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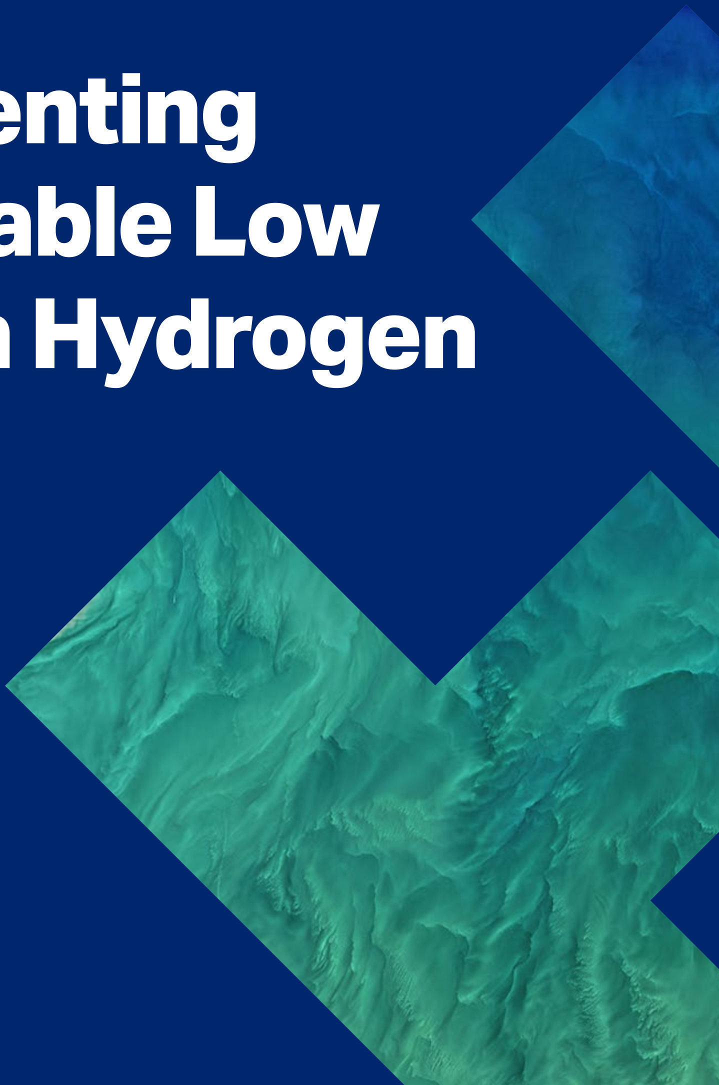
Re-inventing Affordable Low Carbon Hydrogen

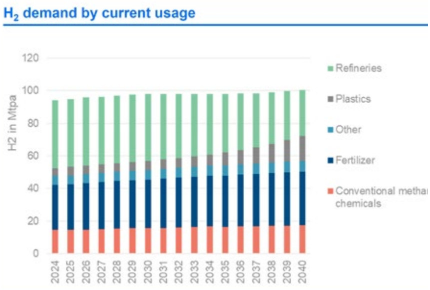


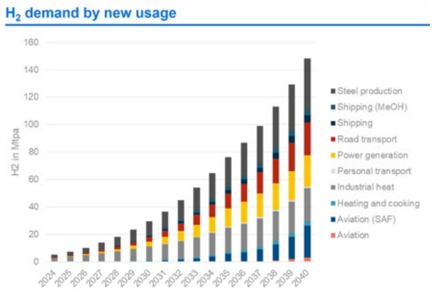
Report
August 2025

Re-inventing Affordable Low Carbon Hydrogen

The global energy landscape is rapidly evolving with decarbonization at its core. As a leading engineering and technology player in the energy industry, Technip Energies brings over 60 years of expertise and has delivered more than 275 hydrogen plants worldwide. Recognizing the urgent need for affordable, low-carbon hydrogen solutions, Technip Energies is at the forefront of developing innovative technologies to support the energy transition.

This article explores the current state of the hydrogen market, production, the challenges it faces, and the innovative solutions the company has developed to make hydrogen production more sustainable and economically viable.





