



**EVALUESERVE**

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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 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 electrolysis.



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.

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

## Unknowns

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

## 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.

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.



### Unknowns

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



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
<b>Alkaline Electrolyser</b>	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.
<b>PEM Electrolyser</b>	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.
<b>SOEC Electrolyser</b>	>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.



# 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 is 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.

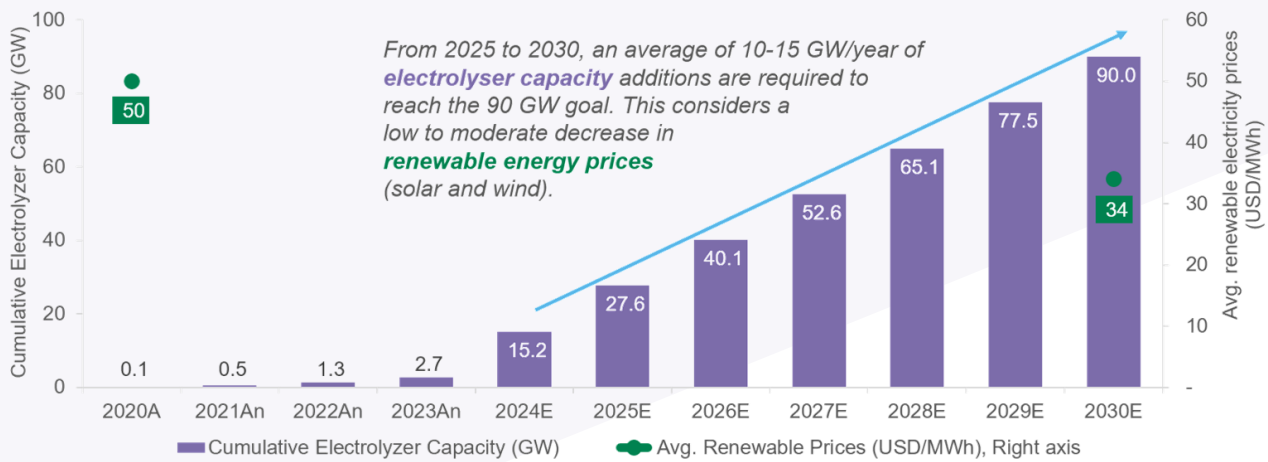
### Is 90 GW achievable in just 9 years?

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, South 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 "green industrial revolution" plan, 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 green 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 (green) 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 majority 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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