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Hydrogen and Its Role in the Energy Transition

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Renewable energy deployment is only part of the energy transition story.

- Electricity accounts for only 20 percent of energy consumption globally. For reliance to be placed on renewable electricity production for a significant part of global power-supply requirements, a large-scale and efficient means of storage is needed to address intermittency issues with current renewable technologies (wind, solar, etc.).
- Renewable energy deployment will not directly address the other 80 percent of global energy requirements where, for instance, reliance is placed on the combustion of hydrocarbons (industrial applications, domestic and commercial heating, etc.) or where electrification is not currently feasible (heavy haulage and shipping).
- There are areas of the world where the deployment of conventional renewable energy infrastructure at scale may not be feasible (e.g., developing countries, remote locations).

In each of these instances, there is a case for hydrogen to play a valuable role.

Where does hydrogen fit within the energy transition mix?

There are many possible applications for low carbon hydrogen in the global energy mix and the position remains fluid as the market for this product grows, technologies are developed and improved and the overall demand picture becomes more clear.

A storage medium for renewable power

Renewable electricity can be used to convert water into green hydrogen and oxygen using electrolyzer technology.[1] As we highlighted in our overview in December 2019, storing the energy as green hydrogen can address the issue of intermittency, one of the key issues facing wind and solar power generation, but compared to storing the power using a battery storage solution, Hydrogen Energy Storage (HES) offers several distinct advantages. For example:

- Hydrogen molecules are easier to store and transport (as gas or in liquid form) when compared with electrons in a battery storage solution.
- Whilst batteries offer limited storage capacity (from two to four hours of dispatchable power), storage using hydrogen is limited only by the capacity in the storage infrastructure available.

The green hydrogen can then:

- Be converted back into power using fuel cell technology—although there will be efficiency losses, the solution offers a zero carbon grid balancing option.
- Be deployed to displace existing carbon intensive hydrogen production for industrial and commercial applications (e.g., replacing grey hydrogen used in the refining industries).
- Be injected into the domestic gas grid and comingled with natural gas for domestic use, although there may need to be upgrades to the gas grid (e.g., installation of polyethylene pipes to avoid leakage risk and embrittlement concerns).
- Be deployed as an alternative to the combustion of carbon rich feedstock in existing industrial processes (e.g., replacing natural gas/coking coal in iron ore reduction for steel production).

Fuel cell technology

Fuel cell technology has a range of applications, from powering buildings to the electrification of transport.

A fuel cell is typically composed of an anode, a cathode and an electrolyte membrane. The process combines hydrogen and oxygen to produce power, water and a small amount of heat through an electrochemical reaction, not combustion.

The electrification of transportation is a key area. Whilst battery technology currently leads the field in the automotive sector, the major car manufacturers continue to invest in fuel cell technologies to develop “Fuel Cell Electric Vehicles (FCVs)” partly in response to ambitious targets set by many countries, especially in Asia, to increase the number of FCVs on the road, [2] and we are likely to see, to some extent, a leveling of the playing field in years to come.

The position may also be influenced by a slowing of battery production globally as capacity within available lithium refining infrastructure becomes more constrained. In addition, hydrogen fuel cell technology in the automotive sector may gain more traction in the developing world or in remote locations where battery car deployment may be more challenging given issues around access to reliable power, wholesale power pricing and the deployment of charging infrastructure at scale. Hydrogen fuel cell technology could take advantage of the ability to supply hydrogen through existing gasoline supply and delivery chains.

Battery technology also becomes more difficult in the context of larger scale transport (buses and trains), heavy road haulage and shipping, given the size and density of the batteries required. It is likely that this is where we will see large-scale deployment of hydrogen fuel cell technology in years to come.

Hydrogen fuel cells also provide a viable alternative to diesel generators in circumstances where off grid power is required. Larger mining companies are looking at captive green hydrogen production at mine sites through the development of renewable projects and the application of electrolyzer technology. Whilst this may initially come at a perceived increased cost, there are likely to be wider sustainability drivers to development (particularly for mining companies producing energy transition metals or rare earths) and there are often challenges in emerging markets with regards to access to reliable power and wholesale power pricing that are likely to encourage development of this kind.

Decarbonize existing hydrogen use

Hydrogen is currently used in various industrial applications, including oil refining and ammonia and methanol production, with the existing market being valued at over $100 billion annually. There is a clear opportunity to decarbonize this aspect of hydrogen use.

