



# Green hydrogen, a catalyst for the energy transition



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Whether it is “grey”, “blue”, “yellow”, or “green”, hydrogen is the topic on everyone’s lips today.

While it is already widely consumed in many sectors, its use as a source of energy is only in its early stages. Its applications are as numerous as they are promising, most notably in the mobility sector.

For it to become the best facilitator for the transition towards a low carbon economy, many challenges still need to be met, starting with the mass production of a zero-carbon hydrogen which will require substantial investment in the coming years.

## Key takeaways

- ▶ A multipurpose gas with **outstanding energy properties**: per kilo, as it contains 2.2 times more energy than natural gas, 2.75 times more than petrol and three times more than crude oil.
- ▶ **Fast-growing worldwide demand** and solid prospects to **shift from carbon-intensive (grey) to renewable (green) hydrogen**.
- ▶ **Colossal investment requirements**: 280 billion dollars between now and 2030 in R&D, infrastructure, mass production<sup>(1)</sup>.
- ▶ A highly favorable political, regulatory, industrial and financial environment: standards, public sector investment, French pure players, etc.
- ▶ Multiple financing opportunities: infrastructure, equity, green bonds, etc.

## HYDROGEN, AN ENERGY CARRIER WITH A FUTURE

### A multipurpose gas

Today, approximately 70 Mt of pure hydrogen is produced, with the two main markets being **crude oil refining** (52%) and the **production of ammonia** (43%). When combined with other gases, hydrogen is also used in the **production of methanol, steelmaking, the food industry and glassmaking<sup>(1)</sup>**.

But as soon as it becomes “green”, hydrogen takes on **new applications** and stands out as one of the most **promising energy carriers**, as it can be used to stock and distribute energy.

Converted into electricity, heat or natural gas, it offers the opportunity to **harness surplus electricity generated from renewable energies, produce natural gas** without using fossil fuels, and provide the transport

sector with a **low-carbon and zero local pollution fuel**.

In the near future, low-carbon hydrogen could also replace its “grey” version in a move to **green industries** that today depend on hydrogen in their production processes (refining and ammonia) or substitute coke in steelmaking.



