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Is the International Hype of Hydrogen Justified? | *Frank Umbach*

Clean hydrogen is currently the only real technology option for decarbonising the world's hard-to-abate-sectors such as heavy manufacturing and energy-intensive industries such as steel or the chemical sector. But a projected production of 38 mt of clean hydrogen, up from less than 1 mt today, demands a cumulative investment of US$170bn in projects involving electrolysers and carbon, capture, utilisation, and storage (CCUS). But whether or to what extent the use of hydrogen can be adopted by other sectors such as transport, aviation or buildings remains to be seen owing to the uncertainty of future costs, commerciality, and further technological innovation. Given the technological uncertainties, recent cost increases, the need for technology innovation and criticism that the potential of hydrogen has been exaggerated, private investors and banks have become more cautious about investing in hydrogen projects as they are considered a risky investment. Although the international hype has not died down, governments, industries and independent experts have begun to realise that they need a more sober and realistic perspective.

As far as global energy megatrends go, clean hydrogen (H2) is currently the only real technology option for decarbonising the world's hard-to-abate-sectors such as heavy manufacturing and energy-intensive industries such as steel or the chemical sector. It is also a storing option for electricity through intermittent energy sources such as wind and solar. However, hydrogen is currently used in few industry sectors, (notably the refining industry), and in limited volumes. More pertinently, it is currently produced mostly from fossil fuels, with no benefit for mitigating climate warming.

In 2022, global hydrogen use accounted for 95 million tonnes (mt), with strong growth in all major consuming regions (except Europe, where skyrocketing gas prices have made it uneconomical for countries to use gas to produce hydrogen).

The energy generated through hydrogen made up about 2.5% of total global energy consumption. But demand remained concentrated in industry, notably refining. Only 0.1% of demand came from new applications in heavy industry, transport or power generation. Low-emission hydrogen still accounted for just 0.7% of the worldwide total hydrogen demand in 2022.

The International Energy Agency (IEA) estimated in 2023 that worldwide hydrogen demand by 2030 will only grow modestly up to 115 mt, of which low-emission hydrogen could comprise up to 38 mt. Less than 2 mt of demand would come from new uses. Hydrogen use could replace 14 billion cubic metres per year of natural gas use, 20 mt of coal use per year and 360,000 barrels per day (bpd) of oil use. And an estimated 12 mt of hydrogen could be exported annually. But a projected production of 38 mt of clean hydrogen, up from less than 1 mt today, demands a cumulative investment of US$170bn in projects involving electrolysers and carbon, capture, utilisation, and storage (CCUS).

However, by 2050, the world's hydrogen market is expected to grow almost sevenfold to 600–650 mt, with green hydrogen replacing hydrogen produced from fossil fuels. That could abate more than 20% of the global energy demand.

Both Germany and the European Union had already acknowledged in their hydrogen strategies of 2020 that they would become heavily import dependent owing to the need for huge additional capacities of renewable energy sources to generate the needed electricity for hydrogen production through electrolysis. (Electrolysis is a process that involves using electricity to derive hydrogen from water.) These are on top of the imports of renewable energy sources needed to replace fossil fuels in the traditional energy mix. To counterbalance its future import demands for green hydrogen production, the European Union has doubled the production target for 2030 from 5 mt to 10 mt to achieve economies of scale. This change is an important pillar of its REPowerEU plan of 2022. To meet the 2030 target of producing 10 mt of green hydrogen, almost 500 terawatt-hour (TWh) of renewable electricity is needed, alongside the mass rollout of large-scale electrolysers. That would correspond to 14% of the European Union's total electricity consumption.

But whether or to what extent the use of hydrogen can be adopted by other sectors such as transport, aviation or buildings remains to be seen owing to the uncertainty of future costs, commerciality, and further technological innovation.

Outside of Europe, many countries (such as Japan and Australia) still favour not just green hydrogen, based on renewables and electrolysis, but also "clean" blue hydrogen, which includes the carbon capture and storage (CCS) process. But whether those projects will really meet the requirements defined by buyers and offer commercial viability (owing to the even higher energy demand and lower energy efficiency arising from using the CCS process, as well as higher shipping costs) is equally uncertain at the present stage of development. Despite some progress with CCS processes, offshore geological storage sites are still limited in numbers and capacity. Green hydrogen projects, compared to brown and blue hydrogen options, have been projected to become cost-competitive by 2030.

Options other than green hydrogen, such as brown hydrogen and nuclear hydrogen production, are even more uncertain. By using coal to produce hydrogen, the brown hydrogen option is the most emissions-intensive one, creating 18–20 times more carbon than the amount of hydrogen produced.

On the positive side, 41 governments now have announced their hydrogen strategies. Some of the early movers such as the European Union, United States and China have already revised their original strategies by enhancing their hydrogen ambitions. Meanwhile, China, after a rather slow start, has become the world's largest deployer of electrolysers, with 30% of global capacity. It will cement its position in the forthcoming decade as it accounts for more than 40% of the world's electrolysis projects that have already reached a final investment decision (FID).

Pipeline Networks to the Rescue?

