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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 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 (call black or brown hydrogen, respectively) and natural gas (called grey hydrogen), which 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 energy sources.

Currently, most of the hydrogen produced (primarily grey) is used in industrial applications including oil refining, ammonia production and steel manufacturing. 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 sources (on average a 70-80% decrease since 2010 especially 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 carbon hydrogen (especially green) is now increasingly being considered an important part of the clean energy mix, majorly in transport applications followed by power generation. 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 an increase in conventional transportation 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, especially in long-range segments. 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 lots of activities and announcements are already visible. For instance, the EU as a part of Hydrogen Roadmap has announced 3.7 Mn fuel cell passenger vehicles on road by 2030; Japan also has a target to have 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.

Currently, hydrogen plays an almost negligible role in power generation, accounting for only ~0.2% of total electricity generation globally (IEA, 2019), mostly linked to the use of gases from various industries including 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 energy in the form of compressed gas, ammonia or synthetic methane for many days, weeks and months, 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 renewables.

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, most of the 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 these advances in technology and scaling of application across sectors, the high cost associated with renewable hydrogen production remains a major challenge. The cost of renewable hydrogen from electrolysis includes two major components: the cost of renewables (fuel cost, specifically solar and wind) and the cost of electrolysis (process or technology).

Opportunity areas to watch are those countries where input 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, and hence blue hydrogen is expected to remain a favorable choice for decarbonization strategies in these regions. However, gas importers like Japan, Korea and China are struggling due to the high import prices of gas, leading them to consider electrolytic or renewable hydrogen (hydrogen electrolyser) as a 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 CCUS between regions, the choice of technology will very region specific, with some countries betting on blue and others on green hydrogen.

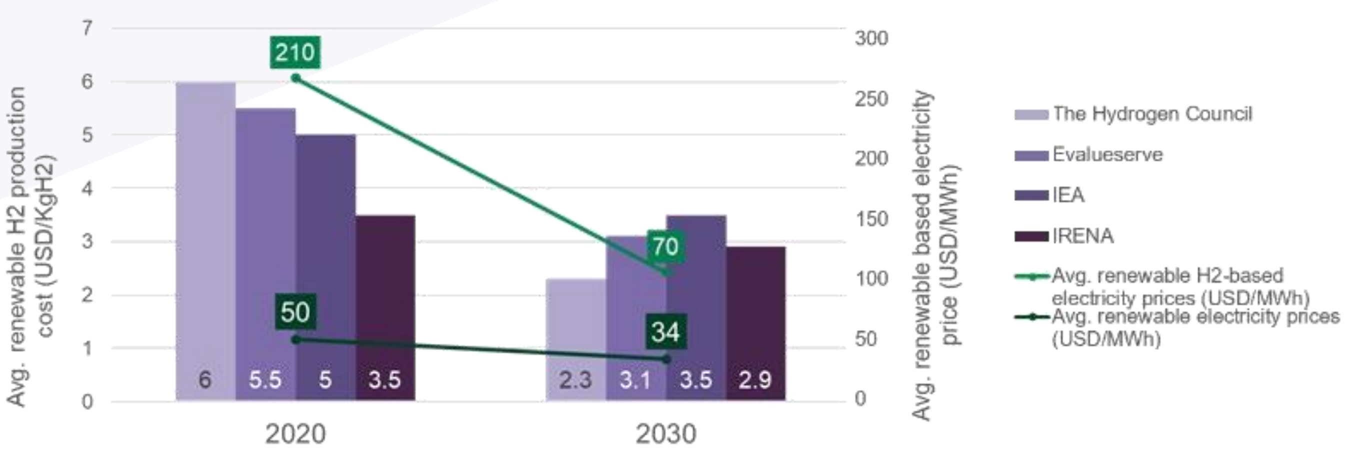
In the next section, we examine what the hydrogen market's evolution might look like.

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 widely 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: Renewable Hydrogen Production Cost and Resulting Electricity Prices

Renewable H2 production cost estimates (2020 vs 2030)



Source – IEA, IRENA, The Hydrogen Council.

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 renewables enter 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 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.

The Way Forward

There are contradicting pictures in the market, with many claiming green hydrogen is ready to compete in the energy mix sooner than expected, and others suggesting the poor economics of hydrogen will be a major challenge at least for the next 10 years.

According to The Hydrogen Council, at the global level, **~90 GW of electrolyser capacity will be required by 2030 to make green hydrogen cost-competitive with grey hydrogen**; in other metrics, green hydrogen production cost would need to decline to $1.40-2.3/kg from the current $5-6/kg. However, currently, only ~100 MW of electrolyser capacity are added every year. The rate of this capacity growth is set to accelerate, as based on current project announcements, new capacity is estimated to reach up to 3 GW/year in the near term.

