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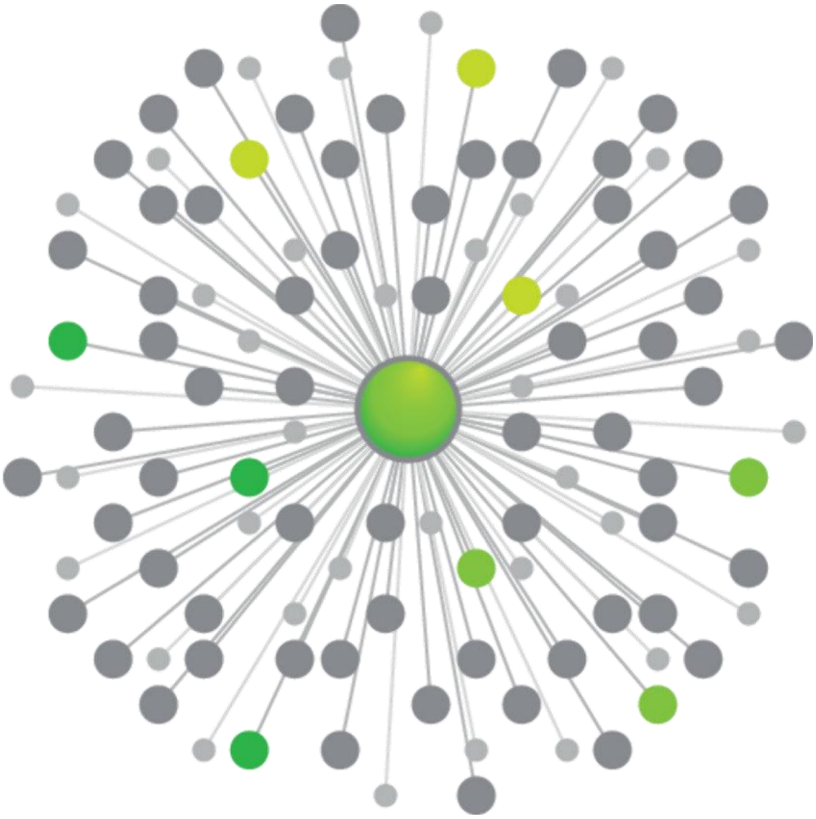


Hydrogen economy

Key insights

Objective: Identifying key opportunities and challenges for adoption of green hydrogen and major levers to scale up a hydrogen economy

With the abundance of affordable renewable power, governments, corporates, and energy leaders across the globe are considering integrating 'green hydrogen' into the energy ecosystem to accelerate the decarbonisation drive in several sectors.

What questions are we trying to answer?

What is green hydrogen's role in decarbonisation?

- Various forms of hydrogen and production methods
- Analysing the roles green hydrogen can play in decarbonisation
- Identifying use cases for green hydrogen

What are the major challenges

- Identifying the major challenges in scaling up green hydrogen adoption through achieving commercial parity
- Analysing the value chain and potential components of cost structure
- Identifying the infrastructure and policy bottlenecks

What are the key levers for scaling up green hydrogen

- Evaluating the key levers to achieve cost competitiveness
- Identifying enablers to achieve cost parity
- Assessing the roles of industry, government, and academic institutions in shaping up the green hydrogen economy and agenda

Key insights and implications

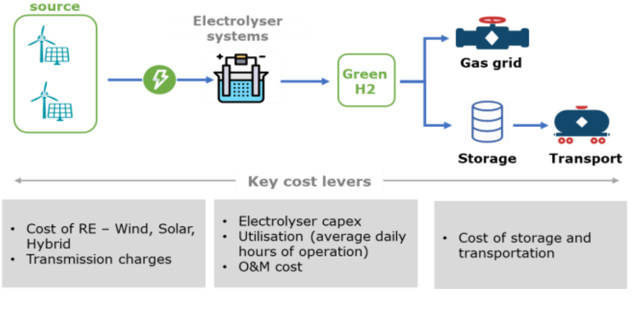
Green hydrogen's role in decarbonisation