The Current Hydrogen Market

Hydrogen is a vital component in various industries, including refining, plastics, fertilizers and metal-based chemical production. While hydrogen use in these conventional sectors is projected to remain stable over the next 15 years, optimizing existing production methods is crucial for reducing carbon emissions and helping these industries achieve their emission reduction goals.

Future Hydrogen Production

Looking ahead, the demand for hydrogen is expected to grow with an additional 140 million tons per annum anticipated over the next 15 years. This growth will be primarily driven by the need to decarbonize industries such as steel, shipping, power and industrial heat. The successful expansion of hydrogen production will depend on several factors such as infrastructure availability, access to low-cost feedstock and regulatory frameworks.

Main Technological Pathways

There are various technological pathways for producing low-carbon hydrogen:

- **Green Hydrogen:** Produced through electrolysis powered by renewable energy, green hydrogen holds significant promise and is supported by regulations in various regions. However, challenges related to technology maturity, cost and scalability need to be addressed.
- **Blue Hydrogen:** Produced from natural gas with carbon capture and storage (CCS), this method is gaining traction due to its proven technologies and lower cost. It can be seamlessly integrated into existing industrial environments, maximizing benefits and synergies in infrastructure development.
- **Turquoise Hydrogen:** Produced through methane pyrolysis, which yields solid carbon as byproduct, this method offers advantages in areas with limited CCS infrastructure and is growing in scale.

Not a single definition of “green” or “blue”; most markets are open to LC H_2 due to its competitive advantage vs green. CC infrastructure is critical.

Low Carbon (LC) Hydrogen definition (kg of CO_2/kg of H_2)	
Japan	4
South Korea	4
China	4.9
United Kingdom	2.4
EU 27	3.38
India	2
Brazil	7
Argentina	4.1
Saudi Arabia	3
United Arab Emirates	3
Qatar	3
United States	2.5-4
Canada	4

Regulatory and Economic Considerations

Regulations and economic incentives are pivotal in accelerating low-carbonhydrogen technologies. The definition of low-carbon hydrogen may vary by region or country, directly influencing the choice of production methods. Regulations also influence whether the focus is on promoting the production of low-carbon hydrogen or decarbonizing industries that utilize hydrogen molecule. For example, North America’s 45V tax credit used to promote the production of low-carbon hydrogen, while Canada’s carbon tax incentivizes the reduction of carbon emissions in industry, favoring the offtake of low-carbon hydrogen.

Decarbonizing Existing Hydrogen Assets

Existing hydrogen plants are significant contributors to global emissions, accounting for approximately 2.5% of total emissions. Decarbonizing these assets is crucial for both environmental and business reasons. Increasingly stringent legislation is driving the need to reduce carbon emissions through incentives and penalties for noncompliance. Decarbonizing existing asset operations will help establish a low-carbon hydrogen ecosystem, extend asset life and ensure continued operational permits.

Optimizing Existing Hydrogen Plants

Technip Energies employs several strategies to optimize the operations of existing hydrogen plants, aiming to reduce the carbon emissions and enhance efficiency:

1. **Process Intensification:** Using technologies and optimization know-how to minimize feedstock consumption and increase hydrogen throughput. Proven recuperative reforming technologies such EARTH® and TPR® allows carbon intensity reduction up to 20% or additional hydrogen capacity up to 30%.

