Green Hydrogen Superpower

With the right policy impetus, India can become a leading electrolyser manufacturer

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Every year, India's energy consumption from fossil fuels is worth approximately Rs 7 trillion (1). Adding other monetary expenses such as taxes and subsidies would further increase the expenditure, creating an even bigger energy exchequer for the government. To meet the climate goals, it is imperative to see the amount of fossil-free energy in the energy exchequer. From a sustainable development standpoint, for benefits to outweigh costs, decarbonisation of the energy sector is the need of the decade.

Though renewable energy sources have gained much-needed traction, this decade will determine where we are in terms of the overall progress—often measured as the carbon intensity of energy (CO_2/PJ). A scalable and carbon-free source could significantly tilt the carbon intensity of energy sources towards an acceptable norm. Hydrogen has that potential, especially green hydrogen.

Hydrogen can act as a feedstock and fuel. Currently, hydrogen is produced primarily from reformers that use natural gas. This hydrogen is used in fertilisers and refineries. The government might make it mandatory for these demand centres to meet a predetermined per cent of their hydrogen needs via green hydrogen purchase obligations (GHPOs) (2). Green hydrogen is produced from electrolysers using renewable energy and water. Water is split into hydrogen and oxygen through electrolysis, and hydrogen is then stored and used for energy requirements.

The need for polymer exchange membrane electrolysers

To meet its target of 1 million tonnes of green hydrogen by 2030, India would need around 38 GW of renewable energy with an average capacity utilisation factor of 21 per cent at a footprint of 1,824 km^2 in total (0.048 m^2 per kW) (3). Assuming an average plant load factor and throughput, a total of 9 million cubic meters [roughly 9 litres of water (4) for every kg of H_2] of water would be required to meet this target. Meeting the target can abate a total of 42,000 tonnes of CO_2 per year (5). To achieve this, establishing a robust electrolyser market will be imperative, given its importance in green hydrogen production.

By and large, electrolysers can be categorised into three types: polymer exchange membrane (PEM), alkaline, and solid oxide (see Table for comparison). If water scarcity were to be a challenge in the future, instead of pure water electrolysis, seawater electrolysis could be adopted, which is at a nascent stage of development at the moment. Owing to PEM's ability to ramp up and down, better flexibility (while using renewable energy), and desirable power density, hydrogen produced from PEM electrolysers offers better returns despite the overall cost. An estimated total of Rs 3 trillion [at Rs 81,400 per kW of the current price(6)] would be required as the capital expenditure to set up PEM electrolyser manufacturing plants for producing 1 million tonnes of green hydrogen.

Apart from the number of components encompassing the electrolyser, the high cost will be a challenge for large-scale adoption. However, new materials (7) usage is being explored and innovative cell designs (8) are currently being developed. These developments are expected to reduce the overall cost in the future. Alkaline electrolysers are matured technologies and offer minimal scope for market capitalisation, given the diverse application of the produced hydrogen (and its purity). Although solid oxide could be a better choice in terms of metrics (see Table), it is still at a lab scale. Therefore, it is prudent to invest in PEM-based technology, which will drive electrolyser needs for the next decade.

Table: Comparison of electrolysers

Criteria	Alkaline	PEM	Solid oxide
Electrolyte	KOH (20%–30%)	Polymer Nafion	Yttria-Stabilized Zirconium
Current efficiency (%)	50–70	40–65	80
Specific energy Consumption system (kWh/Nm^3)	4.5–7.5	5.8–7.3	2.6–3.5
Technology maturity	Fully commercial	Demo scale	Lab scale
Catalyst	Ni/Co/Fe, Ni/C-Pt, Non-noble metal	Platinum, Iridium oxide	Ni-Cu
Operating cost	Low	High	Medium
Advantages	- Mature technology - High nominal output	- Highest H_2 purity - High load gradient: Ideal for fluctuating renewable energy systems	- Highest efficiency - Suitable for co-electrolysis

Source: Author's compilation

In a PEM electrolyser, the anode-side (responsible for oxygen evolution reaction) is filled with water, which diffuses through the porous transport layers (PTL) to the iridium electrode. The liquid is subsequently split into oxygen and hydrogen. Through the proton conductive membrane, the protons are transported to the cathode-side by the PEM and combine at the cathode-side (for hydrogen evolution reaction) with electrons from an external circuit to form hydrogen gas. Though membrane electrode assembly (MEA) is the core component, bipolar plates (BPP) and PTL are the most expensive components in a PEM electrolyser stack.

The stack, membrane, catalyst, cathode, and anode account for around 60 per cent (9) of the overall cost. The anode-side uses stable metals since it is responsible for splitting water. Titanium is the key material used for manufacturing PTLs and BPPs. It is important to note that large-scale penetration of PEM electrolysers is contingent on the availability of rare and expensive metals required to withstand acidic conditions.

Benefits of PLI schemes

With the right policy impetus, India could become a leading global electrolyser manufacturer. Both AatmaNirbhar Bharat Abhiyan and Production Linked Incentive (PLI) schemes could act as enablers and offer the much-needed policy thrust from the government. PLI schemes could ensure that the cost of electrolysers come down from Rs 81,400 per kW to a desirable range for larger adoption. At reduced prices, green hydrogen production could become competitive with other main fuels. The PLI schemes could also eliminate sectoral disabilities (rare metal dependency) and foster economies of scale, further assisting in establishing a complete supply chain in India. Moreover, the domestic manufacturing capability will be scaled up with higher import substitution and possible employment generation.

PLI schemes offer turnover-linked incentives to investors when the specified investment and capacity are achieved. Like the PLI schemes designed for white goods such as air-conditioners and LED lights, component manufacturers of PEM electrolysers should drive the incentives within the scheme to bring down the cost. The local procurement of materials could have a positive impact on the incentives drawn from increased production. Ultimately, PLI schemes could allow the qualifying companies to avail themselves of incentives of a said per cent on the incremental sales (over the base year) of goods manufactured in India. Usually, this target must be achieved within 5 to 10 years after the base year.

India's first green hydrogen electrolyser (PEM) manufacturing unit was started in Bengaluru recently by a multinational private company, with a current manufacturing capacity of 0.5 GW per year (10). The recent announcements from the government, such as GHPOs and the National Hydrogen Energy Mission, are expected to increase the uptake of electrolysers. Also, growing interests from other private players in the energy sector will bolster the electrolyser manufacturing capacity in the foreseeable future. This would also mean that the policy landscape is concise and robust enough to enable businesses that contribute to the electrolyser supply chain.

The task of accomplishing the green hydrogen production target by the end of this decade can be daunting. However, the energy sector in India has already demonstrated that production costs could be reduced significantly with good governance and sound policies. The mass adoption of solar photovoltaic over the past decade is a case in point. A similar approach would revolutionise the hydrogen portfolio and establish India as a global leader in the electrolyser market.

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