

How can hydrogen spark the next zero-emissions revolution?

Strategy realized



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How can hydrogen spark the next zero-emissions revolution?

New technology, lower costs and the right incentives can position green hydrogen to play a much bigger role in global decarbonization.

Three questions to ask

1. What is driving the new hydrogen business imperative?
2. Who stands to benefit most?
3. How can companies accelerate the shift to hydrogen?

After decades of debate about the viability of earth's most abundant chemical element as a clean energy source, hydrogen is finally getting some attention.

For years, fossil fuels – wood, natural gas, oil and electricity – dominated the energy discussion. More recently, in the race toward decarbonization, green hydrogen has been largely dismissed as a viable option, either because of cost, technology or safety. Instead, most of the green energy effort has focused on solar, wind and geothermal. However, to meet international energy decarbonization targets, countries will have to achieve massive electrification through renewable energy systems (RESs).

As technology advances and costs come down, green hydrogen has the potential to play a much bigger role in reaching the global goal of a sustainable, green society.

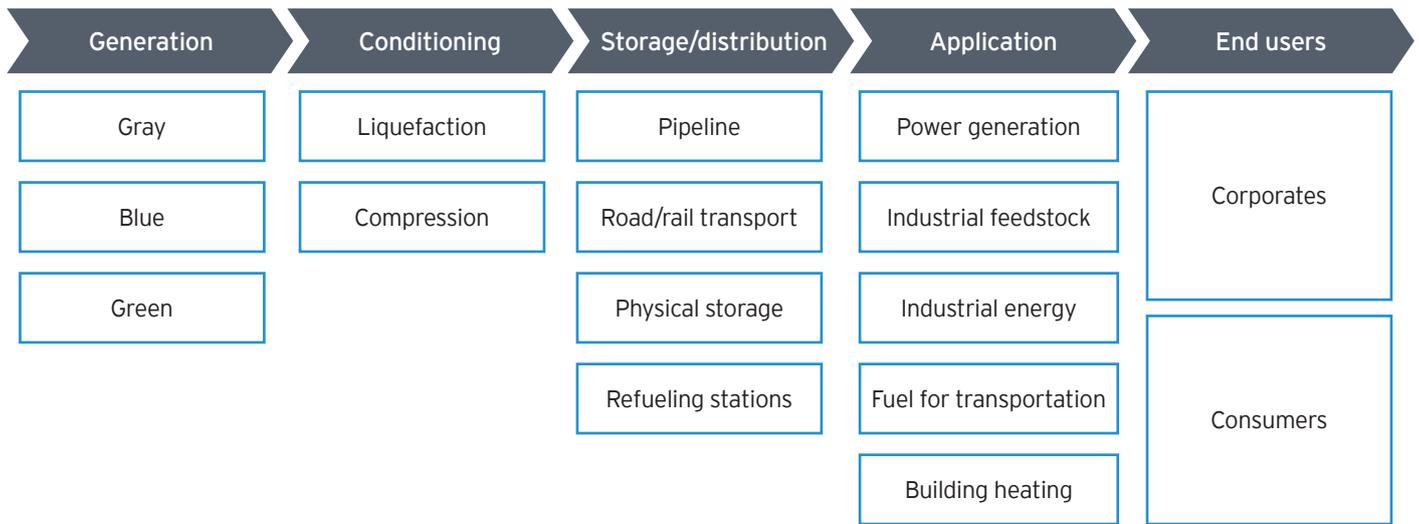


Business opportunities abound for stakeholders across the value chain

Hydrogen is already in use in industrial applications (either as-is or through conversion into other elements as ammonia). Therefore, there is already a value chain in place

based on production (mainly based on steam reforming or oxidation of hydrocarbons), virtual pipeline (trucks) and storage close to industrial plants.

Figure 1: Overview of hydrogen value chain



Source: EY-Parthenon analysis



However, the need for greener generation, expected growth in traded volumes, and new and increasing applications will require an evolution in the sector's current configuration, bringing several opportunities for investment across the value chain, including:

- ▶ New technologies for hydrogen production
- ▶ New business models and solutions for transportation and distribution
- ▶ New applications as a green energy source

If achieved, green hydrogen can help to decarbonize a variety of sectors and create numerous business opportunities across the value chain, from power generation to transportation to energy to industrial feedstock.