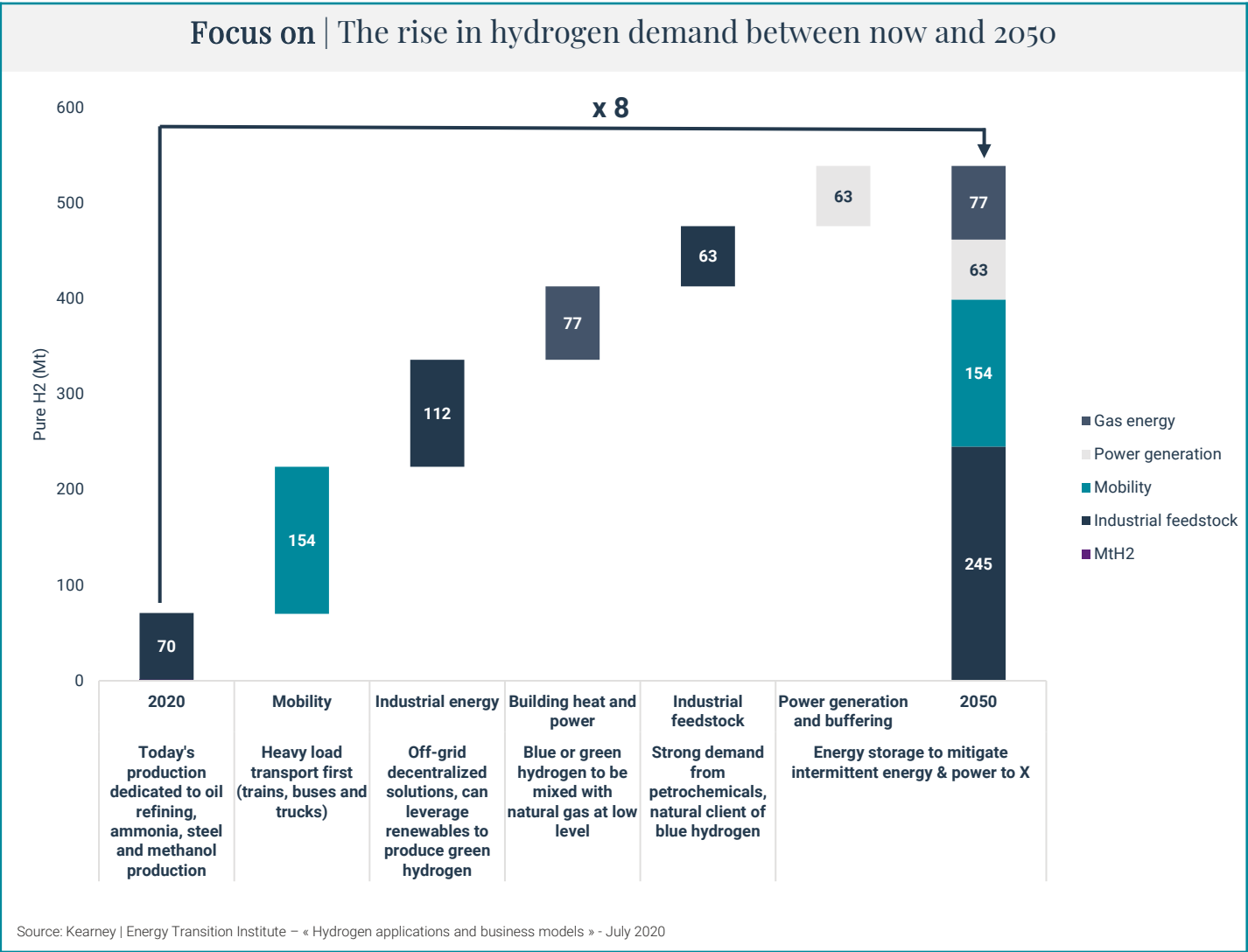
Strongly rising demand

Driven by the growth of its current applications on the development of new markets such as mobility, world demand for hydrogen could be multiplied by a factor of between 2 and 8 between now and 2050.

Depending on the scenario<sup>(1)</sup>, **mobility** could account for **36 to 165 Mt** of the market.

And by 2030, the **requirements for renewable hydrogen** (known as “green”) or **low carbon hydrogen** (“blue” or “yellow”) could make up between 10% and 20% of total demand, i.e., **between 11 and 22 Mt**.

This pathway, according to the Hydrogen Council, would require annual investment of around 20 to 25 billion dollars, representing **280 billion dollars between now and 2030**.





## WHY INVEST IN GREEN HYDROGEN

Is an “all green hydrogen future” a realistic proposition? In the current state of affairs, the answer is “no”, since substituting all the “grey” hydrogen produced today (approximately 70 Mt) with “green” hydrogen would mean supplying the equivalent of 3,600 TWh of renewable energy, or the annual amount of electricity generated in Europe.

Nevertheless, “green” hydrogen is destined to play a major role in the fight against climate change by offering low carbon solutions in three sectors which alone account for more than two thirds of global greenhouse gas emissions: transport, energy and industry.

### Greener transport

In the area of clean mobility, battery-powered electric vehicles cannot be the sole solution.

This is where “green” hydrogen, **as a storage vector**, provides an **additional solution** to cater to the growing electrification of the transport sector.

While batteries are perfectly suited to personal electric vehicles, they reveal their shortcomings (weight, bulk, charge time and range in particular) for so-called “**heavy-duty**” **transport** (heavy goods vehicles, buses, trucks, trains, boats) or **intensive-use modes** such as taxis which require fast charging.

In the latter case, fuel cell vehicles offer charge times of 3 to 5 minutes, comparable to the refueling time for a petrol or diesel car, while a battery-powered electric vehicle needs around half an hour on a fast charger.



“Green” hydrogen helps to decarbonise these forms of transport and also fulfils the requirements of the **logistics sector** (delivery vehicles, specialist handling machines) and vehicles that travel **repetitive circuits, round trips** and/or have easily **predictable consumption**.

In most transport segments, batteries and hydrogen do therefore not compete with one another.

Indeed, quite the opposite: progress in **battery electrochemistry** will contribute to further progress in **electrochemistry** **for electrolyzers/fuel cells** and vice versa which, ultimately, will accelerate the development of sustainable mobility.



## Renewable and storable energy

“Green” hydrogen offers a way of storing clean energy and distributing it on demand, thus resolving the **problems of intermittency of renewable energy** (most notably wind and solar power).

Furthermore, in **island situations**, where energy is often expensive and/or of fossil fuel origin, this combination of renewable energy and storage in the form of “green” hydrogen offers a sustainable and affordable alternative which previously did not exist.



Associated with carbon captured from factory emissions, **hydrogen becomes methane** and can replace natural gas.

In due course, a proportion of the gas in today’s networks could therefore be generated from green hydrogen.



## Decarbonised heavy industry

Whether green or grey, hydrogen has the same properties in industrial processes.

However, green hydrogen offers a way of **decarbonising high-pollution industries** (refining, steelmaking, industrial chemicals, etc.) which today use grey hydrogen and which, under increasingly stringent environmental regulations, will be obliged to reduce their carbon footprint.