The hydrogen currently used in these industries is mainly grey hydrogen, which is produced using natural gas or methane using steam methane reformation—so it remains carbon intensive. To decarbonize this aspect of hydrogen production, the current means of production would need to include a carbon capture application or would need to be produced using a renewable energy source.

Whilst the supply of green hydrogen to the oil refining industries seems counter intuitive, the feedstock is being decarbonized and, importantly, by replacing feedstock supply to an existing end user market it opens up the opportunity for high volume green hydrogen production that can bring costs down for deployment in other areas.

Ammonia has a vital role to play in food production globally, with 80 percent of global production being used to produce nitrogen fertilizer. Conventional ammonia production is carbon intensive given it relies on grey hydrogen being combined with nitrogen under the *Haber* process. By using green hydrogen produced from a renewable source and extracting nitrogen from the air, green ammonia can be produced via the *Haber* process (provided energy inputs are from a renewable source), which can contribute to reducing carbon from food production. There is also increasing discussion around green ammonia produced being a next generation combustion fuel source in its own right.

Displace carbon intensive feedstock in otherwise 'hard to abate' sectors

As we have previously noted (see our commentary from April 2022), another use strategy for green hydrogen is as a combustion feedstock in sectors that are carbon intensive and in which emissions are hard to abate (i.e., it is difficult to extract carbon from the process using a carbon capture solution).

Of particular interest is steel production. As demand for steel increases, the demand for green alternatives also increase, particularly in sectors that are generally moving towards decarbonization, such as the automotive industry. It is thought that consumers in this sector are likely to accept paying a premium for a car produced from green steel. The Direct Reduced Iron (DRI) process uses green hydrogen (in place of natural gas) to reduce iron ore to sponge iron, which is then processed to steel using oxidization. There are a number of successful pilot projects (e.g., the HYBRIT initiative in Sweden[3]) and it is anticipated that mills using this hybrid DRI process will achieve full commercial production in the next couple of years.

As a means of controlling the entire value chain, projects in this space are entering into power purchase agreements (PPA) directly with renewable energy producers and are producing the green hydrogen at site using electrolyzer technologies.

Current issues and opportunities

We address below some of the key issues we are seeing in projects that produce blue or green hydrogen.

Establishing the carbon reduction standard – It will be important to define the carbon reduction standard required in respect of the hydrogen offtake and how this will be measured. The standard may be driven by regulatory requirements, requirements to access capital or revenue support or by wider environmental, social and governance (ESG) requirements of the producer or the value chain. It is likely that these standard requirements will evolve over time and compliance will be placed under increased scrutiny as carbon reduction credentials are stress tested. At conceptual design stage, it will be necessary to audit current requirements to test what they actually mean in practice and to analyze likely plans for future regulation and international consolidation and standard setting.

The key areas that will require evaluation are as follows:

- **The source of renewable power for green hydrogen electrolyzer projects** – The hydrogen developer will likely seek a PPA providing for onsite renewable energy production or involving a private wire to a local renewable energy generator. It will be important for the developer to consider the pricing regime, volume security, the management of intermittency risk, tenor, options to break and the impact and management of changes in law and events of force majeure. Other options that may be available for the purchase of renewable energy will need to be capable of standing up to scrutiny in terms of their ability to demonstrate that they added to renewable energy production.
- **The level of "at source carbon" produced by a carbon capture, utilization and storage (CCUS) project producing blue hydrogen –** CCUS hydrogen production is not carbon free and there remains a risk of fugitive emissions. The level of carbon produced by the process must be limited to satisfy carbon reduction credentials and the means of measurement will be an important factor. Furthermore, the developer must consider the transportation, use/storage model and how this is factored into emissions consideration. Even with permanent sequestration of the carbon, there remains a risk of long term degradation of the storage site and leakages that must be taken into account. Please refer to our previous article "Carbon Capture, Utilization and Storage – What is the big deal?" for the more in-depth discussion around CCUS.
- **Point of measurement** – Will the carbon reduction measurement be an "at source" calculation or will it consider the wider value chain? For instance, will the assessment include consideration of the material used in the manufacturing and construction of the facility (e.g., the carbon intensity of the operations of the mining companies providing platinum for the electrolyzer catalysts)? This is clearly at the limit of the

scope 3 considerations, but we make the point simply to emphasize that there remains a lack of clarity on how any such assessment may be undertaken.