Figure 2: H2 applications

Power generation and storage	H2 as fuel for transportation	H2 as feedstock for industry	H2 as energy source for industry	Gas for heating buildings
Power generation	Public refueling station	Ammonia production	Gas burning	Gas for heating and buildings
Power storage (backup power)	Industrial refueling station	DRI ¹ production	Heating and drying	
Power trading		Oil refining		

¹ Direct reduction in iron (DRI)



Hydrogen generation comes in three shades, but only one is green

As an unlimited resource, hydrogen has the potential to power the world to infinity. Among its many advantages, hydrogen can be produced anywhere from a variety of resources for use either on-site or through distribution to a destination. Further, when combined in a combustion cell with oxygen, it produces energy in the form of electricity with a strong improvement on greenhouse gas emissions.

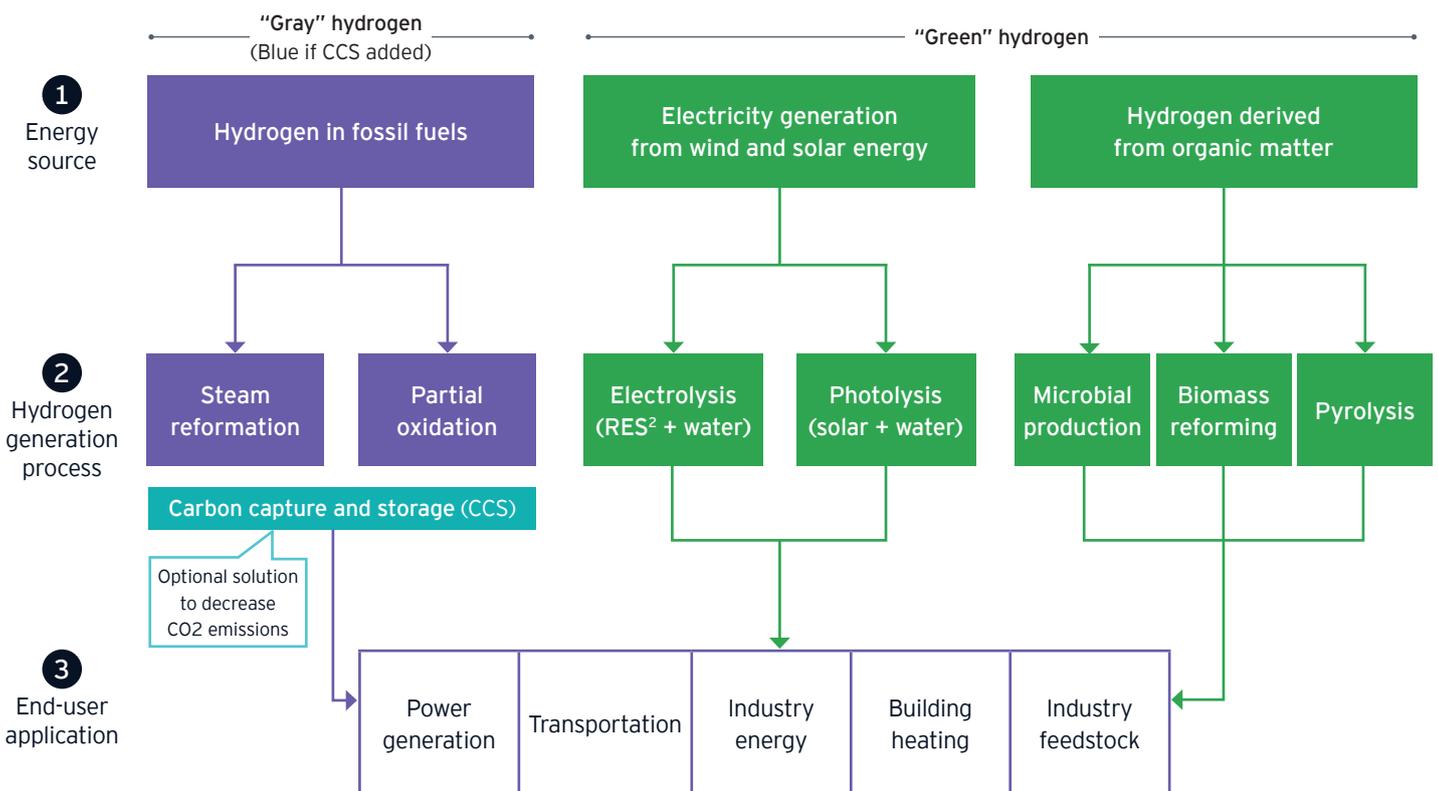
However, while it produces zero emissions at its end point, how green hydrogen is depends on the fuels used to make it.

