Hydrogen, energy for the future

Hydrogen, a potentially environmentally friendly and highly efficient energy source, offers hope for global decarbonisation. Compared to traditional sources of renewable energy, this colourless gas primarily provides a stable supply for developing and supporting the economy, thus making it possible to overcome the problems associated with climate and geographical conditions. Hydrogen can also bridge the gaps where electricity cannot easily replace fossil fuels, for example in naval and air transport and in heavy industries (steel and chemicals).

Thanks to the continuous development of production capacities, storage, transport and fuel cell technology, hydrogen is becoming increasingly important in the energy transition. However, in order to exploit its potential on a wide scale, increase supply and reduce production costs, significant investments need to be made in infrastructure.

KEY MESSAGES

Hydrogen generated from renewable energy sources plays a key role in decarbonisation.

What is hydrogen?

Hydrogen is the most abundant chemical element in the universe. It is present in water and in almost all living beings, such as plants and animals. It is a source of usable energy, as fuel or raw material (e.g. feedstock), in a range of applications including transport (electric vehicles and fuel cells) and industrial processes (fertiliser production). Compared to other fuels, hydrogen contains more energy in terms of weight – around three times as much as petrol – but without emitting greenhouses gases. When it is used as a fuel, its most common by-products are water vapour and heat.

However, the production of hydrogen may emit significant greenhouse gases depending on the production process used. 95% of hydrogen is currently derived from fossil fuels, generally through a process known as “steam methane reforming” (SMR). As part of this process, water is converted to water vapour, which in turn becomes hydrogen and carbon dioxide (CO_2) following a reaction with natural gas. This process emits a significant amount of gas, similar to the carbon emissions produced by oil combustion.

The hydrogen generated using renewable energy sources is still only of marginal significance. It is, however, the element that governments are concentrating their efforts on, given its potential contribution to reducing CO_2 emissions.

The technology for producing hydrogen therefore constitutes a key factor in making a tangible contribution to the decarbonisation of the economy!

KEY MESSAGES

The most abundant types of hydrogen are green, grey and blue.

The colours of hydrogen

Depending on the production method, hydrogen can take on a variety of colours, each of which are associated with different environmental impacts and costs. The three main types are green, grey and blue.

Overview of the types of hydrogen and their respective characteristics (Capgemini, 2024)

- *Green* (renewable energy): this type of hydrogen is produced using electrolysis, a process that uses renewable energy to divide water into hydrogen and oxygen. It is the most sustainable but also the most expensive type of hydrogen, as it depends on the price of the renewable energy and the efficiency of the electrolyser.

- *Grey* (methane): this is produced from natural gas through the SMR process, and thus cannot capture the resulting carbon emissions. It is currently one of the most economical forms of hydrogen.
- *Blue* (methane): this type of hydrogen is also produced through SMR and, in order to reduce emissions, incorporates carbon capture and storage technology (CCS). This process is more expensive than those used to produce grey hydrogen.
- *Black/brown* (carbon): depending on the type of carbon used, the hydrogen obtained may be classified as brown (produced from lignite) or black (deriving from bituminous coal). These types of hydrogen are among the biggest pollutants and most incompatible with the environmental objectives of decarbonisation, and are relatively cheap thanks to the low cost of carbon (between EUR 1 and 1.5 per kg)
- *Turquoise* (methane): this is an intermediate solution between grey and green hydrogen. It is produced through methane pyrolysis, a process that, in the absence of oxygen, involves the thermal decomposition of methane. This process produces hydrogen and solid carbon and does not emit CO_2. The production costs vary depending on the technology used.
- *Yellow* (solar energy): this is created through water electrolysis using solar or electrical energy derived from a combination of renewable and fossil energy sources available in the grid. The electricity used is therefore not carbon neutral. Still in the experimentation phase, exact estimates of production costs are not available.
- *Pink* (nuclear energy): this type of hydrogen can be generated in a similar way to electrolytic hydrogen (yellow and green), but is powered by nuclear energy rather than wind or solar energy. The cost of production is considered low if the nuclear plants are already amortised.

Despite being the most expensive, green hydrogen is the most sustainable in the long term. In 2024, costs were reported to be reduced thanks to advancements in electrolysis technology and an increase in the capacities of renewable energies. Costs do, however, need to be reduced further in order for hydrogen to become a competitive and widespread energy solution.

KEY MESSAGES

The demand for hydrogen is rising. It is therefore necessary to reduce production costs, among other things.

Hydrogen demand and production

Demand for hydrogen is on the rise, particularly in industrial and heavy transport sectors, thanks to favourable policies and technological innovations. However, in order to fully exploit its potential, it is necessary to address and resolve various challenges, such as reducing production costs, expanding infrastructures and creating global markets.

