**Hydrogen and Green Hydrogen**

**Hydrogen is the most abundant chemical element in nature.** As noted by the IEA, the global demand for hydrogen for use as a fuel has tripled since 1975 and reached 70 million tonnes a year in 2018. In addition, **green hydrogen** is a clean energy source that only emits water vapour and leaves no residue in the air, unlike coal and oil.

This technology is based on **the generation of hydrogen — a universal, light and highly reactive fuel — through a chemical process known as electrolysis.** This method uses an electrical current to separate the hydrogen from the oxygen in water. If this electricity is obtained from renewable sources we will, therefore, produce energy without emitting carbon dioxide into the atmosphere. As the IEA points out, this method of obtaining green hydrogen **would save the 830 million tonnes of CO2 that are emitted annually when this gas is produced using fossil fuels.** Likewise, replacing all grey hydrogen in the world would require **3,000 TWh/year from new renewables.**

**Scope the opportunities and challenges in the Green Hydrogen space**

**Opportunities**

* Demand drivers for hydrogen are highly sector specific. They depend on whether hydrogen is used as industrial feedstock with no other alternatives or whether it requires adopting new technology and displacing existing fuel or technology. Further, the pace of energy transition, new technology adoption, and the presence of requisite policy and financial support will also determine the demand outlooks for hydrogen. Globally, demand for hydrogen has increased by 17% between 2010 and 2018,22 used mostly to produce ammonia and in refineries. With the global decarbonization push, current policy momentum, and improvement in economics and durability of end-use technologies like fuels cells, hydrogen could serve 7%–18% of global final energy demand in 2050.
* Adoption of green hydrogen will also result in 3.6 giga tonnes of cumulative CO2 emissions reductions between 2020 and 2050. Energy import savings from green hydrogen can range from $246 billion to $358 billion within the same period. Hydrogen can help reduce the nation’s reliance on oil imports and bolster a domestic job market. Additionally, it provides the ability to participate in the ensuing global energy transition and the economic opportunity that transition presents
* From a price parity basis alone, green hydrogen’s share of this demand could grow from 16% in 2030 to almost 94% by 2050. This translates to an implied cumulative electrolyser capacity demand of 20 GW by 2030 and 226 GW by 2050, promising a sizeable opportunity for indigenous manufacturing of a global emerging energy technology. The cumulative value of the green hydrogen market in India could be $8 billion by 2030 and $340 billion by 2050. Electrolyser market size could be approximately $5 billion by 2030 and $31 billion by 2050. The cost of electrolysers must decline for hydrogen to become cost-competitive, research and development and scaled manufacturing of electrolysers is becoming an area of global technology competition. India will benefit greatly from enabling domestic manufacturing of electrolysers (and relatedly fuel cells). This will allow the country to achieve technical capability, participate in an emerging global market underpinning the clean energy transition, and capture more of the economic gains of this transition.
* Industrial decarbonization (both energy and feedstock) is driving near-term hydrogen demand creation. But longer-term opportunities fall in transport, power, and even for decarbonization of the shipping and airline industry
* Electrolyser price and the pace of its decline will be the most crucial determinant of long-term price trajectory of green hydrogen. Limitation of storage and the high cost of transportation means that early market development should centre on identifying clusters of industrial demand that could be served by localized generation of hydrogen. Green hydrogen can be produced anywhere there is ample renewable potential. This will enable the emergence of an energy carrier that is domestically produced, reducing the dependence on imports for key energy commodities like natural gas and petroleum

**Potential for Green Hydrogen**

* National Hydrogen Mission needs to be complemented with further policy direction in the form of a national roadmap/strategy. The emphasis of this roadmap should be to elaborate on the government’s vision for green hydrogen in multiple sectors with timelines and investment aspirations given the long-term cost advantage and multiple benefits that we have established in this report. This will improve investors’ confidence and will converge the entire value chain and the various government agencies towards a singular vision.
* Cost-competitive green hydrogen opens the possibility for market development, especially in industries that are already consumers of grey hydrogen. The share of green hydrogen will depend on the cost of production compared with alternative hydrogen sources, the share of hydrogen cost in the end cost of the product, as well any exogenous demand creation efforts that may be imposed in the near term. Purely based on cost-competitiveness, green hydrogen is expected to dominate the hydrogen market in the long run. Even in the 2030 timeframe, green hydrogen can play a significant role for both existing brownfield consumption and new greenfield investments. Almost 94% of hydrogen demand in 2050 can be met by green hydrogen, up from 16% in 2030. The cumulative value of the green hydrogen market in India could be $8 billion by 2030 and $340 billion by 2050.
* In Energy security perspective, domestically produced green hydrogen can translate to a net energy import savings of $246–$358 billion cumulatively between 2020 and 2050 ($3–$5 billion between 2020 and 2030 alone). This is on account of a reduction in both natural gas imports as grey hydrogen is replaced with green hydrogen and oil imports as long-haul freight transitions to hydrogen fuel cells trucks.
* India’s robust economy and manufacturing and industrialization ambitions present other opportunities to partake in the emerging global hydrogen economy. A robust market for green hydrogen translates to a growing demand for production and consumption technologies such as electrolysers and fuel cells and an opportunity for scaled manufacturing.
* Driven by the low cost of renewables in the country, India can still emerge as a one of the most competitive sources for green hydrogen in the world. Green hydrogen as a tradeable energy commodity in the long term, albeit with challenges. We are already seeing early momentum as traditional energy importers like Japan and South Korea, willing to pay premium prices, are increasingly pursuing the possibility of importing hydrogen through ocean shipping.