The decarbonizing power of hydrogen relies primarily on its production method and on the natural resources that go into its production.

- ▶ Hydrogen is classified as “gray” if it uses a fossil fuel as a source.
- ▶ It is named “blue” if carbon capture and storage (CCS) solutions are in place when using fossil fuels, to contain carbon emissions emitted from the production process
- ▶ Hydrogen is defined as green if it is generated from water and renewable energy to power the electrolyzers, making the process completely green and sustainable.

Almost all of the hydrogen produced today is gray hydrogen and is predominantly used to produce ammonia and fertilizer, and refine oil.

Figure 3: Hydrogen gray, blue and green



² Renewable sources

There are three business models to distribute green hydrogen

Although there are several ways to produce green hydrogen, electrolysis offers the widest array of practical applications. However, the biggest opportunity lies in green hydrogen generation and distribution.

There are three ways green hydrogen can be generated, depending on how end-users plan on consuming it.

1. On-site production: in an on-site plant model, the end-user installs and operates the technical solution to generate green hydrogen at the point of use, employing renewable power generated on-site.

- ▶ **Benefit:** no transportation costs and no transportation infrastructure needed.
- ▶ **Detriment:** small production capabilities; need to have a balance between generation capacity and required volumes.

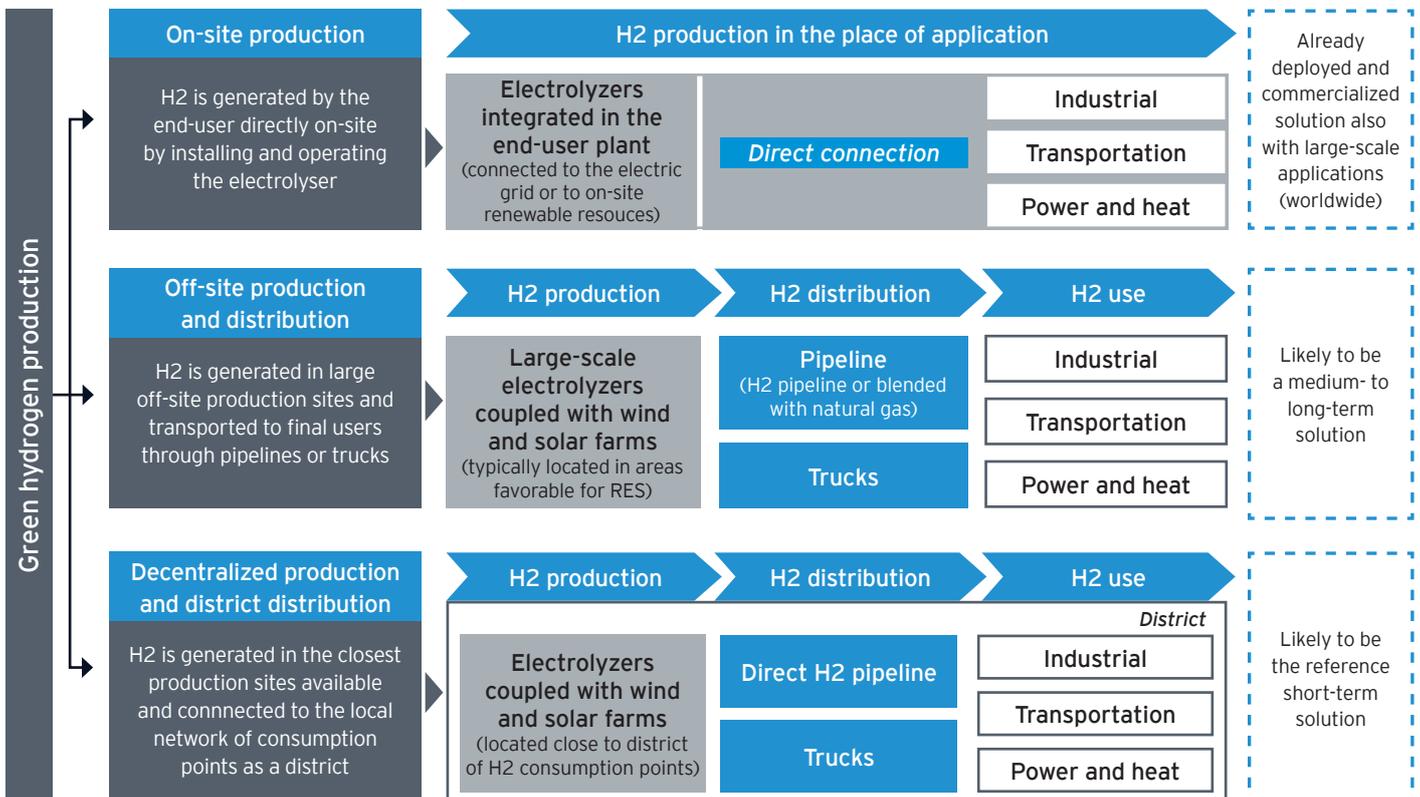
2. Off-site production and distribution: in an off-site plant model, power and utilities companies generate green hydrogen at large off-site production plants and transport the gas directly to the consumer leveraging different channels (e.g., pipeline, trucks).

