The potential of hydrogen to accelerate the energy transition

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Hydrogen as an energy vector is back in fashion due to its potential to support the transition to a decarbonised energy system required to meet the emission reduction goals of the Paris Agreement. Hydrogen made from renewable or low carbon electricity could help decarbonise those sectors that have been less amenable to electrification, such as transport and heating. Hydrogen produced in this way can be characterised as a synthetic “green” fuel and may part-replace or displace conventional fossil fuels in the energy mix.

Today, the majority of hydrogen used, whether in industrial applications or as a transport fuel, is produced by reforming methane gas. In its report, “The Future of Hydrogen” published in June 2019, the International Energy Agency (IEA) estimates that the majority of hydrogen produced comes from fossil fuels with less than 0.7 percent of current hydrogen production coming from renewables or from fossil fuel plants equipped with carbon capture use and storage. The IEA estimates that this industry of itself accounts for 830 million tonnes of carbon dioxide per year (MtCO2/yr). The production of hydrogen by electrolysis of water using low carbon electricity could reduce emissions in hydrogen production.

Perhaps of greater interest is the potential for hydrogen to help to decarbonise those sectors that have been harder to electrify. The market for green or low carbon hydrogen is expected to change in the coming years as there is potential for synergy between hydrogen and the production of renewable or nuclear energy. However, the cost of low carbon hydrogen production is still a significant barrier. The IEA reports that the cost of electricity is the single most significant cost in electrolytic hydrogen production. Cheaper, low carbon power sources therefore represent an opportunity. Other barriers will also need to be addressed, with commentators citing the cost of electrolysers and a need for a minimum number of operating hours for economic viability.

Once produced, low-carbon hydrogen can be stored and transported, making it a more flexible energy vector than electricity. The IEA observes that the development of storage and transportation markets will be important if large-scale, international hydrogen value-chains are to emerge. Storage of hydrogen is possible in compressed gas or liquefied form, in tanks or in geological storage such as salt-caverns or depleted gas wells. The appropriate storage option will often depend on the volumes stored, the duration of the storage and the available geology. Storage as ammonia is also possible and may be attractive due to its higher energy density. Transport options include via tanker, pipeline (blended with methane gas or dedicated) or by vessel.

The end uses for hydrogen are multiple and include applications in the industrial sector, transport and heating, as well as in the power sector.

In relation to industrial applications, the IEA reports that hydrogen is used in oil refining (33 percent), ammonia production (27 percent), methanol production (11 percent) and steel production via the direct reduction of iron ore (3 percent). In the short to medium term, there is significant potential for green hydrogen to be used in production of ammonia for the fertiliser sector in particular. Currently, the US$250 billion per annum sector is consuming 3 to 5 percent of global natural gas production and has a carbon footprint of 1.5 percent of global emissions. Ammonia, produced using on-site renewable electricity or power sourced from a renewable energy generator under a corporate renewable power purchase agreement to produce the requisite hydrogen, could significantly reduce sector emissions. With fewer stakeholders and less reliance on associated infrastructure, green fertiliser solutions can be developed and implemented comparatively quickly.

Deployment of hydrogen in the transport and heating sectors is likely to require greater policy intervention. In the road transportation sector, the IEA notes that cost reductions in hydrogen fuel cell technology (where the hydrogen is combined with oxygen to produce electricity with the only by-product being water) and construction of hydrogen refuelling infrastructure will be needed for the market to develop.

Challenges include the time required to replace the vehicle fleet and the scale of demand needed to achieve the necessary technology cost reductions. There is however strong potential for hydrogen to be used in transport, and in particular in the heavy-duty vehicle market segment. Policy and regulation are likely to play an important role in the development of hydrogen refuelling infrastructure, particularly in the early stages of adoption, when utilisation levels are low.

The IEA estimates that nearly 28 percent of global energy-related CO2 emissions result from energy use in buildings. Hydrogen has a short-term application in heating, by blending green hydrogen with natural gas. Trials are using blends of up to 20 percent hydrogen but the production costs of low carbon hydrogen are likely to be a barrier to wider adoption without policy intervention. Developing direct hydrogen applications in buildings, such as hydrogen boilers or fuel-cell micro-generators, is more challenging due to the number of stakeholders and diverse property ownership models. Here again, the IEA notes that hydrogen prices and technology costs will be important factors in wide-spread adoption.

In the power sector hydrogen presents opportunities to assist in providing energy storage solutions for off-grid electricity systems, and in balancing electricity systems, shifting oversupply of electrical energy temporally and / or geographically. The IEA identified a number of end-uses for hydrogen in the power sector, including for use in fuel cells or in co-firing hydrogen gas or ammonia to provide flexible generation. DNV GL in their “Hydrogen as an Energy Carrier” report in 2018 found that using hydrogen for peak shaving, by using large-scale storage and dispatchable hydrogen power generation systems that can be deployed on-demand, is unlikely to be cost-effective. This is due to the significant energy losses involved. DNV GL found that each MWh of output power requires 3 MWh input power to the electrolyser, which implies that the number of hours during a year when hydrogen for peak shaving is cost-effective is limited.

