EVALUESERVE

Hydrogen

Can it fuel the energy transition?

Background

Hydrogen is being hailed as an energy of the future and is seen as a viable decarbonization strategy. The use of hydrogen in industrial applications such as oil refining and ammonia production is not new, but it is yet to be adopted at scale in other industries such as transport and power generation.

Although naturally occurring as a gas, there is no viable approach to capturing it from the air nor tapping into the rare underground reserves. Hydrogen, therefore, must be produced. Most of the hydrogen used today is produced from fossil fuels, majorly bituminous or lignite coal (called black or brown hydrogen, respectively) and natural gas (called grey hydrogen) emits ~830 Mn tonnes of CO2 emissions per year. This is equivalent to the CO2 emissions of the UK and Indonesia combined. In some countries, the bulk of emissions generated from the steam reforming process to create grey hydrogen are captured and stored (Carbon Capture, Utilization and Storage); this is called blue hydrogen and is often considered a preliminary step towards a hydrogen-based economy. Green hydrogen is produced from renewable power sources using water electolysis.

Currently, most of the hydrogen produced (primarily grey) is used in industrial applications including oil refining and ammonia production. As most of the hydrogen used is grey, there is an opportunity to equip these facilities with CCS/CCUS or electrolysis to reduce emissions.

In the past few years, continuously decreasing global prices of renewable power (on average a 70-80% decrease since 2010 primarily in Asia, Europe, and the US) along with the decarbonization policy push by different governments have accelerated the momentum for low/zero carbon technologies, including blue or green hydrogen. Hence, low/zero carbon hydrogen (especially green) is now increasingly considered an important part of the clean energy mix, majorly in transport, followed by industrial, and power generation applications. Furthermore, some of its uses are also expected to be visible in building applications.

Unknowns

What are the value chain dynamics of hydrogen and what are the key success factors to be successful in this environment?

These shifts indicate the nascent development of a global hydrogen ecosystem.

Application Areas

In the transport sector, hydrogen fuel is expected to become economical with the decrease in fuel cell cost, lower hydrogen supply cost, and increasing conventional transport costs. Hydrogen fuel will become convenient as the necessary development of refueling infrastructure happens. In the past few years, battery technology has emerged rapidly; however, fuel cell electric vehicles (FCEVs) are now emerging as an alternative solution (through facing infrastructural challenges similar to Hydrogen), especially in long-range segments (rail, trucks). Hence, hydrogen fuel cells are increasingly considered an integral part of FCEVs to generate clean power. Economies such as the US, Japan, Europe, and China are front runners, where many activities and announcements are already visible. For instance, the EU, as a part of Hydrogen Roadmap, has announced a target of 3.7 Mn fuel cell passenger vehicles on the road by 2030; Japan also has a target of 0.8 Mn FCEVs by 2030 as a part of its Hydrogen Strategy 2017. More countries are expected to follow the practice in the near term.

In industrial applications, the opportunity for green hydrogen is majorly limited due to its high cost. However, industrial gas players are expected to be one of the earlier takers, potentially leveraging their established logistics capability. In the medium term, we also expect some of the end markets such as refining, chemicals, etc. to be one of the early adopters of green hydrogen, possibly starting with blue hydrogen and eventually shifting to green.

Currently, hydrogen plays an insignificant role in power generation, accounting for only ~0.2% of total electricity generation globally (IEA, 2019), mainly linked to the use of gases from industries such as steel, petrochemicals, and refineries, i.e., grey hydrogen. In the power industry, just like fossil fuels, stored power in the form of hydrogen can be transported to other geographies that do not have abundant renewable energy resources. Green hydrogen can also be used to store excess renewable power in the form of compressed gas, ammonia or synthetic methane for an extended amount of time, which is not technically feasible and financially viable in battery storage technologies. It can also act as a long-term storage option to balance the seasonal variation in power generation from renewable sources.

A combination of hydrogen and ammonia can be used in hydrogen co-fired gas turbines to increase power system flexibility, providing potentially lower-carbon generation options. As per the IEA, many existing gas turbines can handle a hydrogen share of 3-5% and a few can handle shares of 30% or higher; these are mostly located in the US, Europe and Asia. However, flashback and high NOx emissions are a few technical challenges that need to be addressed to make hydrogen co-firing compatible in gas turbines at a sizable scale.

The extent that renewable hydrogen can be scaled for these applications and in these combinations will be a true measure of its success.

Unknowns

How well does hydrogen integrate with gas-fired plants and how can this accelerate the decarbonization process?

One of the largest near-term opportunities lies in building applications (space heating, hot water production and cooking) by blending hydrogen into the existing natural gas network. However, infrastructure upgrades and safety concerns are challenges that must be addressed to make it viable.

Cost Remains a Hurdle

Even with advances in technology and scaling of application across sectors, the high cost associated with green hydrogen production remains a major challenge, along with the massive investments required in the related infrastructure. The cost of green hydrogen production from electrolysis includes two major components: the cost of renewable powers (fuel cost, specifically solar and wind) and the cost of electrolysis (process or technology).