- ▶ **Benefit:** mass consumer distribution, lower production cost due to economies of scale.
- ▶ **Detriment:** infrastructure as a project enabler.

3. Decentralized generation and district distribution: in this hybrid model, a near-to-end-user diffused system of electrolyzers is hooked up to an existing electrical grid powered by renewables. A local grid is developed to serve a district of consumers.

- ▶ **Benefit:** lower production cost due to economies of scale, limited time to develop the hydrogen grid.
- ▶ **Detriment:** need to collect consensus to increase local volume consumption.

Figure 4: Green hydrogen generation - three supply chain models available



Source: EY-Parthenon analysis

The challenge: green is great, but it comes at a cost

The biggest barrier in turning gray hydrogen into green hydrogen and expanding its industrial and commercial use is cost. Currently, green energy is prohibitively expensive when compared to the production of gray or blue hydrogen. Three factors may contribute to decrease the important production cost gap.

- 1. The evolution of the electrolyzer cost.** Technology CAPEX needs to decrease by 60-70%. This is in line with the cost projections of the technology producers, which are expecting strong savings by the economies of scale of large factories planned and the learning curve they are gaining.
- 2. Decline in renewables cost.** Energy consumed during the conversion of hydrogen is a key contributor of the running costs and needs to decrease by half. This should be reachable as well considering the path of LCOE of renewable technologies as wind and solar.
- 3. Increase in CO2 costs.** For the countries where an emission trading scheme is in place, the cost of CO2 emissions is expected to increase by 50% over the next 10 years. As a cost applied to gray hydrogen technology and natural gas, these rising costs will help to accelerate the cost competitiveness of green hydrogen.

Hydrogen has a wide range of applications: it can be used as an energy vector (both to be burnt and converted into heat or re-converted into electric power), as a chemical element (and therefore feedstock for industrial applications) and finally as a gas with special features.

To cluster all the potential application and uses across several industrial sectors, we identified five groups, based on the underlying need that the gas can address.

- 1. Power generation:** through the opposite conversion used to produce it (electrolysis), hydrogen can be reconverted into electric power. In this way it can provide energy when needed; considering the fact that is long-lasting and reliable, it is a new solution to address the need to store power. Moreover, it is also a way to stabilize discontinuous energy production flow and shift over time, as in the case of renewable energy generation.
- 2. Fuel for transportation:** among the utilization close to consumer applications, hydrogen can be used to supply energy for cars and other transportation vehicles.
- 3. Feedstock for industry:** apart from being a gas able to become an energy source, hydrogen is a chemical element applied in several industries for its transformation power. Among the most known sectors that are already using it in their process flow are refining and steel production.
- 4. Energy source for industries:** hydrogen can be burnt to produce heat as a substitute of natural gas. Critical part is that features are different (e.g., density, heating power) but with either a retooling or an investment on the equipment replacement is feasible. Implications are clear from an environmental perspective, with a strong cut on greenhouse gas emissions.
- 5. Energy source for heating buildings:** in parallel to what has been just described for industries, gas hydrogen can be used to heat buildings (residential buildings, schools, hospitals etc.)