In 2023, global demand reached 97 million tonnes (Mt), representing an increase of 2.5% compared to 2022. China is the main user, accounting for around a third of global demand (approx. 28 Mt), more than double that of the United States, the second-highest user at 13 Mt.

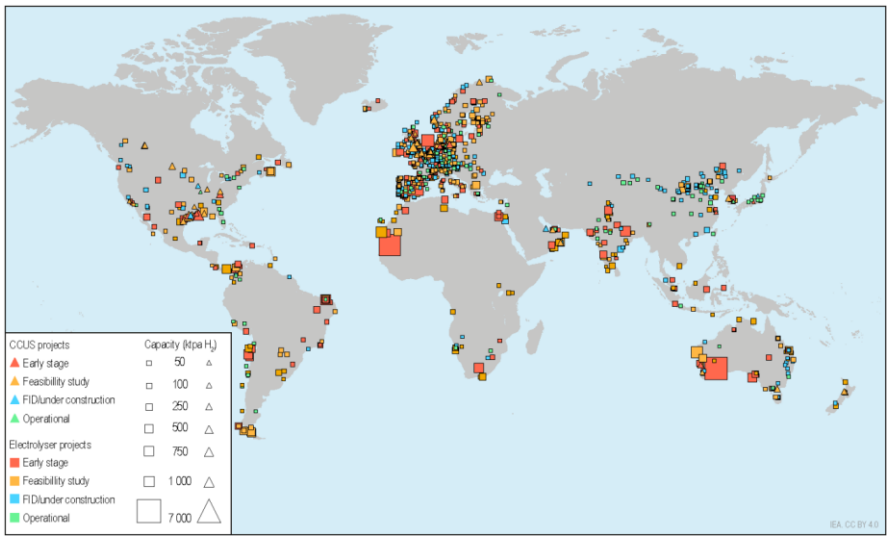
Thanks to fast refuelling times and more efficient use of the energy reserve, hydrogen is mainly used in traditional applications such as refining, the chemicals (e.g. ammonia and methanol production) and steel sector, as well as transport (e.g. lorries, buses and trains). Nevertheless, around 40% of global demand comes from new applications.

In 2024, the global hydrogen market was valued at around 167.62 billion dollars, and is estimated to grow to 278.26 billion by 2032 (Fortune Business Insight, Hydrogen Generation Market Size, Share & Industry Analysis, 2025).

As part of the transition towards a zero-emission energy system, the aim is to gradually replace hydrogen produced from fossil fuels with low-emission hydrogen.

According to the International Energy Agency (IEA), hydrogen production still poses the greatest challenge. The "*Global Hydrogen Review 2024*" annual report highlights the gap between the demand for this raw material and government targets. The vast majority of hydrogen is produced using the SMR method, while hydrogen produced using low-emission technology − such as electrolysis powered by renewable sources or methane reforming with CO_2 capture (CCUS) − represented less than 1% of total production in 2023, which translates to 1 Mt. This percentage does, however, have the potential to increase significantly thanks to various projects in the pipeline. If these are implemented, the production of low-emission hydrogen could reach around 49 Mt per year by 2030, representing approximately 30% of the global demand anticipated for that year (Energia Italia news, 2024).

Technological innovation is a key factor driving the uptake of hydrogen; the rise in investments in research and development worldwide is proof of this.



Source: International Energy Agency, October 2024, Hydrogen Production and Infrastructure Projects Database

China continues to be the world leader in the large-scale production of clean energy technologies. The People's Republic accounts for 60% of global electrolyser manufacturing capacity, the continued expansion of which is expected to drive down costs, as has been the case for solar PV and battery production.

According to the IEA, government intervention is essential in order to fully exploit the potential of hydrogen as a key technology. In particular, it is necessary to boost demand through measures such as quotas, public tenders and incentives to provide more security for investors. At the same time, infrastructure will need to expand at a rapid rate in the coming years in order to ensure that there is a balance between supply and demand.

Opportunities

- *Hydrogen has the potential to become an important energy carrier, with growing global demand. The energy transition and decarbonisation policies are factors that favour its development.*
- *Investing in shares in companies that are active in the hydrogen sector may represent an interesting opportunity for investors, given the increasing global attention on hydrogen as a solution to reducing emissions.*

Risks

- *The hydrogen market is relatively new and growing. Information and forecasts may, therefore, be uncertain and prices volatile.*
- *Stock market fluctuations: depending on market phases, shares are subject to major fluctuations in their value, both upwards and downwards.*

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