**Steps to make India a global hub of green hydrogen**

* Enabling the roadmap which requires both demand and supply side interventions. In tandem with cost reduction targets in the roadmap, the government should also focus on enabling a cost reduction pathway for green hydrogen to be produced in the country.
* End-use sectors should be further assessed to identify those sectors ready for scaled consumption and those ripe for small- and large-scale pilot development. They should also be supplemented with geographical assessments to identify potential clusters around existing factories, transmission infrastructure, and renewable hubs. Such cluster identification can also include the prospect of exports. A plan should also be set to propose clear mandates around hydrogen blending in existing and potentially future consumption sectors.
* Given, how important electrolyser cost is to the cost-reduction pathway for green hydrogen and the significant manufacturing opportunity it represents, the roadmap should identify a timeline and scale of manufacturing support for electrolyser. India should envisage a production capacity accounting not only for Indian demand, but also for burgeoning global demand. Radically improving the speed of regulatory clearances coupled with preferential treatment in public tenders will help catalyse local manufacturing.
* India should invest $1 billion in R&D by 2030 to catalyse the development of commercial green hydrogen technologies across the value chain. Industry and academia should be encouraged to participate together as teams in well capitalized grand challenges with specific aspirational targets. R&D in alternative clean hydrogen production processes like bio-hydrogen technologies should also be encouraged.
* Though standards are already available for grey hydrogen, they are designed for limited industrial use. It is important to construct new hydrogen standards keeping in mind the widespread use of hydrogen across sectors. Standards for new products such as electrolysers, fuel cells, and other new products are required. A digital (AI/ML equipped) labelling and tracing mechanism certification of origin should also be initiated for ascertaining the green credentials of all supply route of hydrogen including electrolytic, fossil fuel based and bio-based hydrogen.
* The government must explore forming government-to-government partnerships with target geographies such as Japan, Korea, Germany etc and integration of hydrogen into existing energy and industrial partnerships globally.
* The government has a large role in providing financial certainty to early adopters of energy transition technologies. In the near term a credit worthy offtakers like SECI can be nominated to aggregate demand in the initial period. In the long run, a smooth and market oriented green hydrogen industry should be developed. Efforts should be made to ensure availability of long tenor and low-interest finance for viable green hydrogen projects.
* Focus must go beyond to include business models, policies, and geopolitics. A scalable skills programme will have to be designed, developed, and deployed rapidly.
* An interdisciplinary Project Management Unit (PMU) with globally trained experts must be created which can dedicate fulltime resources to effectively implement the mission. The PMU must be nimble enough to adapt to global trends in this fast-evolving sector. At the policy level, an inter-ministerial mechanism should be instituted to coordinate across the various line ministries and departmental efforts required to achieve the target of the mission.

**UK-India collaboration and funding opportunities**

* India had been ranked among the top five performing countries in the Climate Change Performance Index and the country’s per capita greenhouse gas emissions were below the world average of 6.3 tonnes carbon dioxide equivalent in 2020.
* The Union Budget proposals for FY2023-24 cover diverse aspects of climate change and energy transition under the Rs 35,000 crore allocated for the purpose. These comprise funding for the National Green Hydrogen Mission and biofuels, viability gap funding (VGF) for 4000 MWh of battery storage systems, capital support for a renewable energy project in the union territory of Ladakh, and the establishment of a programme for facilitating green credit.
* India has also rolled out a ₹18,100 crore production-linked incentive (PLI) scheme for building Tesla-style giga factories to manufacture batteries. The plan is to set up a 50 giga watt hour (GWh) manufacturing capacity for advance chemistry cell batteries by attracting investments totalling ₹45,000 crore. More government support is on the move with India announcing a $2.1 Billion plan to promote the growth of green Hydrogen.
* European Investment Bank has signed an agreement with the India Hydrogen alliance and is willing to invest 1 billion Euros in bankable Green Hydrogen projects.
* The **UK-India Green Hydrogen Hub** is a coalition of UK and India research groups and innovators that join forces to drive science and innovation, accelerate and enhance the role of hydrogen in the UK and India’s decarbonisation journey.
* A range of Green Hydrogen Hub events and networking opportunities will create links between the ideas of the future and the funds that can make them happen, and give members access to masterclasses on how UK-India research partnerships can deliver optimal results through
* Bilateral platform for the academic community to improve understanding of the ongoing research and innovation in the sector in UK and India.
* Opportunity for researchers to build their capacity, participate in knowledge exchange, connect with researchers working on similar thematic areas to co-develop research outcomes and overcome common barriers.