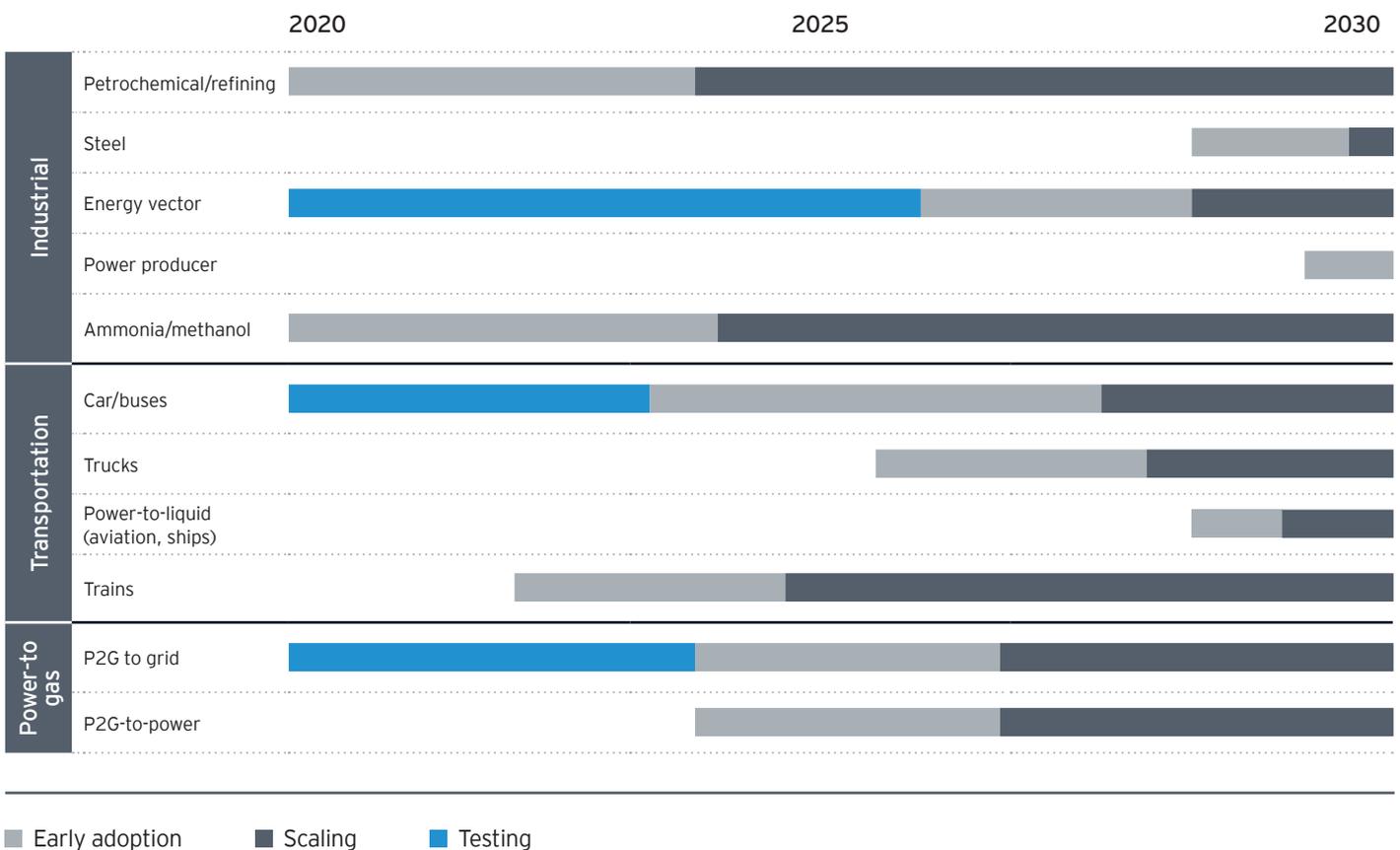


Without government incentives, it will take at least until 2030 before green hydrogen becomes economically competitive with other hydrogen production methods.