- **Data collection** – The data required to verify carbon reduction standards will need to be very carefully defined, both in terms of the nature of the data and the frequency of collection. These requirements will need to be tracked through into the design of the distributed control system (DCS) at the facility and software capability. The ability to demonstrate on an objective and transparent basis a "carbon free" value chain will be of paramount importance in the coming years.

Technology risk – The efficiency of the electrolyzer will be of critical importance as this is likely to drive the economics of the project. If, for example, the technology provider has warranted an efficiency level of 80 percent (i.e., the energy value of the green hydrogen is 80 percent of that of the power used to produce it) but the electrolyzer only generates 70 percent efficiency, the project may immediately be in distress. It will be important to consider how efficiency shortfalls can be managed. This will include an assessment of the financial position of the technology provider and the security provided to underwrite any efficiency warranty. The producer will want to consider options for optimization or replacement of the electrolyzer as well as the development of contingent electrolyzer lines using altering technologies and technology providers—we have seen this approach taken by developers to mitigate technology failure risk.

A key challenge to electrolyzer technology is the intermittency of operation, especially during commissioning. This will place increasing pressure on the need for robustness in the commissioning process and procedures and initial contingency plans.

Linked to technology risk will be the licensing arrangements with the technology provider. The producer will want to understand how access will be secured to technology upgrades and optimization as well as long term technical services and maintenance support. A further important factor will be access to source codes fundamental to the operation of the technology in the event that the technology provider ceases to trade or becomes insolvent. This can be addressed through the use of source code escrow arrangements that allow for the release of such information and data upon the occurrence of an agreed set of circumstances.

Works delivery structure – It is likely that a project of this nature that brings together a number of different elements and stakeholders and contains inherent technology and technology integration risk is unlikely to attract a single engineering, procurement and construction (EPC) contractor to underwrite delivery of the entire project on time, on budget and to a required technical and performance specification. This issue is further exacerbated by the fact that the supply chain in the green hydrogen sector is immature and in many respects untested.

Projects of this nature tend to be delivered on a multi-contract basis. It will be important for the developer to limit interface risk by packaging the works up into a limited number of separate packages especially because lenders traditionally prefer an EPC wrap over multi-contract structures. Steps should be taken to encourage the main contractors to take ownership of key risks relating to interface management and technology integration. Residual interface risks may them be managed by the developer team or through the use of a highly structured EPC management (EPCm) contract delivery model. Whilst the EPCm contractor will not underwrite project delivery, it will instead typically be a highly skilled and competent professional consultant engineer who will manage and will be incentivized to manage (through a bespoke *bonus-malus* regime) all aspects of project delivery and interface risk on behalf of the supplier.

The EPCm model has been used successfully across the resources, oil and gas and petrochemicals industries for many years and can bring large benefits to a project if properly deployed.

The model brings with it bankability challenges (e.g., uncertain construction period, lack of fixed lump-sum construction price and no single point of responsibility), but there are precedent solutions and other newer emerging market solutions available to mitigate perceived issues in this regard.

Offtake terms – As with any project of this nature, a long term stable offtake with a robust counterparty with a strong balance sheet represents the ideal scenario. The offtake markets for green and blue hydrogen are not developed and this is perhaps demonstrated best by the level of government support now being offered to new project development in the sector to pump prime production and fast track market development. Perhaps the best opportunity lies with the decarbonization of existing hydrogen use by large industrials who will have the creditworthiness to stand behind and provide credibility to the offtake arrangements. Aside from the carbon reduction standard, the offtake terms are likely to specify pressure requirements for delivery. They will typically include minimum supply levels based on a take or pay arrangement that will need to factor in production plant intermittency and possible outages that may arise as the technological process is optimized. Other routes to market may include ammonia/urea, production of synthetic aviation fuel or even methanation of hydrogen to form synthetic natural gas, but each will have to be considered in term of their certainty of use cases—which will feed into offtaker credit risk and ultimately the need for credit support.