Other end uses for hydrogen may therefore prove more economic, begging the question of whether it is necessary to re-convert hydrogen into electricity to characterise it as energy storage.

As interest in hydrogen increases, we consider policy and emerging frameworks in key markets: the European Union, Japan and Australia.

European Union (EU)

Recognising the important role hydrogen can make in decarbonising the European economy, the EU has already started to take steps towards encouraging the deployment of hydrogen. It adopted the Renewable Energy Directive II (RED II - 2018/2001), which provides for the guarantees of origin that are currently in place for renewable electricity to be extended to cover ‘renewable gas’. This will enable hydrogen produced from renewable sources with guarantees of origin to be counted against 2030 renewables targets. It also requires member states to assess the need to extend existing gas network infrastructure to facilitate the integration of gas from renewable sources; requires system operators to publish technical rules, in particular regarding network connection rules that include gas quality, gas odoration and gas pressure requirements; and require system operators to publish the connection tariffs to connect gas from renewable sources based on objective, transparent and non-discriminatory criteria.

However, at EU level, hydrogen production and storage is still classified as the production and storage of hazardous (industrial) gases. As such, it is subject to a strict regulatory regime, including rules relating to the prevention of major incidents involving dangerous substances, health and safety, the regulation of industrial emissions, environmental impact assessment, and relating to pressurised equipment.

For large-scale hydrogen value-chains to develop, EU member states will need to work together to develop a regulatory framework that would support the production and storage of green hydrogen, but without compromising on health and safety and protection of the environment. For example, consideration should be given to lifting the land use restrictions for producing and storing green hydrogen, simplifying environmental permitting procedures, creating a one-stop shop for all necessary permits and creating a support scheme for the production of green hydrogen. It is expected that creating a favourable legal environment would encourage further development and research in the area and drive manufacturing costs down leading to greater deployment of hydrogen.

The Electricity Market Design Directive (2019/944), amongst other things, establishes common rules for the energy storage of electricity, defining energy storage as “in the electricity system, deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy or use as another energy carrier”. This definition clearly encompasses hydrogen produced by electrolysis, its storage and re-conversion to electricity, but also seeks to take account of sector coupling and permit other end uses of hydrogen produced by electrolysis.

Existing gas infrastructure can provide large seasonal energy storage capacity, but there are no common EU technical and safety standards that apply to the injection and blending of hydrogen with natural gas in the natural gas network. This is left to the member states to determine and the rules currently differ across member states. As hydrogen and natural gas have different quality characteristics, some member states impose limits on the concentration of hydrogen in the natural gas network (between 0.1 percent to up to 10 percent). However, there are also those member states that have either not formally legislated for this or do not generally allow hydrogen injection into the natural gas network. The approach also varies in terms of the quality of hydrogen that can be injected with some members states permitting injection of ‘pure’ hydrogen and others requiring it to be blended down. Therefore, there is a need to develop a common EU approach to defining the permitted levels of hydrogen concentration and gas quality in the gas network that would encourage the production and storage of hydrogen and its transportation through the natural gas network and avoid problems at cross-border connection points.

The Hydrogen Initiative was launched by the Austrian presidency and signed in Linz in September 2018. The signatories of the initiative collectively aim to increase their focus, ambitions and efforts in a number of areas including the integration and coupling between the electricity, industry and mobility sectors through the use of hydrogen, deployment of storage options for renewable hydrogen and setting multilateral frameworks and standards to ensure maximum consistency for implementing hydrogen technology application in diverse sectors. Although non-binding, this initiative shows strong EU support for hydrogen and its potential to contribute to the EU’s pathway of decarbonising the economy.

Japan

Japan is one of the leading countries for hydrogen deployment, research and development, and has developed a Ministerial Council on Renewable Energy, Hydrogen and Related Issues. In December 2017, this council unveiled its national “Basic Hydrogen Strategy”. This strategic release followed the request by Prime Minister Shinzo Abe for the development of a plan to transform Japan into a world-leading “hydrogen society”.

The goal of the Basic Hydrogen Strategy is to coordinate public and private hydrogen initiatives that have been ongoing in Japan since the 1970s. From hydrogen-fuelled cities, development of fuel-cell cars and supply infrastructure, Japan has been committed to developing the energy source. Building on the developments over the last 40 years, the 2017 Basic Hydrogen Strategy introduces additional targets for 2020, the “long-term perspective of around 2050”, and explains the motivations and policy-details behind Japan’s ambitions. It is worth noting that the Basic Hydrogen Strategy is only a pilot at this stage. It will be re-assessed in 2020 and further investment will be dependent on the outcome of this reassessment.

A key goal of the strategy is to drive down the cost of hydrogen fuel and related technologies along the entire value chain. The strategy places heavy emphasis on reducing the cost of hydrogen production and procurement, with the goal of achieving an 80 percent cost reduction around 2050. While the goal is not without challenges, such a significant reduction would make hydrogen fuel-competitive with natural gas.