Opportunity areas to watch are those countries where input fuel prices are competitive or expected to become competitive; the game-changer comes when lower fuel costs, which account for 45-75% of the total hydrogen production cost, are coupled with a decrease in electrolyser costs, improved technology, and the scale to justify the associated CAPEX. This is one of the reasons that the Middle East, Russia and North America have the lowest hydrogen production costs, due to lower gas prices. Hence, blue hydrogen is expected to remain a favorable choice for decarbonization strategies in these regions. However, gas importers like Japan, South Korea, and China are struggling due to high prices of imported gas, leading them to consider electrolytic or renewable hydrogen (hydrogen electrolyser) as a significant part of their decarbonization strategy.

Unknowns

How can hydrogen play a larger role in energy transition and where to invest in the hydrogen value chain to get maximum returns?

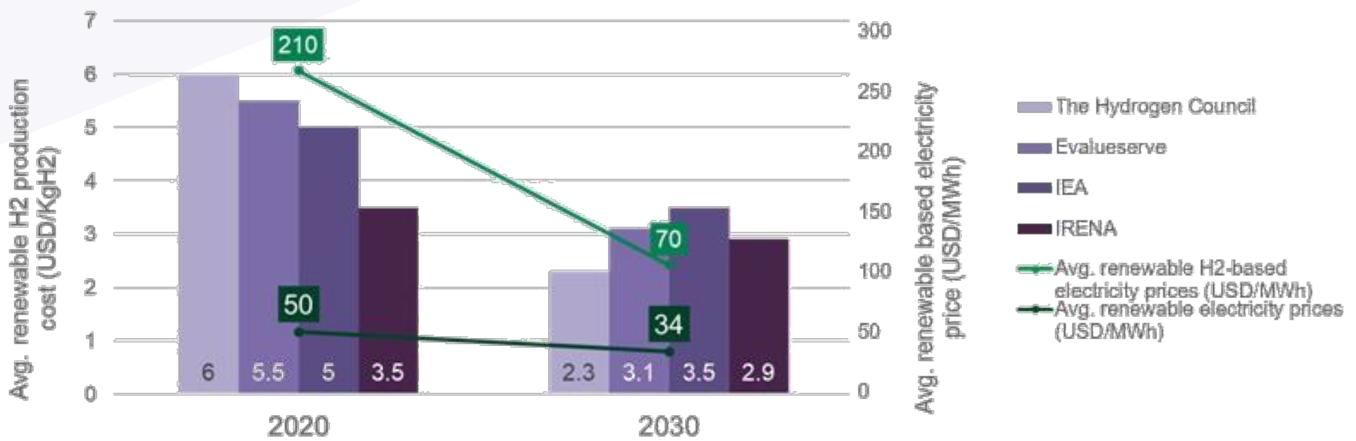
As there is significant variation in low carbon electricity prices and attractiveness of CCS/CCUS between regions, the choice of technology will be region specific, with some countries betting on blue and others on green hydrogen.

In the next section, we examine what the hydrogen market's evolution might look like.

Getting to Cost Competitive

In the figure below, we use leading sources to visualize how hydrogen production costs might decrease in the coming 9 years. Although the sources vary in assumptions and realities vary by country and region, we can begin to model how renewable electricity (mostly solar and wind) and specifically hydrogen-generated electricity prices might decline, estimating decreases of 32% and 67% between 2020 and 2030, respectively. Although our estimate suggests that hydrogen-generated electricity does not become cost competitive on that timeline, we see a notable improvement from approximately 4x to 2x the price of renewables overall.

Figure 1: Green Hydrogen Production Cost and Resulting Electricity Prices (2020-30)



Source – IEA, IRENA, The Hydrogen Council, Evalueserve, and other Secondary Literature
Please see notes at end for calculation methodology and differences in assumptions by report.

The hydrogen electrolyser market is witnessing a significant increase in activity and investment, as electrolysers offer an effective avenue for generation of truly clean hydrogen (green hydrogen). The operational flexibility offered by electrolysers positions them well as a reliable energy storage and transport avenue during peak load of renewable power generation.

The following three electrolyser technologies are the most widely deployed

	CAPEX (USD/kWe)	Electrical Efficiency	Operating Temp. (°C)	Operating Pressure (bar)	About
Alkaline Electrolyser	500-1350	55-70%	60-80	>30	The most widely adopted and mature technology owing to the lower cost of the technology and because the system supports a higher MW range stack with a stable operating environment.
PEM Electrolyser	300-1750	55-65%	50-80	30 to 80	The second most adopted technology. It offers benefits such as higher suitability for distributed systems, lower maintenance equipment and higher quality hydrogen output.
SOEC Electrolyser	>2300	70%	500-1000	Approx. 1	Nearing attractive economics, with improvements in performance and durability, and offers unrivalled conversion efficiencies, a result of the favorable thermodynamics and kinetics at higher operating temperatures versus those of low-temperature electrolysis.

Source - Kearney – Energy Transition Institute and other Secondary Literature

Electrolyser technologies will scale as more renewable power enters the energy mix, and through scale, the production costs for PEM and SOEC should decrease and become more cost competitive with Alkaline Electrolysers.

Apart from cost, the water-intensive nature of the hydrogen production process is a concern for many. However, according to Hydrogen Europe, 1kg of hydrogen production requires only 8.92 liters of water (fresh or demineralized). In context, this is minimal – to meet the EU's 10 Mn tonnes hydrogen production target by 2030, 89 Mn tonnes of water would be consumed, which is 0.00478% of all the freshwater resources in the EU. This signifies that the availability of water may not be a challenge in the production process, with the potential exception of water-scarce regions.