Izzet Bensusan

Founder & Managing Partner

Captona

An Overview & Outlook on Hydrogen

A Proven Vessel To Strengthen & Support Our Energy Transition

We are excited about the diversity of applications for hydrogen, especially when looking at the global transition to a cleaner energy economy. This article aims to harness our enthusiasm and shares insight into how impactful hydrogen – and emerging development of green hydrogen – will be in the upcoming decades.

Key Article Insights:

- Currently, hydrogen is used globally as an industrial feedstock, with 98% of hydrogen production coming from fossil fuels
- Green hydrogen can replace gray hydrogen in current industrial use, provide alternative fuels for the transportation sector, and support the transition to a 100% clean energy grid
- Clean hydrogen factors into nearly all net-zero carbon pathways, and thirty-nine countries have already established hydrogen strategies
- A significant capital gap still exists between the current $160 billion in direct investments for the hydrogen supply chain and what's projected to be needed to reach a net-zero carbon economy by 2050

Hydrogen may be the Swiss Army Knife of the energy transition: versatile, reliable, and packed with potential.

Hydrogen is also extremely abundant. It is, however, only found in nature as part of compounds, such as water and methane, so it takes energy to isolate and produce pure hydrogen.

While there's a growing buzz around hydrogen, using it is nothing new. The hydrogen fuel cell was proven effective in the 19th century, and a mature hydrogen market currently exists for industry. What is relatively new is the dynamic opportunities for clean hydrogen.

Clean hydrogen provides incredible potential to decarbonize hard-to-abate sectors and complement other energy initiatives as we develop a clean energy economy. With countries worldwide pledging emissions reductions strategies, clean hydrogen will experience booming demand as it proves to be a critical component for our energy transition.

What Are The Different Colors of Hydrogen

At standard conditions, hydrogen is a colorless, odorless, highly combustible gas. Once produced, hydrogen will always have those properties.

The color spectrum of hydrogen defines how the molecule *was* produced. The different production methods vary in their carbon intensity.

- **Black & Brown Hydrogen**

  This is the dirtiest production method, as both black and brown hydrogen are derived from coal — black hydrogen from bituminous coal and brown hydrogen from lignite. Producing black or brown hydrogen releases carbon dioxide and carbon monoxide directly into the atmosphere.

- **Gray Hydrogen**

  Produced from natural gas, this is the most abundant type of hydrogen on the global market. Steam-methane reforming is the most common gray-hydrogen production process, which involves isolating hydrogen through a reaction with natural gas, steam, and heat. Although natural gas is less carbon intensive than coal, it is still a fossil fuel. That makes it a non-renewable source, and using it to produce hydrogen also releases greenhouse gases

- **Blue Hydrogen**

  This is a low-carbon intensity hydrogen production process. Similar to gray hydrogen, blue hydrogen is produced from natural gas, yet the process incorporates Carbon Capture, Usage, and Storage (CCUS) technology to mitigate the amount of carbon expelled to the atmosphere.

- **Green Hydrogen**

  Green hydrogen is produced from renewable energy sources — like wind and solar power — making it the cleanest hydrogen. Isolating the hydrogen involves electrolysis, a process that splits water into its constituent oxygen and hydrogen atoms.

Gray hydrogen is the most common; green hydrogen is the most virtuous. Fossil fuels currently dominate hydrogen production, which leaves a lot of opportunity for clean hydrogen — both blue and green — to decarbonize industry.

The Current Hydrogen Landscape

Hydrogen is an internationally traded commodity that's used as an industrial feedstock for a number of applications: oil refining, chemicals production, steel manufacturing. The 2020 global demand for hydrogen was roughly 91 Mt, of which: 40 Mt was used in oil refining, 33 Mt in ammonia production, 13 Mt in methanol production, and 5 Mt for direct reduced iron (DRI) applications in steel manufacturing.[1]

Gray hydrogen dominates the market, making up roughly 76% of all hydrogen produced globally. Coal-based hydrogen follows with 22% of global hydrogen production, and only 2% of the world's hydrogen is produced via electrolysis.

The varying economics of the different hydrogen production methods is largely based on fuel costs and infrastructure, with unabated fossil fuels being cheaper than using CCUS or renewable energy technologies.[2]

- gray hydrogen: $0.90-$1.78 per kg
- blue hydrogen: $1.20-$2.60 per kg
- green hydrogen: $3.00-$8.00 per kg

This cost disparity shines light on the need for policy and investment to support the scaling of blue and green hydrogen. There's been dramatic cost reductions in renewable energy over the past decade, and it's highly likely that clean hydrogen will experience a similar trend as renewable energy costs continue to decline and clean hydrogen production ramps up.

Governments, businesses, and savvy investors recognize hydrogen's versatility and potential within a carbon reduction strategy, which has led to momentous surge in policy adoption and funding for clean hydrogen development.

The recently passed US Infrastructure Bill allocates considerable resources to green hydrogen research and development. The bill's Clean Hydrogen Research and Development Program (Section 40313) includes $8 billion to build out a network of green hydrogen hubs. To support development, $500 million is allocated for grant projects or cooperative agreements with entities capable of developing demonstration projects that advance clean hydrogen production, processing, and storage.

The bill focuses on advancing clean hydrogen technologies for commercialization and application in transportation, utility, industrial, commercial, and residential sectors. The aim is to lower costs and increase efficiencies of green hydrogen technologies to make it a more cost-effective solution.