The European gas industry has analysed and demonstrated that it can largely use its existing gas pipeline networks also for transporting hydrogen. (This network facility is known as the "European hydrogen backbone".) Germany, for instance, has a long-distance natural gas network of around 40,000 km as well as a local and regional distribution network of 470,000 km. But the network needs to be expanded for hydrogen use in the coming decades. Nevertheless, the repurposing of the existing pipeline network can decrease investment costs 50–80% relative to building new pipelines for hydrogen transmission. While Germany can use its existing gas pipeline network for blending hydrogen with natural gas as an interim solution or hydrogen exclusively, that may not be the case elsewhere in Europe and globally: much would depend on whether the quality of the steel used in the pipelines allows hydrogen to be piped exclusively or blended, and whether sufficient quantities of hydrogen can be produced for domestic consumption and imports. In Europe, an estimated 39,700 km of long-distance hydrogen pipeline infrastructure may be needed by 2040 to connect low-cost hydrogen production centres to hydrogen demand hubs.

Challenges in Shipping Hydrogen

Hydrogen as a low-carbon fuel can be transported in the form of liquid hydrogen (LH2), or through carriers like ammonia or various liquid organic hydrogen carriers (LOHCs) over varying distances. McKinsey has projected that 400 mt of the forecasted 660 mt needed by 2050 to meet the EU's climate goals will be transported long distance. Seaborne transportation is the most cost-competitive option for distances more than 2,000–2,500 km.

Similar to the difference between liquefied natural gas (LNG) and natural gas, liquid hydrogen is easier to store than hydrogen itself. But it is also more technologically challenging than LNG as it has to be cooled and kept at -253°C (versus -162°C for LNG) or it boils off. The liquefaction of hydrogen transported long distances could lose another 30% or more of the energy content of hydrogen. Other projections have suggested that hydrogen lost in boil-off and fuel use for propulsion via a 9,000 km shipping tour could be up to 40%. The boil-off could be as high as 9 times, compared with the loss in LNG shipping. A fully loaded LNG carrier transports about 72,000 tonnes of LNG, which is equivalent to 1 TWh of energy. In comparison, to produce the same 1 TWh of energy from hydrogen, one needs to transport 2.5 liquid hydrogen carriers. The delivery and regasification at the receiving hydrogen import terminal could consume another 5% of the energy content of the cargo.

Japan, Australia, Saudi Arabia and other potential hydrogen importers and exporters pin great hopes particularly on ammonia as a low-carbon fuel. In June 2023, Japan – which imports 90% of its energy needs – unveiled a public–private investment of US$104bn to build hydrogen and ammonia supply chains. The advantage of using ammonia as a carrier is that it needs to be cooled at just -33°C (and not -253°C, as required by liquid hydrogen) and users can utilise existing ammonia shipping options.

Cost and Technological Challenges

Although costs of solar and wind power projects have constantly decreased over the last decade, green hydrogen projects demand additional solar and wind power capacities for the electrolysis process. Furthermore, building any new infrastructure for transporting hydrogen is costly: repurposing an LNG terminal for the import of ammonia would cost an additional 11–20% of the investment needed to build a new terminal, and building a hydrogen storage tank to replace an LNG tank can be 50% more expensive. Since 2023, project costs have increased further owing to inflation, which has affected the costs of equipment, raw materials and supply chains. In addition, the lengthy bureaucratic time lags between the announcement of projects and channelling the agreed funding to project developers, unclear regulation, and different internationals standards are delaying project implementation and even putting some projects at risk. As of 2023, only 4% of the announced projects have reached at least FID.

More and faster technological innovation is needed to close the cost gap between unabated fossil fuel–based hydrogen and green or low-emission hydrogen, particularly in the case of electrolysis: using electricity to derive hydrogen alone causes a loss of about 25% of the energy. The energy stored in hydrogen is around 60% less than that from LNG owing to the lower volumetric energy density.

Moreover, any major investment in Africa, with its favourable conditions for green hydrogen, needs to come from outside owing to the financial constraints of almost all African energy companies. The Africa Green Hydrogen Alliance, with its six members, namely, Egypt, Kenya, Mauritania, Morocco, Namibia and South Africa, needs some US$450–900bn of investments by 2050.

Like several other countries, the US government has created a new tax credit for clean hydrogen as part of its Inflation Reduction Act in order to enhance investor confidence in new hydrogen projects. This incentive could make the United States the world's cheapest hydrogen producer in future, with exports of ammonia starting by 2027. In Europe, the European Commission has sought to subsidise green hydrogen projects by creating a "Hydrogen Bank" with €800m from the European Union's innovation fund for low-carbon technologies.

Given the technological uncertainties, recent cost increases, the need for technology innovation and criticism that the potential of hydrogen has been exaggerated, private investors and banks have become more cautious about investing in hydrogen projects as they are considered a risky investment. Although the international hype has not died down, governments, industries and independent experts have begun to realise that they need a more sober and realistic perspective. Their concerns are due in part to the rapidly changing geopolitical environment but also to new emission studies that are critical of the climate impact of hydrogen, which would further complicate the timely implementation of their ambitious hydrogen projects.

About the Author

Dr Frank Umbach has been an Adjunct Senior Fellow of RSIS since September 2017. He graduated from the University of Bonn with an MA in Political Science and

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