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INSIGHTS

PF in the Early Stages of Hydrogen

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Hydrogen, and especially green-hydrogen, is the current buzz word of the energy transition. The long-term theoretical potential of green hydrogen to be a major part of the energy transition and help decarbonise the planet is undeniable. However, the abundance of recent commentary and articles comparing the nascent green-hydrogen industry to LNG and predicting an imminent boom in mega-projects seems premature.

The idea of multi-gigawatt renewable energy plants electrolysing water into hydrogen that is then liquefied, shipped around the world and sold at competitive prices to end customers, all without creating any carbon emissions, is very appealing and can't come fast enough. The challenges, however, of implementing such a vision, including the technical challenges and high cost of building such facilities, the low volumetric density of hydrogen and the absence of infrastructure for consuming the hydrogen mean this vision is still a way off.

The focus with hydrogen project today should be (and, based on our discussions with clients, to a certain extent already is) on less ambitious projects that help decarbonise our existing use of hydrogen and research and develop the technology needed for efficient, large-scale and cost-competitive hydrogen electrolysis of the future. Project finance can help with this journey. This article will briefly discuss the current state of the hydrogen sector, the challenges that must be overcome for hydrogen to become a general, competitive and widespread fuel and how and where project finance can play a role in this journey.

Hydrogen today

According to the IEA[1], global demand for pure hydrogen in 2018 was approximately 73.9 Mt. The largest consumers of hydrogen are refineries (approximately 38.2 Mt in 2018, or 51.5% of global demand, according to the IEA) where hydrogen is used for hydrotreatment by hydrogenation of unsaturated hydrocarbons and hydrosulfuration as part the refining process. The second largest consumers of hydrogen are producers of ammonia (approximately 31.5 Mt in 2018, or 42.5% of global demand, according to the IEA), of which hydrogen is a building block. The vast majority of ammonia is produced by fertiliser plants for use as fertiliser in various forms, such as salts or solutions. Between them, refineries and ammonia producers account for over 95% of global hydrogen consumption.

Hydrogen is the most abundant element in the universe but it does not occur naturally on its own and is always found in combination with other elements, for example in water and in hydrocarbons such as coal and methane. Obtaining pure hydrogen therefore requires a process of separating the hydrogen from the other elements. The most common process for producing hydrogen is steam reforming of natural gas whereby methane reacts with steam at high temperatures to produce hydrogen. While this method is cleaner than reforming other hydrocarbon fuels, such as gasified coal, it still emits significant amounts of carbon. A clean alternative to this process, discussed further below, is electrolysis which splits water into hydrogen and oxygen using an electric current. Recent hydrogen taxonomy broadly categorises hydrogen into ‘colours’ (notwithstanding that all hydrogen is transparent) by the method of production. The most common are:

- **Grey hydrogen** – Hydrogen produced by syngas processes from fossil feedstock, such as steam reforming of natural gas.

- **Blue hydrogen** – The same processes for hydrogen production as grey hydrogen, but with the carbon emissions from the process being captured and stored.

- **Green hydrogen** – Electrolytic production of hydrogen utilising electricity generated through renewable and non-carbon emitting sources, such as wind turbines or solar photovoltaic systems.

Additional colours may be used to refer to hydrogen produced from other sources of energy. For example, pink hydrogen may denote electrolytic production of hydrogen utilising nuclear energy as the source.

Most large consumers of hydrogen, such as refineries and fertiliser plants, produce “grey” hydrogen on-site for captive use or pipe hydrogen from nearby centralised plants. For example, a modern refinery may incorporate a hydrogen production unit as part of its many components to produce the hydrogen needed for its refining processes. Transportation of hydrogen in compressed or liquefied form exists, and has for some time (for example, liquid hydrogen has been used by NASA and others as rocket fuel for many years), but these methods of transportation do not currently account for a significant portion of global hydrogen production or demand.