The Japanese government also stresses that hydrogen must be a carbon-free energy source with timing for achieving this goal being sometime after 2050. As mentioned above, current methods of production from fossil fuels are emissions-intensive and therefore solutions such as green hydrogen and carbon capture are being considered. However, the current pilot is still heavily reliant on reforming methane gas shipped from Australia, an emission-intensive method of producing hydrogen. Japanese corporates are however supportive of the Japanese government initiatives;

one example being Japan’s Kawasaki Heavy Industries’ recent development of facilities in Australia to liquefy and ship hydrogen with the aim of exporting the fuel to Japan in the second half of 2020.

The last objective is to develop hydrogen and fuel cell applications in various sectors, which necessitates the development of relevant infrastructure. The Japanese government hopes to use the 2020 Tokyo Olympics to showcase the technical performance, marketability and scalability of ongoing demonstration projects.

Despite these ambitious goals, Japan has yet to remove certain regulatory roadblocks that impede the development of their “hydrogen society”. Hydrogen is tightly regulated as an industrial gas, with standards intended for large-scale chemical plants with high explosive risks. The same standards are currently applied to hydrogen fuelling stations. This results in hydrogen fuelling stations being required to be surrounded by much more space than a gasoline station, significantly increasing the cost of building and maintaining a hydrogen fuelling station, particularly in dense and expensive cities such as Tokyo. In reality, hydrogen does not present high explosive risks because it dissipates quickly. The stations are also equipped with sensors that immediately shut down the pump if any leaks are detected. These and other safety measures are currently under review by the government, which has been passing reforms on the fuelling stations since June 2016.

By law, cars must be fuelled by specialists licensed in handling high-pressure gases. Such a stringent requirement, and the limited amount of skilled, limit the working hours of the fuelling stations, many of which close for weekends or in the afternoon. To encourage the use of hydrogen vehicles, Japan could legalize self-service pumps. The use of the pumps are largely automated and therefore the requirement for specialists is unnecessary and restrictive. That being said, the complexity of high pressure, cryogenic storage of hydrogen will likely require trained personnel on-site to handle necessary repairs and maintenance.

Australia

With its abundant renewable resources, Australia is well positioned to be a global centre for hydrogen production, storage and export. Coupled with increasing regulatory oversight of Australia’s electricity sector and reliability of electricity supply, there is also a real focus on Australia’s domestic use of hydrogen as a reliable power source.

At federal level, a ministerial forum for the Commonwealth, states, territories and New Zealand has been established – the COAG Energy Council. The COAG Energy Council is responsible for pursuing priority issues of national significance and key reforms in the energy and resources sectors. The COAG Energy Council has recently established the Hydrogen Working Group to develop a national strategy to build a clean, innovative and competitive hydrogen industry and position Australia’s hydrogen industry as a major global player by 2030. Chaired by Australia’s Chief Scientist, the working group is currently developing the national strategy and coordinating the approach to projects that support hydrogen industry development.

In March 2019, the working group issued a discussion paper to encourage conversation about Australia’s emerging hydrogen industry and subsequently published submitted responses. In July 2019, the working group released nine 'issues papers' for consultation and subsequently published responses.

This work builds on themes captured in the Commonwealth Scientific and Industrial Research Organisation (CSIRO)’s National Hydrogen Roadmap published in 2018 and addresses key areas for consideration, including:

- Hydrogen at scale
- Attracting hydrogen investment
- Developing a hydrogen export industry
- Guarantees of origin
- Hydrogen in gas networks
- Hydrogen to support electricity systems
- Hydrogen for transport
- Hydrogen for industrial users

The key drivers behind the working group and developing a national strategy are clear and consistent with those of other jurisdictions focusing attention on the evolution of their hydrogen economy – driving down costs across the value chain and identifying and addressing barriers to commercialisation at scale. Key overarching themes that are recommended in response are:

- Ensuring clear, consistent, unambiguous and efficient regulatory pathways that are appropriately harmonised with existing regimes to ensure long-term investor confidence
- Supporting knowledge-sharing and community acceptance of hydrogen as an energy source

Following on from their own hydrogen road map in 2017, in September 2019 the South Australian Government also released its own State-based “Hydrogen Action Plan” wherein the key themes for early implementation are consistent. Other areas for consideration include funding, ongoing development and investment in technologies and supply chain capabilities.

While there are multiple opportunities for Australia (including export to Japan as described above), one of the key focus areas of industry is the adoption of green hydrogen into the electricity sector. When coupled with renewable technologies, electrolysis-based hydrogen is well placed to manage the inherent variability of renewables and the current Government’s reliability requirements that have been legislated under the Retailer Reliability Obligation.

However, the same themes arise as challenges for the electricity sector: removal of regulatory barriers and regulatory uncertainty/ambiguity (particularly to enable hydrogen to act as a 'swing energy' producer, i.e. energy carrier and energy source), facilitating clear and transparent pathways to implementation of pilot projects and promoting knowledge sharing.