[1] IEA. (2021, November). *Hydrogen*. https://www.iea.org/reports/hydrogen

[2] Ochu, E., Braverman, S., Columbia Center on Global Energy Policy, Smith, G., & Friedmann, J. (2021, June 17). *Hydrogen Fact Sheet: Production of Low-Carbon Hydrogen*. Https://Www.Energypolicy.Columbia.Edu/Research/Article/Hydrogen-Fact-Sheet-Production-Low-Carbon-Hydrogen. https://www.energypolicy.columbia.edu/research/article/hydrogen-fact-sheet-production-low-carbon-hydrogen

The United States is one of many countries investing in clean hydrogen. Globally, there is an estimated $70 billion in public funding to support the hydrogen transition.[3]

The Potential of Clean Hydrogen

Clean hydrogen (both blue and green) has amazing potential to decarbonize industry and also support the larger transition to a clean energy economy. In almost all pathways to net-zero carbon, clean hydrogen plays a critical role.

Hydrogen's versatility makes it suitable for a wide range of applications, but that won't make it the best option in all settings. Clean hydrogen will be critical for those processes which already use hydrogen, and it will also be an integral solution for those applications with limited fuel alternatives, such as steel manufacturing, shipping, and aviation.

- **Replace gray hydrogen used in industry**

  Hydrogen — primarily gray hydrogen — is used extensively in a number of industrial processes, primarily oil refining, chemicals production, and steel manufacturing. Clean hydrogen can offset gray hydrogen used in these applications. At this initial stage of the transition, this utilization will be more economic than introducing clean hydrogen into sectors in which it isn't already present.

- **Complement the transportation sector**

  There's been an increase in governmental commitments to phase out sales of new internal combustion engine (ICE) vehicles. Both battery electric vehicles (BEV) and hydrogen-powered fuel cell electric vehicles (FCEV) are viable alternatives to the traditional ICE vehicle. These alternative vehicles produce zero tailpipe emissions, and a recent test drive in a Toyota Mirai showcased the FCEV traveling 845 miles on a single tank of hydrogen gas.[4]

  Hydrogen fuel also serves as a promising solution to decarbonize long-haul trucking, shipping, and aviation. Heavy-duty trucks can convert from diesel to hydrogen fuel cell. The shipping industry can adopt clean ammonia as a reliable fuel source. The aviation industry can utilize green hydrogen as a key precursor ingredient for synthetic jet fuels and derivatives.

[3] McKinsey and Company & Hydrogen Council. (2021, February). *Hydrogen Insights*. Hydrogen Council.

[4] Pattni, V. (2021, October 11). *Toyota Mirai drives 845 miles on a tank of hydrogen, sets world record*. Https://Www.Topgear.Com/Car-News/Electric/Toyota-Mirai-Drives-845-Miles-Tank-Hydrogen-Sets-World-Record. https://www.topgear.com/car-news/electric/toyota-mirai-drives-845-miles-tank-hydrogen-sets-world-record

- **Strengthen the power sector**

    Green hydrogen presents a solution to one of the largest challenges facing a renewable energy powered grid: energy storage. Because renewable energy sources like wind and solar are intermittent and non-dispatchable, it's critical to have storage solutions for times of over-production and under-production.

    Renewable energy sources can power an electrolyzer that produces hydrogen. This hydrogen can then be stored to provide emergency backup power later on, be dispatched for peak demand shaving, or it can be transported elsewhere for other industrial use.

Hydrogen has numerous other potential applications — such as providing heat to industry and buildings — that could prove to be viable alternatives should the economics work out.

The Investment Outlook

Momentum for hydrogen is surging. Not only is demand for its current industrial applications projected to grow, but hydrogen will also be utilized in other sectors to help decarbonize the global economy and balance out the energy grid.

More than ninety countries have made net-zero carbon commitments, and thirty-nine countries have established hydrogen strategies. In addition, the number of proposed hydrogen projects in 2021 doubled that of the previous year, representing $160 billion in direct investments towards the hydrogen value chain.[5]

Despite this positive momentum, significant acceleration is needed to reach a net-zero carbon economy by 2050. A 2021 report by McKinsey & Company calculates that there is a $540 billion capital gap through 2030 between what's currently proposed and where the hydrogen landscape should be to maintain pace with a 2050 net-zero target.[6]

Realizing hydrogen's potential will take a concentrated and collaborative effort between policy, business, and private investment. To maximize impact and get on track to meet 2030 targets, focus should be on:

- optimizing clean hydrogen production at industrial ports
- building on existing infrastructure, such as gas pipelines, to Accommodate for clean hydrogen penetration
- expanding use of hydrogen-powered vehicle fleets

[5] McKinsey and Company & Hydrogen Council. (2021b, November). *Hydrogen for Net-Zero*. Hydrogen Council.

[6] McKinsey and Company & Hydrogen Council. (2021b, November). *Hydrogen for Net-Zero*. Hydrogen Council.

Commercialization of equipment, widespread infrastructure improvement, and increased clean hydrogen production are all needed to reduce costs for clean hydrogen. A strong way to pursue that is to start by offsetting gray hydrogen in existing industrial applications. This will enable the economies of scale to introduce clean hydrogen to sectors and industries where it isn't already prevalent, such as in transport and the power sector.

Regardless of whether we rise to meet 2050 targets, demand for hydrogen will increase in the coming years. Alongside its demand in well established industrial processes, the urgency to address climate change will make hydrogen a pivotal part of our clean energy transition.

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