Challenges with hydrogen

The use of hydrogen by refineries and fertilizer plants today is driven by hydrogen’s chemical properties. That is, hydrogen is used because it is uniquely required for certain processes and cannot be easily replaced. However, in order to play a role in the energy transition, hydrogen must be used as a general store of energy and as a general fuel – to power vehicles through fuel cells, to drive gas fired turbines for large scale electricity generation and as feedstock to boilers for heating. As a general fuel, hydrogen has many competitors, from traditional hydrocarbons through to batteries. Key considerations for the practicability of any general fuel include transportability, energy density and energy efficiency:

- **Transportability** – Similar to methane, hydrogen can be transported through a pipeline or by truck, train or ship in either compressed or liquid form. However, due to the differences in properties between hydrogen and methane, existing infrastructure would require substantial modifications or replacement to deliver pure hydrogen. In addition, the cost and complexity of transporting hydrogen is significantly higher than transporting fuels that are in liquid form at room temperature, such as gasoline, diesel and fuel oil.

- **Energy density** – Hydrogen, both in compressed and liquid form, has a higher energy density than its main zero-emission energy storage rival, the lithium-ion battery. According to DNV-GL[2], liquid hydrogen has an energy density of approximately four times that of a typical NMC lithium-ion battery, meaning liquid hydrogen requires a quarter of the space to hold the same amount of energy as a typical NMC lithium-ion battery. However, when compared to traditional hydrocarbons, diesel has an energy density of approximately 3.5 times that of liquid hydrogen and even LNG has an energy density of over double that of liquid hydrogen.[3] Compressed hydrogen, which is commonly used in fuel cells, requires more space than liquid hydrogen. This means that larger (and more sophisticated and expensive, given the requirement to store compressed or liquefied gas) storage tanks will be required for wide adoption of hydrogen and that it may not be practical for some purposes (for example, as a bunkering fuel for shipping, given the needs to frequently refuel compared to the alternatives).

- **Energy efficiency** – The energy lost in the production and transportation of hydrogen is relatively high. When considering grey hydrogen, energy contained in the natural gas feedstock and consumed as part of the steam reforming process is lost when producing hydrogen and, if capture and storage technology is also used that will consume additional energy. However, the more relevant consideration is the energy cost of green hydrogen produced through electrolysis. Volkswagen's research[4] estimates that up to 45% of the existing energy is lost during the production of hydrogen through electrolysis and subsequent compression/liquefaction, as compared to 8% for transmission and storage of the same electricity on a grid. While more efficient electrolysis technologies, such as polymer electrolyte membrane electrolysers and solid oxide electrolysers, are in various stages of development, it could be some time before they are ready to be deployed cost effectively and at scale. In addition to these losses, where hydrogen requires liquefaction, transportation and storage, further energy is consumed or lost.

Notwithstanding these challenges and costs, the appeal of hydrogen remains threefold: (i) when hydrogen is consumed, the only by-product is water; (ii) it is possible (even if inefficient) to produce emission-free hydrogen using existing technology; and (iii) hydrogen can be stored and transported (even if inefficiently) using existing technology.

The role of project finance

In addition to the challenges discussed above, there remains a material cost differential between grey, blue and green hydrogen which means that projects across the hydrogen colour spectrum cannot directly compete with each other in terms of pricing. In 2020, according to Platts Analytics (***https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/031920-cost-logistics-offer-blue-hydrogen-market-advantages-over-green-alternative***), producing grey hydrogen can cost under US$1/kg, producing blue hydrogen raises the costs to roughly US$1.40/kg and producing green hydrogen through proton exchange membrane electrolysis more than tripes that cost to an estimated US$4.40/kg. As many other commentators have noted, the real push to the hydrogen sector will have to come from government regulation and incentives. To that end, the UK government recently unveiled its long-awaited Hydrogen Strategy, part of which included commitments to provide a revenue mechanism and market framework for low carbon hydrogen that will support first of a kind projects (which are essential if the UK is to meet its ambition of 5GW of hydrogen production capacity by 2030).