“ The prospects of improving the hydrogen transformation chain’s energy efficiency could, in the coming years, significantly drive the volume of green hydrogen produced.



## Explainer | The differences between grey, blue, yellow and green hydrogen

### Carbon-intensive hydrogen, known as « grey » hydrogen

More than 95% of hydrogen consumed in the world today is extracted from fossil fuels, mainly natural gas (69%), under the effect of **steam reforming** - a technique that requires heating the gas-steam mix at a very high temperature: (between 700°C and 1000°C) – but also from coal (27%) by **gasification**. This production generates substantial carbon dioxide (CO<sub>2</sub>) emissions: **between 10** (for gas) **and 20 tonnes of CO<sub>2</sub>** (for coal) are emitted for each ton of hydrogen produced<sup>(1)</sup>.

The worldwide production of hydrogen is therefore **responsible for the emission of approximately 1 billion tonnes of CO<sub>2</sub> every year**, the equivalent of the emissions of Indonesia and the United Kingdom put together<sup>(3)</sup>.

Steam reforming is currently the cheapest process to produce hydrogen, with a cost evaluated at €1.5 per kilogram.

### « Blue » hydrogen

To decarbonise “grey” hydrogen, it is possible to capture the carbon dioxide emitted during steam reforming. This CO<sub>2</sub> can thus be used as a raw material in certain industries (for the production of foam for example).

Increasingly, it is also stored in empty former gas or oil pockets. With this technique, known as **CCS**, or **carbon capture and storage**, the grey hydrogen becomes “blue” hydrogen.

Adding a CSC plant next to a grey hydrogen plant **increases the production cost by approximately €1/kg**.

### Renewable hydrogen, known as « green » hydrogen and low-carbon hydrogen, known as « yellow » hydrogen

“Green” hydrogen is produced by **water electrolysis**, a process that consists of decomposing water (H<sub>2</sub>O) into dioxygen (O<sub>2</sub>) and dihydrogen (H<sub>2</sub>), using an electrical current.

- ▶ **If the electricity used for this process is of exclusively renewable** origin (produced, for example, by solar power, wind or hydroelectric plants), this hydrogen will be “clean” and referred to as “green”.
- ▶ **If it is produced by a substantial proportion of nuclear power**, the term used is “yellow” or “low-carbon” hydrogen, since the fossil fuel used in nuclear power, uranium, is a non-renewable resource.

Also worth noting is that green hydrogen can be produced from biomass, a process currently being tested in France, in Vitry-le-François in the Sarthe department, and in Strasbourg.

**With a cost of approximately 5 to 6 euros per kilogram, “green” hydrogen (just like “yellow” hydrogen), today remains four times more expensive than “grey” hydrogen - which explains why its worldwide production is as yet very marginal (less than 5%).**



## FINANCING THE DEVELOPMENT OF GREEN HYDROGEN

### A very conducive environment

Green hydrogen today benefits from a highly favorable environment in many countries, including France.

- **From a political viewpoint** (see box below), with substantial public sector investment in France (up to €7 billion between now and 2030 and many projects all over the country) and abroad – Germany, China, South Korea, the USA and Japan are among the countries leading the way and all have adopted a long-term strategy, with investments and a clear roadmap for hydrogen<sup>(4)</sup>.

- **From a regulatory viewpoint** on a European scale: with a CO2 emission ceiling for carmakers that is stimulating the sales of electric vehicles, and the introduction into force of the RED directive which requires fuel suppliers to offer at least 14% of renewable fuels.

- **From an industrial viewpoint** with the growth of many French and European pure players along the green hydrogen value chain (McPhy, Symbio, HRS etc.) but also large corporations that are showing their interest in the vertical (Air Liquide, EDF with Hynamics, Engie, Faurecia and Plastic Omnium, among others).

European expertise in electrolysis technology, fuel cells and hydrogen storage and distribution is a key marker to encourage government authorities to invest in retaining this leadership.

- **From a financial viewpoint**, with increasing interest from the financial community, in particular for companies with high added environmental value, as exemplified by the impressive rise in a share price such as McPhy (+840% in 2020).

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\*: In December 2018, the Renewable Energy Directive called "RED II" was published in the Official Journal of the EU, setting common objectives to be achieved in terms of renewable energy consumption.

### Focus on | A 7 billion euro plan <sup>(4)</sup>

In its **stimulus plan** in September 2020, the French government presented its **hydrogen roadmap** and its vision to make this gas "France's energy of the future".

**A plan amounting to €7.2 billion between now and 2030** (including 2 billion between 2020 and 2022), which should not only contribute to developing a profitable green hydrogen production sector, but also to making its use more widespread, in particular in the area of heavy-duty mobility.