- In India, hydrogen (H_2) is currently sourced primarily from fossil fuels through various production techniques - Natural Gas (NG) Steam Methane Reforming (SMR), and coal gasification (through SynGas production). It is used as a feedstock in refineries, ammonia, and various industrial processes.
- Green hydrogen refers to hydrogen produced via the electrolysis of water; the electricity used in the process comes from renewable sources. It is expected to play an important role in decarbonising the economy's hard-to-electrify sectors, such as long-haul trucking, aviation, and heavy manufacturing.
- Green hydrogen can avoid carbon intensity of grey hydrogen; 8–9 kg CO_2 and 13–15 kg CO_2 per kg of hydrogen produced, respectively, from SMR and coal gasification.
- As fuel cell and electrolyser technologies gain global acceptance, cost efficiency is introduced with scaling up of demand and affordable renewable energy is made available. Green H_2 is poised to reach cost parity with grey H_2 by 2025, enabling decarbonisation in segments such as transport, refinery, and fertiliser.
- Decentralised use of H_2 in remote areas could also unlock demand potential by substituting diesel use for energy.

Key challenges

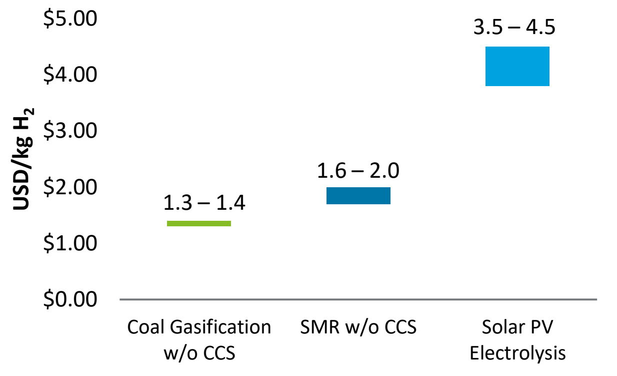
- Green hydrogen is currently not cost competitive vis-à-vis grey or blue hydrogen, produced from fossil fuels. Cost difference of about US$ 2.00/kg of H_2 over fossil fuel based H_2 is a major deterrent for industries to encourage adoption of green H_2
- Production cost of H_2 varies based on production technology and input costs, such as natural gas cost, coal gasification process cost, and cost of renewable sources of electricity. Utilisation (production process utilisation) would also be an important factor in arriving at costs.

Green hydrogen production value chain



Source: Deloitte analysis

Cost of hydrogen production (US$/kg H_2)



CCS: Carbon Capture & Storage

Source:

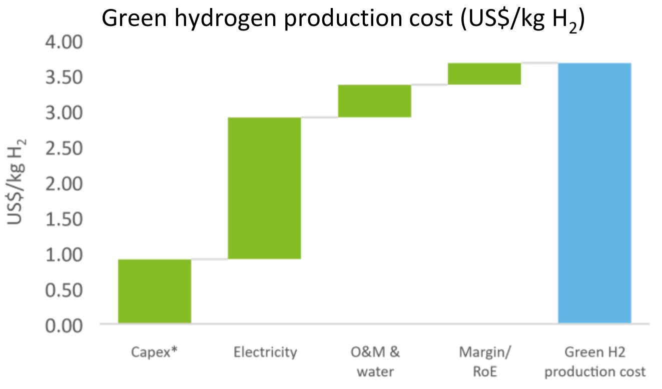
- Deloitte analysis
- Hydrogen strategy: Enabling a low-carbon economy, Office of Fossil Energy US Department of Energy, July 2020
- Hydrogen Production Tech Team Roadmap, US Drive Partnership

- US$3.5–4.5 per kg of H_2 translates into about US$26–33/MMBtu of NG, equating energy content. A reduction to the tune of US$1 per kg of H_2 would make it comparable to NG prices, as available today in India.
- Other major challenges include policy and technology uncertainty, absence of any national policy and roadmap, value chain complexity, and infrastructural challenges related to storage, liquefaction, transport, and refilling stations.
- Hydrogen blending into natural gas grid may require a new and upgraded pipeline infrastructure.
- Hydrogen value chain is complicated and require cross-sectoral coordination, increasing risks for a time-bound implementation roadmap.
- There are significant efficiency losses when producing green H_2 using electricity produced from renewable sources and converting H_2 back into electricity. For example, using electricity to produce H_2 and then compressing, storing, transporting, and converting it back into electricity using a fuel cell can result in almost 60% loss of the original energy content.[1] This indicates green H_2 is more expensive than electricity.