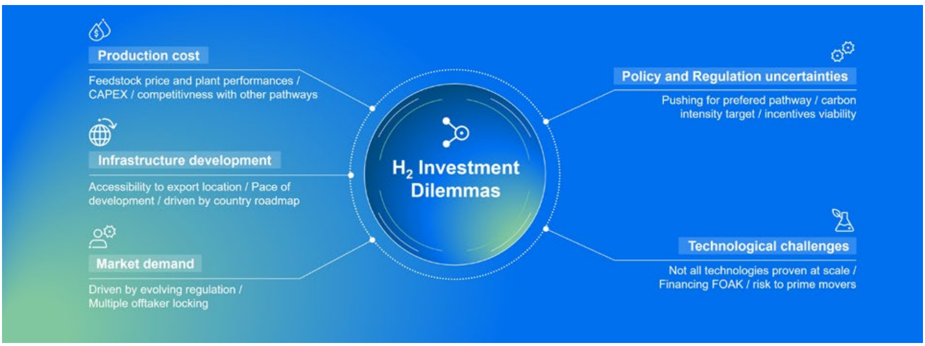
2. **Hydrogen Firing:** Employing low-carbon hydrogen as a fuel in the reforming process can significantly decrease overall emissions. The successful implementation of the LSV® burner in steam methane reformers (SMR) and olefin production crackers not only lowers carbon emissions but also reduces NOx emissions, helping plants meet air quality regulations. Since hydrogen firing extends beyond the hydrogen production unit's battery limit, full integration with the industrial plant can optimize synergies in production and firing demand, advancing industry decarbonization efforts.

3. **Carbon Capture:** Implementing pre-combustion and post-combustion carbon capture technologies can significantly reduce emissions. Pre-combustion capture, which can achieve up to 70% carbon capture rates, is preferred due to its maturity, cost effectiveness and well-established operation in syngas plants (with over 50 units designed by Technip Energies). Combining technologies such as hydrogen firing can reach up to 99% carbon capture rates. Post-combustion capture is also a viable option, allowing up to 95% carbon capture rates, but it results in larger and less cost-effective units to achieve the same target. Finally, cryogenic carbon capture may be an option when liquefied CO2 is the goal.

Technip Energies online tool for H2 plant optimization

Project Development and Delivery

Developing large-scale hydrogen projects is complex, requiring a holistic approach that integrates technology selection, project delivery, and at times operational management. This complexity is even more pronounced for new hydrogen plants, particularly blue hydrogen projects that demand careful consideration of cost, technology selection and offtake.



Affordability

Addressing the energy trilemma requires a blend of innovation, proven solutions and a reliable partner to bridge the gap between sustainability, affordability and energy security. While regulations play a crucial role in aligning production with demand, the energy transition cannot progress effectively if governments through incentives and end-users cannot afford low-carbon molecules and end products. Therefore, cost optimization is critical for both existing and new hydrogen plants. Technip Energies leverages its expertise in technology selection and project delivery excellence to build comprehensive low-carbon hydrogen solutions involving:

1. **Leveraging Upscaling Benefits:** Building larger plants reduces investment costs per target molecule and improves efficiency. Larger plants benefit from economies of scale, lowering the overall cost per unit of hydrogen produced. By leveraging SMR up to 300 kNm^3/h and ROX™ (based on ATR technology) up to 600 kNm^3/h (single line capacity), we optimize both operational and installation costs.
2. **Securing Construction Costs:** Optimizing supply chain management and construction execution to control costs is crucial. Technip Energies' mega project delivery experience indicates that a fit-for-purpose modularization strategy helps streamline construction processes, preventing time and cost overruns and securing CAPEX at an early stage of the project phase and during execution.
3. **OPEX Optimization:** Utilizing proven technologies to ensure best-in-class efficiency and reduce feedstock costs, which typically represent more than 80% of OPEX. Proven technologies also enhance reliability, availability and flexibility, reducing operating and maintenance costs.

Lifecycle Optimization

Maximizing the lifecycle performance of hydrogen plants is essential for maintaining low operating costs. Technip Energies offers digital tools to monitor and optimize plant performance, ensuring long-term efficiency, cost-effectiveness and minimized carbon intensity. These tools enable plant operators to make informed decisions about maintenance and upgrades, further reducing costs over the plant's lifetime.

The transition to a low-carbon hydrogen economy depends on the widespread adoption of affordable and sustainable solutions. Technip Energies remains steadfast in its commitment to advancing cost-effective, low-carbon hydrogen production through innovative technologies and end-to-end project expertise. The future of hydrogen will be defined by the ability to strike a critical balance between sustainability, energy security, and affordability—an ambition Technip Energies is proud to lead..