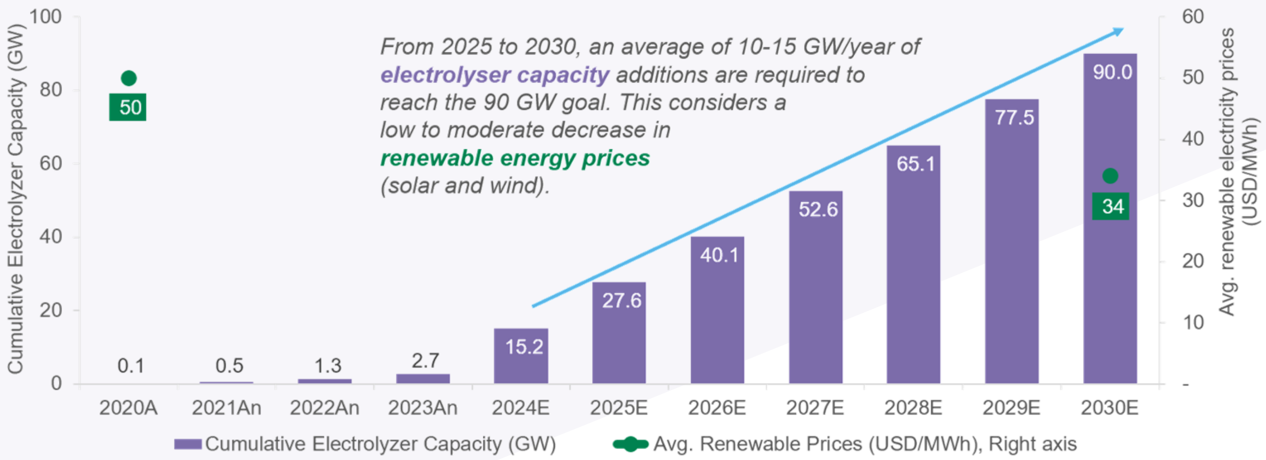
Is 90 GW achievable in just 9 years?
We think an accelerated policy push, significant investment in green hydrogen production, transport and distribution infrastructure, increased R&D to advance electrolyser technology, as well as the continued rise of renewables (in terms of scale and lower costs) are required to enable this.

Unknowns

What could be the role of hydrogen in decarbonization?

How can companies optimize their offerings to meet customer's evolving requirements?

Figure 2: Required Electrolyser Capacity Addition



Note - Capacity based on Actual (A) (2020), Announced (An) (2023), Including EU Green Deal Support (6GW by 2024) and estimated average capacity addition (2025-30) required each year to reach 90 GW goal.

Source - IEA, The Hydrogen Council, IRENA, and other secondary literature

A direct road to green hydrogen will be very difficult without government mandates or significant investments that have longer horizons for returns. Therefore, for many companies and governments, converting existing grey hydrogen infrastructure with CCS/CCUS to start the transition with blue hydrogen instead of making the upfront investment to build out green hydrogen infrastructure can be a steppingstone in the short to medium term to realize the full potential of green hydrogen in the longer term

Japan was the first country to adopt a comprehensive hydrogen strategy in 2017; other countries are now following suit. To date, over 30 countries have already released their hydrogen roadmaps. We see the hydrogen market first picking up in Japan, Korea, Australia, the EU (specifically Germany and Spain) as well as the UK, driven by favorable regulations, clear targets, and policy support including tax breaks and funding, followed by the US.

For instance, the UK released its USD 15.9 billion plan to accelerate renewable development, which includes government-backed investment in hydrogen. The plan focuses on generating 5 GW of low-carbon hydrogen production capacity by 2030 (~0.04% of total capacity). The country also pledged to develop the first town run entirely by low carbon hydrogen (blue hydrogen) by 2030. Spain approved a similar plan to boost green hydrogen production and aims to install 4 GW of electrolyser capacity by 2030 (0.03% of total capacity). The EU, as a part of the European Green Deal, has also announced to add at least 40 GW renewable electrolyser capacity (+40 GW through import) by 2030 in a phased approach. Being the demand centers of Asia, China, and India are also expected to play critical roles in the hydrogen ecosystem. These massive strategic announcements signify that renewable hydrogen is an attractive option to enable decarbonization, opening the door for companies to pivot into greener products and services required for this new ecosystem.

Renewable hydrogen is in a nascent stage. However, with countries announcing hydrogen as a part of their clean energy targets and future strategies, **now is the right time to assess how your company can participate in the blue and green hydrogen ecosystems and fuel the energy transition.**

Unknowns

What is the regional scenario of hydrogen?

How can hydrogen play a larger role in meeting that country's climate goals?

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Figure 1 Notes

Assumptions by source:

IEA - Renewable electricity price = USD 40/MWh at 4 000 full load hours at best locations; sensitivity analysis based on +/-30% variation in CAPEX, OPEX and fuel costs; +/-3% change in default WACC (weighted average cost of capital) of 8% and a variation in default CO2 price of USD 40/tCO2 to USD 0/tCO2 and USD 100/tCO2

The Hydrogen Council – Dedicated renewable/electrolyser system; Fully flexible production; Scale up of renewable hydrogen production; Additional costs to reach end supply price; Gas price 2.6–6.8 USD/Mmbtu; LCOE USD/MWh 25–73 (2020), 13–37 (2030); 65-90GW of renewable capacity added

IRENA - 'Average' signifies an investment of USD 770/kilowatt (kW), efficiency of 65% (lower heating value – LHV), an electricity price of USD 53/MWh, full load hours of 3200 (onshore wind), and a weighted average cost of capital (WACC) of 10% (relatively high risk). 'Best' signifies investment of USD 130/kW, efficiency of 76% (LHV), electricity price of USD 20/MWh, full load hours of 4200 (onshore wind), and a WACC of 6% (similar to renewable electricity in 2021). Estimates USD 1.38 per Kg by 2050, back-calculated accordingly for approximate figures.

Note 1 - All other factors are considered constant including CAPEX, Feedstock Stock, Fuel Cost and based on respective source assumptions.

Note 2 - Above prices are global average appr., figures, however H2 production prices will vary across regions due to difference majorly in renewable source prices. All renewable prices used to calculate hydrogen production price are varying as per the third-party reports - USD 20/MWh to USD 50/MWh. Avg. renewable H2 based electricity prices forecast based on assumption both electrolyser and renewable price will decrease in next 10 years.

Note 3 - All figures approximated as per current year.

Note 4 - Considering the efficiency parameter, 1.5-2 times H2 based renewable electricity is produced considering a unit of renewable power (1 MWh).

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