

PROPELLING BUSINESS SUSTAINABILITY WITH HYDROGEN ECONOMY

All sectors are under immense pressure as the debate around climate change has urged industries to limit carbon emissions. Hydrogen is emerging as a key solution to de-carbonize hard-to-abate sectors and acts as a feedstock for producing other energy carriers like ammonia and synthetic fuels. However, hydrogen's path is not straightforward, with its growth trajectory and profit pools yet to be determined. Opportunities and timing will vary across industries, geography, customer demand, off-take potential, supply conditions, and infrastructure requirements.

Understanding the Hydrogen Supply-Chain

The hydrogen value chain is a comprehensive and multifaceted system that spans from hydrogen production to end-use applications, presenting various business opportunities. It encompasses numerous interconnected stages, technologies, and industries, offering immense potential for economic growth and sustainability. The fundamental segments in the hydrogen supply chain are:

Production



In terms of hydrogen production, businesses can leverage different technologies, such as electrolysis, natural gas reforming, pyrolysis, and biomass gasification, thereby creating opportunities for businesses, including equipment manufacturers, renewable energy developers, and engineering firms, to incorporate low-cost and highly efficient production

Storage & Distribution

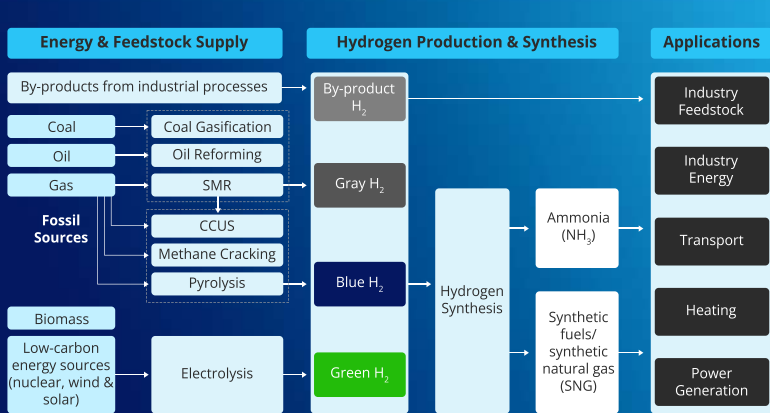


The hydrogen storage and distribution segment includes firms engaged with designing and manufacturing infrastructure for hydrogen storage. In addition, the relevant organizations working towards developing efficient transportation methods are associated with this segment.

End - use



Hydrogen is not just a fuel; it has a wide range of applications across diversified industries. With the commercialization of improved hydrogen production & storage technologies, businesses can seize opportunities in manufacturing fuel cell vehicles, establishing refuelling stations, clean mining, developing sustainable chemicals, and adopting sustainable



Triggers and Roadblocks across the Hydrogen

The hydrogen economy is gaining traction across diversified industry verticals to meet the collaborative goal of the net-zero coalition, and the pace of such sustainable transition is regulated by certain key drivers and restraints, which are elaborated below

Inflection points that are bringing propulsion in the hydrogen economy

Global hunt for greener solutions to meet the surging energy demand:

Considering the growing carbon footprint of various industries, the global demand for hydrogen will potentially touch 180 MMT in 2030 from 95 MMT in 2021.

Addressing the waste challenges:

The generation of MSW is anticipated to double in 2050. Thus, increasing pressure by the government and authorities to find alternative ways to manage MSW and propel bio-energy projects forward.

Regulatory support:

1. EU and Brazil have landfill elimination plans in support of the regulations for MSW to Biofuel.
2. The Inflation Reduction Act encompasses an inflation adjustment of 60 cents per kilogram of clean hydrogen produced.
3. Fit for 55 includes 50% renewable hydrogen consumption as clean energy by 2030.

Major constraints across the hydrogen economy

Revamped Distribution Infrastructure:

To maintain the same level of energy security, we need to expand storage infrastructure by 3-4 folds if we introduce hydrogen instead of natural gas. Such a huge refurbishment demand investment in billions and time in decades.

Inefficient storage facilities:

Hydrogen's low density makes it considerably more challenging to store than other fossil fuels. In addition, its high ignition property and increased risk of leakage are the major hurdles to its widespread use.