Bankability – Technology risk, project delivery risk, power supply risk and offtake risk are all of fundamental importance and will go to the heart of bankability considerations. It is a fact, however, that there is no established offtake market for green hydrogen. This brings with it uncertainty, given having secured long-term offtake arrangements in place with creditworthy offtakers will be the key concern for any lender into the project and it will be such offtake agreements that will generate the expected revenues to service any debt (and ultimately make dividend payments to the sponsors). Furthermore, we are in a constantly moving regulatory environment that could undermine reasonable assumptions made as to the operation and financial viability of the project at financial close. This uncertainty may be managed through a number of means. This could include government revenue or capital overrun support of the kind we have seen in the U.K. or the use of credit support through government guarantees. It may also extend to development bank support in emerging markets or foreign government support of exports through export credit agencies. Given the lack of maturity in the market and the lack of foreseeability as to how it will develop commercially, initial projects are being balance sheet funded by large industrial players seeking first mover advantage. As the market develops and other sources of finance materialize (e.g., project finance), sponsors will also have to grapple with the project-on-project risk that is inherent where you have a renewable energy project being developed independently of the hydrogen supply project. Drawing on solutions that have been deployed in other sectors (for instance some of the infrastructure projects attached to natural resources) will be key.

Regulatory risk and support – As mentioned above, governments are looking to stimulate the development of a reduced carbon hydrogen market through revenue and capital support programs. Developers will see this as an opportunity to secure first mover advantage in a lower risk environment. The nature of the support and conditions to it will vary from one nation to the next depending on the wider policy aims. For instance:

- The U.K. Low Carbon Hydrogen Business Model released in April 2022 offers support for blue hydrogen projects to align with the wider government support for the development of CCUS hubs. Whilst the long term viability of blue hydrogen in the wider hydrogen supply mix may be questioned, the support offered by the government includes revenue support through payment of the differential between the strike price and the reference price (with a floor) and sliding scale volume support that increases the revenue support as offtake volume falls. This is important as it opens up the market and mobilizes supply chains for future projects.

- In Singapore, the National Hydrogen Strategy released on 25 October 2022 recognizes the potential of low-carbon hydrogen as a broad-based decarbonization tool and the Singapore government is clearly positioning itself as a regional hub for hydrogen trade. In addition to funding research and development (R&D), innovation and infrastructure programs, Singapore will pursue regional and global collaborations to enable supply chains for low-carbon hydrogen to be established. Notably, this will include the development of Guarantee of Origin certification methodologies that can apply across jurisdictions and building a trading and financing ecosystem to facilitate global trade of low-carbon hydrogen.
- In the U.S., the Department of Energy has committed $7 billion to fund clean hydrogen hubs (H2Hubs) across the U.S. and has recently released the "National Clean Hydrogen Strategy and Road Map", which is out to consultation.
- The European Union (EU) has recently launched the RePowerEU Strategy with the aim of diversifying the EU's energy demand away from Russian gas and which will involve investment in EU wide projects (including €10 billion for two cross border projects (Hy2Tech and Hy2Use)) and strategies for importing green hydrogen at scale using the block's buying power and the EU Energy Platform.

Any potential supplier will need to consider the terms and conditions to the securing of any central government support to not only ensure that these terms and conditions can be achieved but that they do not undermine the supplier's ability to flex its production and operations to harness new and developing markets in the future or to react to a changing commercial and regulatory landscape. The U.K. government support appears balanced in this regard and is attracting significant interest.

Our practice and experience

We act for energy companies, industrials, investors and governments in the production, storage, transportation, use and regulation of hydrogen. We advise on the largest and most complex renewables and power projects and have advised on genuine pathfinder first in kind projects across the energy and infrastructure sectors. We have a full service global offering from project inception and feasibility, front end engineering design (FEED) and final investment decision (FID) achievement, to detailed design, construction commission and operations. Our areas of expertise include construction, licensing regulations, supply and PPA terms, offtake arrangements, joint ventures, mergers and acquisitions, project financing, debt finance, as well as disputes, restructuring and investigations.

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[1] Either Alkaline electrolyzers, Proton Exchange Membrane electrolyzers (PEM) or solid oxide electrolyzers (SOEC).

[2] Please see "Uses of Hydrogen - Transport (Fuel Cells Electric Vehicles)" in our previous article "The Emerging Hydrogen Economy".

[3] https://www.ssab.com/en/news/2022/10/hybrit-new-research-shows-hydrogenreduced-iron-has-superior-properties.

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