The maturity level of these five applications varies a lot. In all the cases where hydrogen is already used as an input to the process, conversion into green hydrogen requires less investments and the gap in price to fill is smaller. Therefore, an earlier adoption is planned.

On the flip side, conversion of natural gas into hydrogen is a milestone that stands further in the future. Despite the largest impact on emission and the extremely large addressable market, there is a long way to go before green hydrogen becomes as competitive as natural gas.

Figure 5: Timing of expected rollout by application



If green hydrogen won't become cost-effective until 2030, why consider it now?

Despite the higher cost, demand is growing for green hydrogen. Based on an EY-Parthenon study, the forecast market size for green hydrogen production by 2030 should reach almost 140 GW of installed capacity; this implies an incredibly high expansion, considering that as of 2020 the cumulative installed capacity is lower than 1 GW.

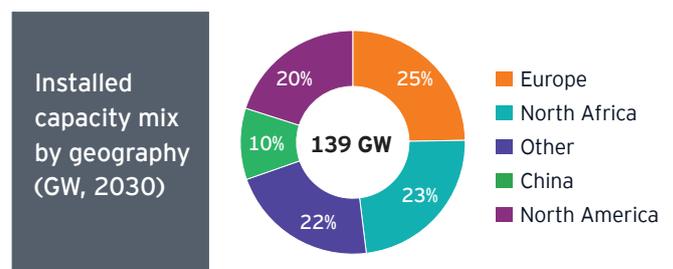
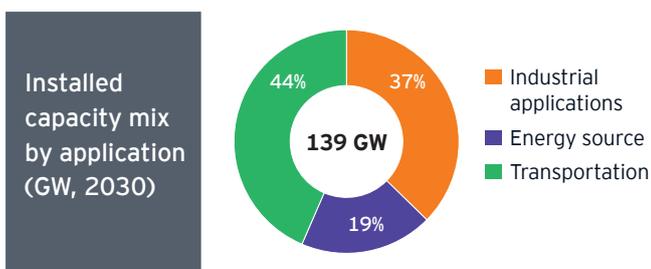
In terms of applications, energy source (that includes both the applications of power-to-grid and power-to-power) is expected to become the most relevant, and is planned to accelerate in the second half of the period. Capacity for industrial applications, with a focus on on-site installed capacity, and for transportation do have a relevant weight as well.

In terms of geographies, there is a good balance between different regions of the world: in Europe, China, North Africa and USA high ambition on the topic are expected.

By definition, this is an average view of an extremely wide range of scenarios. It is still too early to make firm projections of this market. The picture is in continuous evolution: the national and regional targets are strongly linked by the energy agenda of the governments; we foresee a rapid and continuous evolution of the situation mapped.

To achieve these ambitious goals, countries around the world have to take material steps to reduce their greenhouse gas emissions. In 2019, the European Union introduced legislation (European Green Deal) that would aim to reduce the EU's greenhouse gas emissions to between 50% and 55% below 1990 levels by 2030. China, meanwhile, has taken steps to require "480 million tons of carbon capacity from steel production to meet 'ultra-low emission' standards by 2020." It is also upgrading its power grid to reduce its reliance on coal for energy production. In the US, California has led the way, with the Global Warming Solutions Act of 2006, which set a statewide limit on greenhouse gas emissions. In 2016, the state aimed higher, raising the goal for greenhouse gas emission reduction to 40% below 1990 levels by 2030.

Another reason organizations are considering green hydrogen now versus 10 years from now is that by being a pioneer in the green hydrogen arena, they see opportunities to seize a competitive advantage. Technology companies have been the first to move, motivated to be early to market with better, more efficient, more cost effective electrolyzers and fuel cells. Private equity firms with significant amounts of cash on hand are also taking bets on green hydrogen through mergers and acquisitions – a clear sign of booming interest.



What's the reason for the rise in demand? Government and corporate decarbonization initiatives play a key role, as do government and corporate targets for hydrogen-powered vehicles.

In December 2015, 194 countries signed the Paris Agreement, which pledges to keep a global temperature rise this century below 2 degrees Celsius and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius. The agreement also requires all signatory countries to make their best effort in dealing with the impacts of climate change.

Although green hydrogen costs have not yet reached parity with gray and blue hydrogen, for an increasing number of organizations there is enough of an incentive to climb aboard the green hydrogen train now.