This new plan follows on from the plan deployed by former Environment Minister Nicolas Hulot in 2018 – 100 million euros primarily channelled towards small experiments on a local scale. By releasing billions of euros of public sector funds, as Germany has already done and in coordination with Brussels, the French Government wishes to **help the companies in the sector to scale up** and shift from the R&D and demonstrator stage to that of industrial projects.

- The first chapter of the plan, which is the most immediate and most tangible, is devoted to **decarbonising hydrogen through water electrolysis**. The aim is to reduce the cost of this expensive and energy intensive technology by improving it and increasing volumes. €1.5 billion will therefore be devoted to the manufacture of electrolyzers, for a capacity of 6.5 gigawatts.
- Nearly one billion euros will be used between now and 2023 on the development of **hydrogen-powered heavy duty mobility** through several calls for projects (350 million euros for demonstrators, 275 million euros for regional experiments, for example).
- Finally, **aid for research and innovation** will also be boosted with an envelope extended to €650 million between now and 2023.



## Mirova's views on how to catalyse more private investment

### Strengthen public sector support

Given the **wide price gap between grey H2 and green H2**, stronger public sector support is required to make projects using green hydrogen **more "investable" and competitive**: for example, through a hydrogen feed-in tariff/contract for difference.

### Guarantee uses

**Private sector investors** in infrastructure projects also require **visibility as regards offtake**, in particular in terms of **price**.

They therefore need industrial partners to ensure that projects fulfil a **predictable** long term demand for hydrogen.

### Review CO2 prices

It is furthermore imperative that **the price of the tonne of CO2 be adjusted** to favour projects that emit the least CO2. Currently at around €35, the price of a tonne of CO2 needs to increase to €50 per tonne in the short term and even €100 by 2030 to encourage the funding of "green" hydrogen projects, which are the most virtuous.

### Control risks

As **several technologies** are in competition with one another, it is important to properly assess **the risks and opportunities** of each of them in the hydrogen value chain, in particular for electrolyzers, fuel cells and on-board storage.

For each project, it is thus essential to understand their final uses and constraints in the aim of appropriately **matching up technologies and projects**.

Cooperation also needs to be fostered between **all the key actors** in the hydrogen market (electrolyser manufacturers, refuelling station operators, manufacturers of fuel cells, storage solution equipment, etc) to increase the **energy efficiency of technologies and accelerate cost reductions**, two fundamental levers that will enable "green" hydrogen is to become competitive in the various use cases mentioned.

## Mirova's projects and actions

**Mirova can finance the hydrogen sector on different levels:**

- ▶ through its **energy transition infrastructure funds**, by investing directly in projects or unlisted companies,
- ▶ but also through its **Equity management activities** by buying into the capital of the sector's listed players;

- ▶ and finally, in the future, through its bond funds in the eventuality of **green bonds** being issued on the market with "green" hydrogen projects as underlying assets.

“The teams at Mirova are closely monitoring the sector and collaborating to contribute to make “green” hydrogen a genuine asset in the energy transition.



In January 2021, Mirova announced **its first investment in “green” hydrogen** to support the development of **Hype**, the first fleet of hydrogen-powered taxis in France and Europe.

The purpose of this funding is to support Hype in its growth by increasing its fleet from 100 to 700 taxis, available in the Paris region.

This complex project offers two major benefits:

- ▶ **improve the learning curve for manufacturers and investors** on the production of “green” hydrogen and on the use of fuel cell-powered taxi vehicles;
- ▶ **make a powerful positive impact** by removing 700 diesel vehicles from the Paris automotive fleet, thus reducing CO2 and particulate matter emissions.

## Proof by example | Hype, the hydrogen mobility pioneer



### HYPE

**A pioneer in hydrogen mobility** with the world’s largest hydrogen-powered taxi fleet, Hype has shifted up another gear by raising 80 million dollars from four new financial partners, including Mirova. This operation will help accelerate the deployment of hydrogen filling stations with new locations already set to open in 2021 in the Greater Paris region.

[> Discover this investment](#)



**Pierre-Étienne Franc, Vice-President for the Hydrogen Energy World Business Line at Air Liquide:**

“**Air Liquide and Mirova share the same convictions with regard to the development of hydrogen applications as a key solution to meeting the challenge of the ecological transition.**

Our two groups have a shared ambition: make a commitment to ramping up the transition of passenger transport towards a zero-emission model thanks to hydrogen, in particular regarding the reduction of air and noise pollution.

The acquisition of Slota once again illustrates that by converting existing profitable and sustainable business models towards hydrogen solutions, **it is possible to rely on new investor profiles such as Mirova.**”



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