Given this, it can be easy to dismiss a role of project financing in the near future of hydrogen. However, project financing has always been an innovative form of financing that has evolved with the markets it serves and the new breed of hydrogen projects will be no different. While current hydrogen projects are currently primarily financed through equity, we are already seeing innovations that could help future project financings, such as captive offtakers for the hydrogen produced, take-or-pay arrangements, virtual PPAs to limit the project-on-project risk inherit in constructing dedicated power generation and electrolysis facilities and experimentation with hydrogen pricing indicies.

With the right structuring, however, project financing can already play a role in primarily blue but also green hydrogen projects. For example:

- **Grey-to-blue hydrogen** – As mentioned above, almost all current global hydrogen demand comes from existing refineries and fertilizer plants, often with captive or on-site hydrogen production. This creates an obvious starting point to upgrade existing hydrogen production units by adding carbon capture and storage (especially at or near geologically favourable locations for storage). The hydrogen produced already has a captive buyer and, where the blue hydrogen project is structured as a separate project from the rest of the refinery or plant, a project financing could increase the returns from such an upgrade by reducing the sponsor's equity commitment and and spreading the cost over a longer period. Such structures have the obvious cost benefit of allowing a quicker and wider roll-out of such technologies than using equity alone. As decarbonisation regulations continue to advance globally, we can expect more owners of refineries and fertilizer plants to look to blue hydrogen as a solution to reducing emissions, especially in the medium-term.

- **Blending** – Many existing gas-fired power plants can operate on a blend of methane and some hydrogen with minimal (or even no) investment, thereby reducing the carbon intensity of electricity production at that plant. Such plants provide a perfect offtaker to a nearby small-to-medium scale green hydrogen project. The plant can buy all hydrogen produced from renewable energy but still use methane to supplement hydrogen if production or storage levels go down. As above, the plant's incentive to purchase hydrogen at a higher price than methane would be to reduce its emissions. While there are likely to be some challenges with bankability of certain electrolyser technologies (as is the case with any new technology), the increased investment in these technologies means they are becoming more established by the day. Project finance has a long and distinguished history of facilitating the wide-spread roll-out of new technology in the energy sector (for example, the recent project financings of bi-facial solar panels) As we have seen with some of these types of projects, being near favourable geological structures such as existing caves where hydrogen can be stored, can significantly reduced the initial outlay, and make the project more attractive.

- **Hydrogen network PPPs** – Widespread use of hydrogen will require efficient and effective means of transportation. In Europe and the UK that is most likely to take the form of gas pipelines. Many existing pipelines can handle a blend of methane and some hydrogen, but in order to transport pure hydrogen pipelines will need to be upgraded, replaced or newly constructed. It is difficult to see how such upgrades, replacements and new pipelines could be constructed without direct government support. Thankfully, however, such projects lend themselves to government-led PPP projects and could follow traditional forms of PPP procurement and financing. As the European Union and the UK ramp up their hydrogen efforts, we could start seeing an increasing number of such initiatives to put in place the backbone of a hydrogen economy.

In summary, while some of the rhetoric around hydrogen mega-projects seems premature, project finance can have an important role to play even in the early stages of the development of the hydrogen economy. Forward-thinking sponsors who try to structure their hydrogen projects to enable project financing are increasingly likely to find a range of project financiers eager to support the energy transition and invest the time and effort to help make these projects happen.

Footnotes

[1] ***https://www.iea.org/fuels-and-technologies/hydrogen***

[2] "Comparison of Alternative Marine Fuels", DNV-GL, Report No: 2019-0567, Rev. 3 dated 2019-07-05 ***https://safety4sea.com/wp-content/uploads/2019/09/SEA-LNG-DNV-GL-Comparison-of-Alternative-Marine-Fuels-2019_09.pdf***

[3] Note, however, that hydrogen is significantly lighter per MJ than diesel and even LNG.

[4] ***https://www.volkswagen-newsroom.com/en/stories/battery-or-fuel-cell-that-is-the-question-5868***

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