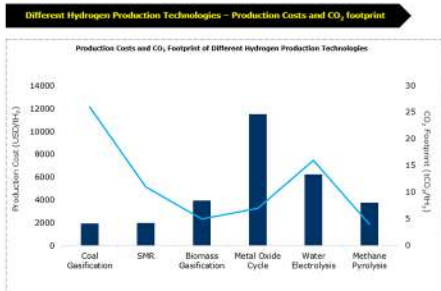
Industries Aggressively Investing to Incorporate Sustainability in their Core Businesses



Hydrogen Production Technologies and their Comparative Assessment

There are numerous hydrogen production technologies in operation, of which the extensively used method is steam methane reforming (SMR) due to its significantly low hydrogen production cost [\$2000 USD per ton of hydrogen (tH₂)]. However, its carbon footprint is comparatively high, as the final products of the reaction are hydrogen and carbon dioxide. Another substantially employed approach is electrolysis, which consumes electricity to split water molecules into H₂ and O₂. The average production cost/tH₂ through this approach is relatively high, over 6000 USD. Also, its carbon footprint is currently elevated due to the utilization of non-renewable energy. On the contrary, although coal gasification is one of the remarkably low-cost hydrogen-producing technologies, the carbon emissions (tCO₂) for producing one ton of hydrogen are exceedingly high, nearly 12,000 tons.

Therefore, researchers and industries are seeking solutions around minimal production costs and accountable GHG emissions. So far, the apt technology as per the objective is Biomass gasification, which not only offers affordable production with low carbon emissions but also eradicates the global issue of municipal waste management.



Hydrogen Storage Options

		H ₂ form							
		Gaseous state				Liquid state			Solid state
H ₂ storage options		Salt caverns	Depleted gas fields	Rock caverns	Pressurized containers	Liquid hydrogen	Ammonia	Liquid organic hydrogen carriers	Metal hydrides
KPIs	Storage capacity (tH ₂)	300 to 10,000 Weeks to months	300 to 2,500 Seasonal	300 to 100,000 Weeks to months	< 1.1 Daily	< 0.2 Days to weeks	< 10,000 Weeks to month	< 4,500 Weeks to month	Small volumes Days to weeks
	Benchmark levelized cost of storage (USD/kg)	0.23	1.90	0.71	0.19	4.57	2.83	4.50	-
	Future levelized cost of storage (USD/kg)	0.11	1.07	0.23	0.17	0.95	0.87	1.86	-
	Technology readiness level	9	3	3	9	8	9	7	9
	Commercial readiness level	3	3	2	2	3	4	2	9
	Geo-graphical availability	Limited	Limited	Not limited	Not limited	Not limited	Not limited	Not limited	Not limited

Although multiple alternatives are available to store hydrogen in different forms, companies opt for a particular storage option based on the state of the product, technology readiness levels (TRLs), benchmark levelized costs, commercial readiness levels (CRLs), and geographical availability, among others. For storing hydrogen in gaseous form, salt caverns are an optimum option due to their considerably low benchmark levelized cost and high TRL. Liquefied hydrogen storage involves conversion into ammonia, as it offers relatively low storage costs and can be efficiently stored for weeks to months. Metal hydrides are a viable option for storing solidified hydrogen, but their storage capacity is limited.

Steps Towards Energy-efficient Future

Besides depending on technology innovation & deployment, administrative policies, and incentives; enterprises across the public and private sectors should also make efforts to the race of sustainability by:

1

Defining energy transition roadmap emphasizing the organizational milestones and efforts to align with business growth.

2

Tracking investments in electrolyzers and understanding the EBITDA of renewable projects to optimally utilize resources.

3

Building a balanced portfolio around renewable energy with tailored digital solutions to monitor demand and accordingly strategize green hydrogen distribution.

Our Expertise Lies Across...

- Technology identification and benchmarking for hydrogen to chemicals and energy route
- Partner identification for second-generation biofuels
- Technology foresight for hydrogen carrier systems
- Market Assessment and Opportunity Identification for hydrogen business and offshore sector analysis from the perspectives of technology, customer demands, and promising markets
- Application and customer identification for 3D-printed heat exchangers
- Assessment of competitors and opportunities for on-site hydrogen technologies
- Competitor due diligence on decarbonization and sustainability practices
- A state-of-the-art study for waste-to-renewable-fuel technology
- Assessing the various hydrogen storage and transportation methods and their competitive assessment
- Identifying the various use cases, uncertainties, trigger points, and unmet market needs for different applications
- Highlight the best-fit hydrogen storage for various industries