Levers for scaling up green hydrogen

- Unless there is policy certainty around Green House Gas emission reduction and strict enforcement of targets by consumer categories, low-cost production is the only key to large-scale adoption of green H_2.
- The cost of green hydrogen mainly depends on the cost of the electrolyser, the price of the renewable electricity used, and system utilisation. These cost inputs would play a vital role in determining the use of green H_2 and large-scale adoption.

[1] Deloitte analysis

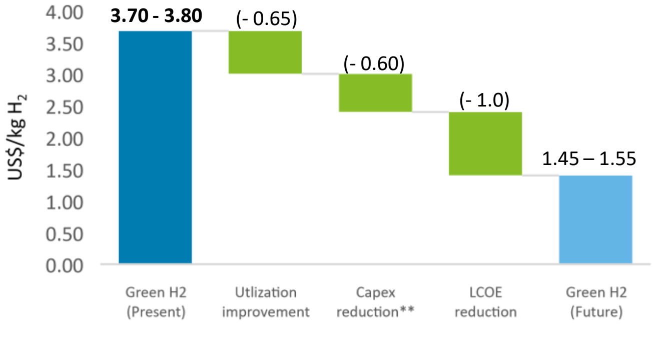


Source: Deloitte analysis

Assumptions
- Electrolyser capex: US$750/kW
- Renewable LCOE: US cents 4/kWh; LCOE – Levelized cost of electricity
- Utilisation: 50%
- Cost components are levelized
- Production cost doesn't include storage & transportation cost
- *Capex includes debt service obligation

- Levers for commercial affordability of green hydrogen can be achieved by reducing the cost of electrolyser (by increasing production scale), improving utilisation (through incentivising and aggregating demand), and reducing input cost of electricity (by ensuring availability of low-cost renewable power).

Future green hydrogen cost optimisation pathways



Source: Deloitte analysis

Assumptions
- Reduction in electrolyser capex: US$750/kW to US$300/kW
- Renewable LCOE reduction: US cents 4/kWh to US cents 2/kWh
- Utilisation improvement: 50–85%
- **Capex reduction includes reduction in debt service obligation and repair & maintenance cost (3-5% of capex)

Key recommendations

- Create a national-level 'hydrogen policy and roadmap.' Form a collaborative national green hydrogen task force, comprising public and private sector leadership to provide momentum for accelerated deployment of green hydrogen.
- Create demand for green hydrogen and address the infrastructure challenges through appropriate policy and budgetary supports.
- Boost demand by focusing on major policy areas, including imposing sectoral obligation to replace grey H_2 with green H_2, allowing 10-15% blending of hydrogen into gas grid, dedicated hydrogen pipeline, incentivisation to end-use sectors, etc.
- Support an accelerated deployment with policies enabling indigenisation of large-scale manufacturing of electrolyser and associated systems to mitigate supply chain risks.
- Consider government intervention and public-private partnerships in case of H_2 use for road transport, where a network of refueling stations will be needed for the mass adoption of Fuel Cell Electric Vehicles (FCEVs), and infrastructure investment is limited.
- Offer initial incentives in the form of subsidies, grants, and concessional financing to provide an impetus to green hydrogen commercialisation.
- Introduce a carbon price adder to accelerate the hydrogen transition (as evident from growing consensus in the industry).
- Further develop and unify standards and safety protocols for hydrogen use and infrastructure that could reduce costs and barriers for technology deployment.
- Put in place an appropriate framework to support research, development, demonstration, and deployment of green hydrogen projects through government funding and public-private partnerships that could be instrumental to enable innovation and cost reduction.

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