product gas is piped from the Idemitsu Kosan refinery and CO2 is pulled out as it passes through an amine solution. By using the remaining gas to generate power and recycling heat, energy costs are cut by one third to one half of a typical extraction plant.

Many developers are trying increase the technical and financial efficiency of producing green or blue hydrogen by using excess heat and power in the electrolysis or capturing process.

Converting the grid

On the end user side, technology keeps advancing to be integrated into daily lives. High-volume hydrogen gas turbines are being developed, looking to replace the ubiquitous natural gas fueled units.

Upgrades are essential as hydrogen blends lead to combustion temperatures that are too high for conventional gas turbines. It is also highly reactive and has a high laminar burning velocity.

The volumetric energy density of hydrogen is a third less than methane or natural gas. Therefore, it takes 3x more volume flow of hydrogen to provide the same energy input as the alternative.

This is why hydrogen is currently blended with slower burning fuels to allow it to extend flammability limits and enhance flame propagation.

As a result, operating a gas turbine requires a fuel accessory system configured to adjust the fuel system accommodating the increased flow. Many companies are committing R&D efforts to use blends of hydrogen without further capital investment as retrofitting hydrogen-friendly turbines is not cost effective.

GE, using a number of new technologies, is promoting its ability to handle 90% hydrogen by volume in its operating pipelines. Its DLN2.6e combustion system, which was developed as part of a US Department of Energy programme to make gas turbines capable of burning high concentrations of hydrogen, will be able to sustain a larger hydrogen percentage for when tides shift towards different fuels.

GE's new combustion system uses small scale jet-in-crossflow mixing of the fuel and air streams. The miniaturized tubes function as fast mixers, enabling premixed combustion for gaseous fuels with higher reactivity.

As we increase the share of hydrogen in the gas pipelines, industry professionals may have more ease of mind when investing in large- or small-scale, gas-fired plants if they can take the increased percentage of hydrogen.

Transport Solution

On the road, new technologies are being accelerated in the automotive industry. Advancements in fuel cell technology are progressing at a pace as years of R&D pay off. However, even if hydrogen vehicles were to be deployed at scale, a hydrogen fuel network must be developed first… a similar issue faced by EV charging.

New technology developed by the EPFL Swiss Federal Institute of Technology is planning to establish small hydrogen fueling stations in private households to facilitate the establishment of a comprehensive hydrogen fuel network.

EPFL has developed a hydrogen compressor with a metal hydride ZrMn1.5. The material can store hydrogen without requiring energy and can release the gas when heated in a liquid state to be used for fuel.

Being able to compress hydrogen in households would allow for private hydrogen fueling stations, which could then be shared with others, creating a hydrogen fueling network.

Meanwhile, a strong push from China's Sinopec – the world's largest oil refiner which emits more than a quarter of the world's carbon dioxide – saw it announce a reallocation of resources along the hydrogen chain, from its production through to refueling stations.

Sinopec last year teamed up with France's Air Liquide to open two hydrogen stations in Shanghai, which combined commercial gas and hydrogen fuel services. The gas stations have two gasoline tanks, two diesel tanks and four hydrogen tanks combining the two fuels and recycling the former gas station to create a secondary energy complex.

The current plan in Shanghai is to have 1,000 hydrogen filling stations and one million hydrogen-powered vehicles by 2030.

China is looking to convert to grow out its fuel cell technology for the benefits it has over other technologies. It is also better for the environment compared with its electric battery counterpart, as hydrogen fuel cells require less charging and do not contain heavy metals which can cause environmental contamination if not managed properly.

The use of hydrogen fuel cells in longer and heavier modes of transport are abundant. There are limitations to the capacity to electrify trucks, trains and aircrafts, leaving hydrogen fuel cells as one of the key means for decarbonization.

The deployment of hydrogen is seemingly endless and answers many questions of what our world may look like without burning fuel. For now hopes centre on the hype lasting long enough to effect change.