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Hydrogen's role in the energy transition

The Paris Agreement is a legally binding international treaty on climate change, signed by 197 countries, with the goal of limiting global warming to well below 2, preferably to 1.5 degrees Celsius, relative to pre-industrial levels. To achieve this, countries aim to hit peak greenhouse gas emissions as soon as possible and as such, the energy transition, away from fossil fuels to renewable types of energy is rising to the top of government agendas. In keeping with this, green energy has also been a key feature of post-Covid, multi-billion-dollar government spending plans including the European Green Deal and Joe Biden's infrastructure package. With capital and resources being channelled towards this pressing issue, a number of alternative energy sources have emerged. In this piece we will focus on hydrogen.

THE CHEMISTRY OF HYDROGEN

Hydrogen is the first and the lightest element in the periodic table and most abundant chemical substance in the universe. At standard temperature and pressure, hydrogen is a colourless, odourless, tasteless, non-toxic, non-metallic, and a highly combustible diatomic (composed of only 2 atoms) gas with the molecular formula H_2.

Most hydrogen on the Earth's surface is bound together with other types of atoms as molecules that form various substances such as water (H_2O) and methane (CH4) or organic compounds. Before it can be used as a fuel, hydrogen must first be extracted from these substances and then contained, usually in highly compressed liquid form.

In relation to mass, hydrogen has the highest energy density of all fuels. By way of comparison, one litre of hydrogen contains almost as much energy as three litres of petrol. [1] However, there are some risks: When liquid hydrogen is stored in tanks, it is relatively safe, but if it escapes, it is highly flammable in the presence of an oxidizer (oxygen is a good one) and burns more easily than gasoline.

As a fuel, hydrogen can be combusted directly (it only emits water when burned and can be made without releasing CO_2), or it can be used in a fuel cell to produce electricity.

HYDROGEN PRODUCTION

In contrast to natural gas, crude oil, and coal, which are primary energy sources, hydrogen is considered as a secondary energy source as it doesn't occur naturally in its pure form; only once it is isolated, can hydrogen serve as a form of fuel. Essentially, it needs to be produced before being consumed.

Hydrogen can be separated from water via several means, including steam reforming (normally involving the use of fossil fuels) and electrolysis (requiring electricity).

As of today, over 90% of the world's hydrogen is produced using the steam methane reforming process (SMR). In this reaction, natural gas is (CH4) reacted with steam (H_2O) at an elevated temperature to produce carbon monoxide (CO) and hydrogen (3H2). As such, whether hydrogen is “clean” depends on how that natural gas is sourced — and subsequently processed.

Hydrogen can also be produced by the electrolysis of water, but this is generally a costlier approach. When electricity is used to produce hydrogen, thermodynamics dictate that you will always produce less energy than you consume. In other words, the energy input in electricity will be greater than the energy output of hydrogen. Nevertheless, if a cheap source of electricity is available — such as excess grid electricity at certain times of the day — it may be economical to produce hydrogen in this way.

Industry players use colour codes to distinguish between the different types of technology used to produce hydrogen.

- **Green hydrogen**, is hydrogen made by using clean electricity from renewable energy to electrolyse water (H_2O), separating the hydrogen atom from its molecular twin oxygen. This is a costlier, infrastructure-intensive process and while green hydrogen is the ultimate aim, it currently accounts for only 1% of the global hydrogen supply.
- **Blue hydrogen** is produced mainly from natural gas via steam reforming, which brings together natural gas and heated water in the form of steam. The output is hydrogen and carbon dioxide, with the latter then caught through industrial Carbon Capture, Utilisation and Storage projects.
- **Grey or black hydrogen** is essentially any hydrogen created from fossil fuels without capturing the greenhouse gases made in the process.

Green hydrogen is the ultimate goal, however, there are still challenges to its use: there are practical issues relating to storage and transportation, the production process requires a lot of electricity and expensive infrastructure, and its production cost is significantly greater than grey alternatives (currently 2.5 to 5 times costlier). Closing this price gap will require financial support on both the production side and on the demand side in order for economies-of-scale benefits to kick-in, making green hydrogen competitive.

As of today, public aid and mechanisms are seeking to improve the competitiveness of hydrogen but more needs to be done. For example, under the EU's carbon credits scheme (European Emission Allowances (EUAs)) whereby companies need to pay for permits to emit CO2 over a certain threshold, the price is currently around €50/ton. EUA pricing will need to rise to a level that encourages fuel switching – to green hydrogen and away from fossil-fuel energy sources such as natural gas and petroleum products and grey hydrogen. According to BNP Paribas research estimates, [2] EU carbon prices will need to reach at least €79/ton by 2030 in order for green hydrogen to become competitive enough for big industrial users to ditch the version made from fossil fuels

Mass production will inevitably lower production costs in the future, but producing, compressing, and transporting low-carbon hydrogen can induce energy losses. Even if there is public aid and mechanisms to improve its competitiveness (CO_2 pricing), shifting towards hydrogen will come at a higher collective cost than today's fossil-based energy mix.