Some have already begun integrating green hydrogen into their strategic agenda. For those looking to get started, leaders will want to seek the answers to the following questions:

- ▶ What is our green hydrogen value proposition?
- ▶ Do we have a solution ready or do we have to implement?
- ▶ Are there new market opportunities that require new support or infrastructure? Are there new business ideas or business models that we need to consider?

Five factors can accelerate green hydrogen adoption

For those looking to capitalize on green hydrogen, there are five factors can help to accelerate green hydrogen adoption.

- 1. Acceleration in cost reductions.** As previously mentioned, forecasts show that it will take at least 10 years to reach cost parity with gray hydrogen. An evolution in production techniques and in economies of scale can accelerate this tipping point.
- 2. Infrastructure.** Another component of the full cost of hydrogen is the complexity of connecting large production points with a decentralized consumption. Countries with natural gas pipelines can accelerate the blending solution with methane to start increasing consumption volumes, driving demand and production. But, there is strong complexity behind this solution. A short-term alternative is to develop H2 district to connect a bundle of consumption points with one or more production points, limiting the complexity.
- 3. Regulation and incentives.** Often, one of the best tools to accelerate green energy adoption is regulation and incentives. It worked for solar and wind, where incentive schemes kicked-off the installation, driving demand and cost decreases that enabled renewables to reach grid parity within 20 years. A similar approach can work for green hydrogen too. In 2017, Japan became [the first country to develop a hydrogen sector with its "Basic Hydrogen Strategy."](#) In November 2019, Australia released a National Hydrogen Strategy. In July 2020, the EU released its three-phase hydrogen strategy as part of the European Green Deal. Also, in July 2020, the US Department of Energy's Office of Fossil Fuels released a hydrogen strategy focused on research, development and use of hydrogen technologies. To see success in the execution of their strategies, countries would benefit from pairing their strategies with incentives and subsidies.

- 4. Commitment from operators.** Operators all along the energy supply chain are beginning to turn their attention toward green hydrogen. Big energy players becoming early adopters of green hydrogen have the potential to accelerate generation, storage and distribution capabilities.
- 5. Robust communications campaign to attract consumers.** One of the biggest barriers to adoption is the myth that hydrogen is dangerous. In an anonymous social media survey highlighted in a [World Economic Forum article](#), 49.5% of respondents thought hydrogen was "generally safe," while 31.4% thought it was "generally dangerous." Apart from such sensational disasters as the Hindenburg and the Space Shuttle Challenger, there is a perception that hydrogen is highly flammable and that if used in such applications as fuel cells for vehicles, could result in an explosion in the event of a collision. An information campaign that dispels the myths of hydrogen's dangers and highlights the benefits of green hydrogen in achieving a decarbonized, green society, could motivate consumers to push for faster adoption of green hydrogen.

Green hydrogen's time has come

For the past five years, electric vehicles (EVs) languished in obscurity, gaining little traction and constantly missing forecasted adoption rates. Then suddenly, a network effect started. [By 2025, fully electric models of most vehicles are forecasted to become competitive against their fossil-fuel cousins.](#)

Green hydrogen is poised to follow a similar path. After decades of languishing in relative obscurity, technology advances and diminishing renewables costs could soon make green hydrogen the new darling of decarbonization.

Organizations that are currently using gray hydrogen are particularly well-poised to take advantage of the green hydrogen wave as first mover. Organizations that can benefit from a green hydrogen revolution are developing strategies and testing business models. But even organizations that have no hydrogen agenda, but want to reduce their carbon footprint, can be thinking about green hydrogen now.

To borrow a phrase from the film *Field of Dreams*, "If you build it, they will come." The more the focus of organizations around hydrogen the faster the path to make it attractive and competitive, the faster consumer demand will raise. To be a builder at the right time, you need to pour the foundation today.



Authors



Giacomo Chiavari

Partner

EY Advisory S.p.A.

Italy

giacomo.chiavari@parthenon.ey.com



Matteo Savoldelli

Senior Manager

EY Advisory S.p.A.

Italy

matteo.savoldelli@parthenon.ey.com



Matteo Foffano

Manager

EY Advisory S.p.A.

Italy

matteo.foffano@parthenon.ey.com

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