HYDROGEN-POWERED CARS?

A key technology associated with hydrogen is a fuel cell. This device converts the chemical energy contained within the hydrogen to generate electricity, as well as water and heat. It must be noted that the double conversion mechanism (production of hydrogen + transformation of hydrogen to generate electricity) embedded in the fuel cell technology means larger energy depletion. [3]

Fuel cells are being explored for use in passenger cars as propulsion systems, however, interest from private car markers has been limited. Hydrogen-powered cars face competition from electric cars which, as of now, more efficient. Only Toyota, Hyundai and Honda still investing in and fuel cell electric vehicles with most automakers betting on battery electric vehicles for the passenger market.

Fuel cell electric vehicles are victim to the chicken-and-egg problem. As you cannot refuel at home, a massive infrastructure transformation would be required. But this doesn't mean that we should throwing out the baby with the bathwater.

WHERE HYDROGEN HAS A ROLE TO PLAY

A quietening down around hydrogen passenger cars says nothing about the prospects for trucks, buses, trains, ships, and airplanes. For these forms of transport, the expectations for hydrogen as a sustainable alternative fuel are still high. For longer-distance travel, hydrogen's greater energy density becomes more attractive. Hydrogen compressed to 700 atmospheres contains between two and five times more usable energy per litre than a lithium-ion battery. If it is liquefied (which requires more complex technology) that increases further. Worth to mention is the recent announcement of Daimler Truck AG and Volvo Group that they plan to jointly manufacture hydrogen fuel cells for trucks in Europe starting in 2025 (while calling on EU policymakers to boost incentives). According to Daimler and Volvo, electrical batteries will work for short haul trucks but they see hydrogen fuel cells playing a major role for heavier loads and longer distances. [4]

The double constraint of being economically competitive and environmentally friendly means that hydrogen will probably remain a luxury energy vector for some type of mobility issues due to its structural limits. Low-carbon hydrogen should be dedicated to high emitting and hard to abate industrial sectors that cannot be electrified, like steel and ammonia production.

The scaling up of clean hydrogen for heavy transportation, freight and industry is a major pillar of the EU's commitment to become carbon neutral by 2050. The strategy contains an ambitious target of 40 Gigawatts of European electrolyser capacity to produce up to 10 million tonnes of green hydrogen by 2030 in the EU.

At the same time, there is huge potential for innovation in the space of hydrogen electrolysers and fuel cell technologies. Economies of scale and expanded production will be crucial in bringing down prices for low-carbon hydrogen, as will continued low prices for electricity from renewable energy.

A key advantage of hydrogen is that it could help balance the use of variable renewables to generate electricity. Solar panels, wind turbines and hydropower are all highly dependent on the weather, making them inconsistent. With renewable energy sources being unstable, hydrogen electrolysis could deliver backup power for when there is little wind or sun. Moreover, facing a surplus of green electricity, hydrogen could be conveniently produced via electrolysis.

HEAVEN ON EARTH

Scotland's Orkney Islands have an over-abundance of renewable electricity. The windy islands at the Northeast corner of Scotland had been generating wind energy with large wind turbines for several years, but since 2013 they have been producing more energy than needed and the power grid connection to the mainland was too weak to send it elsewhere. As such, they were forced to shut off large turbines on occasions to avoid damaging the power lines. Thanks to this reliable source of clean electricity, the Orkney Islands were an ideal place to start producing hydrogen via electrolysis. The hydrogen produced acts as an energy storage medium which can be used at a later date to produce heat, power, fuel for use as low carbon transport or for any other purpose. The hydrogen produced can be used for heating buildings and vessels in Kirkwall harbour, as well as for fuelling several hydrogen vehicles on the Orkney Islands. Work is underway on a zero-emission hydrogen-powered flight from an Orkney airfield, as well as investigation on the feasibility of producing local gin using hydrogen as a fuel.

The Orkney Islands' learning experiences in the sphere of hydrogen inspired hydrogen valley projects, like for instance, the HEAVENN (H_2 Energy Applications in Valley Environments for Northern Netherlands) project in the Dutch city of Groningen. A hydrogen valley is a geographical area where several hydrogen applications are combined into an integrated ecosystem that covers the entire value chain: production, storage, distribution and final use. They make particular sense, both commercially and environmentally, in industrial areas which both produce and consume large amounts of energy in a small amount of space. As of now, the goal is to make green hydrogen the go-to type of hydrogen when it comes to production and consumption.

HYDROGEN'S ROLE IN THE ENERGY TRANSITION

"After many false starts, hydrogen power might now bear fruit, but it will fill in the gaps, rather than dominating the economy". – The Economist

Hydrogen has certain advantages: it is abundant, it can replace certain uses of fossil fuels and it can be complementary to the energy transition by helping to balance the use of variable renewables to generate electricity. Certain characteristics of hydrogen production make it a solution that is probably more suited to certain uses than others from an industrial, financial and ecological point of view, for example in energy-intensive industries or for longer-distance travel.

On the other hand, to deploy green hydrogen on a large scale, massive amounts of renewable energy would be required which in turn would require substantial investment in infrastructure. As such, the case around zero-carbon hydrogen mobility on a grand scale is far from a done deal, even if it's currently attracting significant R&D investment from some major companies. Scaling-up is, as usual, the main trigger to make it economically viable, but demand from end-users will also be key..

INVESTMENT CONSIDERATIONS

Ultimately, we believe that ambitions to reach carbon neutrality will reduce the costs of hydrogen and that demand will rise. Concrete commitments and investments from significant players (EU, the US and Chinese authorities, industrial leaders such as Air Liquide, Daimler, Siemens, Linde, etc.) are also at play to make hydrogen a credible solution in the long term.

However, we advocate that investors consider hydrogen among a broader mix of solutions that seek exposure to the energy transition. Indeed, proponents of the hydrogen economy inside the investment community must be careful not to succumb to the marketing myopia. Decarbonizing our economy is the objective: Hydrogen is part of the means to an end, but it is not the end it itself and while governments have started to support the growth of low carbon hydrogen market, just as they did for renewables, just as a successful decarbonization path cannot solely rely on renewable electricity, the same is true for hydrogen.

The growth of hydrogen as an alternative source of energy offers opportunities for those investors that are able to deduce where the financial rewards will be greatest. Tracking down tomorrow 's winners is not always easy feat in this space where there is a limited number of pure players and a handful of early-stage small companies. As such, diversification is recommended while the nascent nature of the hydrogen industry could mean that existing investment vehicles exhibit volatility levels that will not suit all investors.

To conclude on a positive perspective, if resilience to preserve common good is our priority, we need pioneers and people that are willing to take risks. When it comes to the energy transition, we have no guarantee that it's going to work perfectly, but in order to progress we need to get out of our comfort zones and search for alternatives and complementary solutions with enthusiasm. While it is not a silver bullet, hydrogen does have promising advantages: it is abundant, it makes it possible to advantageously replace certain uses of fossil fuels, it can be complementary to the transition to sources of renewable electricity production.

References:

[1] Hydrogen energy density (in electrical terms) is equal to 33.33 kWh/kg, while methane is 13.9 kWh/kg and petrol is 12 kWh/kg.

[2] https://mediaroom-en.bnpparibas-am.com/news/new-bnp-paribas-asset-management-research-shows-potential-impact-of-green-hydrogen-on-carbon-pricing-357b-0fb7a.html

[3] From the International Energy Agency: The Future of Hydrogen Report prepared by the IEA for the G20, Japan Seizing today's opportunities (June 2019)

"All energy carriers, including fossil fuels, encounter efficiency losses each time they are produced, converted or used. In the case of hydrogen, these losses can accumulate across different steps in the value chain. After converting electricity to hydrogen, shipping it and storing it, then converting it back to electricity in a fuel cell, the delivered energy can be below 30% of what was in the initial electricity input. This makes hydrogen more 'expensive' than electricity or the natural gas used to produce it. It also makes a case for minimizing the number of conversions between energy carriers in any value chain. That said, in the absence of constraints to energy supply, and as long as CO2 emissions are valued, efficiency can be largely a matter of economics, to be considered at the level of the whole value chain."

[4] Metal hybrids are also in development with the idea to store hydrogen at lower pressures in small spaces, allowing the use of smaller tanks operating at lower pressure and temperature (via GKN Powder Metallurgy, acquired by Melrose industries in 2018). Furthermore, energy storage density techniques are under development via a joint agreement of Daimler Truck and Linde.

Sources:

https://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/hydrogen-vehicle-danger2.htm

https://www.carbonbrief.org/in-depth-qa-does-the-world-need-hydrogen-to-solve-climate-change

https://simpleflying.com/airbus-zero-emissions-plane/

https://www.economist.com/science-and-technology/2020/07/04/after-many-false-starts-hydrogen-power-might-now-bear-fruit

https://studylib.net/doc/25364527/iea-the-future-of-hydrogen

https://www.orkney.com/life/energy/hydrogen

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