# Hydrogen development strategies: a global perspective

The EU, UK, US, China and Japan all expect hydrogen to play a significant role in the decarbonisation of their economies. Alicia García Herrero, Simone Tagliapietra and Victor Vorsatz appraise their approaches

Nearly all global decarbonisation scenarios agree that the future is electric. There are two basic reasons why electrification is the primary and most cost-effective pathway to decarbonisation. First, after decades of subsidy-driven technological innovation, solar and wind have now become the cheapest electricity generation sources in most of the world.

Second, rapid technological advances enabling cheaper batteries, heat pumps, electric motors and similar technologies are now allowing electricity to enter sectors traditionally dominated by fossil fuels such as transport, heating and industry.

As global energy systems become electrified, the key challenge for system operators will be to keep up with electricity demand in real time to avoid blackouts. But as the share of solar and wind power increases, matching becomes more challenging: how do you meet electricity demand when the sun isn't shining or without wind?

One of the two main reasons hydrogen is now 'in vogue' is that, as a chemical energy carrier, it meets the storage and flexibility needs of a renewable energy. Also, hydrogen can be used to decarbonise hard-to-abate sectors, such as heavy industry, trucking, aviation or shipping.

Hydrogen appears to be the perfect complement to renewables in the path to decarbonisation, but only if produced via electrolysis based on electricity from renewables themselves.

Since 1975, global hydrogen demand has grown more than threefold, reaching 70 million tonnes per year in 2018. It is currently used as a feedstock in either oil refining or ammonia production. On the supply side, hydrogen is currently almost entirely supplied from fossil fuels, which makes it an emitter of 830 million tonnes of carbon dioxide per year, equivalent to the combined $CO_2$ emissions of Indonesia and the United Kingdom.

However, renewable hydrogen is now looking increasingly viable thanks to reductions in the cost of wind and solar technology usage. While the production costs of fossil-based hydrogen are currently estimated at €0.8-2.7 per kilogram, renewable hydrogen can already be produced at €2.5-6.3 per kilogram with further cost reductions projected. Given this, countries around the world are gearing up to develop a renewable hydrogen strategy.

Below, we provide a first comparison of the plans in the European Union, the United Kingdom, the United States, China and Japan to draw some initial perspectives on the current status of hydrogen development strategies globally.



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## European Union

The EU expects hydrogen to play a significant role in delivering the deep emissions reductions required between 2030 and 2050 to achieve climate neutrality, and for this reason is predominantly focusing on the development of renewable hydrogen.

However, the EU also envisages a temporary use of other forms of low-carbon hydrogen to decarbonise existing fossil-based hydrogen production. Overall, the EU foresees a gradual trajectory for hydrogen deployment in Europe with three different phases (Table 1).

### Table 1. The EU's hydrogen strategy

| Period | | Installed renewable hydrogen electrolysers (gigawatt) | Renewable hydrogen production (million tonnes) | Main sectorial target |
|---|---|---|---|---|
| Phase 1 | 2020-2024 | 6 | 1 | Decarbonise existing hydrogen production in industry |
| Phase 2 | 2025-2030 | 40 | 10 (1% of EU final energy demand*) | Take-up in new end-use applications |
| Phase 3 | 2031-2050 | Large-scale | Large-scale (10% of EU final energy demand*) | Reach all hard-to-abate sectors |

**Note: this is the role of hydrogen in EU final energy demand envisaged in different EU long-term energy and climate scenarios. See European Commission (2020), p 56*
*Source: Bruegel on European Commission (2020)*

The EU strategy envisages two main lead markets for hydrogen: industrial applications and mobility. An immediate industrial application would target the reduction and the replacement of the current fossil-based hydrogen in refineries and in the production of ammonia, as well as the partial replacement of fossil fuels in steel making.

In the longer run, a greater utilisation of hydrogen would fully decarbonise the European steel making process. In transport, hydrogen is promising where electrification is more difficult. In the short run, it can be used in city buses, specific parts of the rail network where electrification is not feasible, or in heavy-duty road vehicles.

The EU sees a role for hydrogen in the decarbonisation of the aviation and maritime sectors. Here, a role may exist for hydrogen via fuel cells, but also in the production of synthetic kerosene and ammonia.

The EU strategic vision is additional to national hydrogen strategies and investments. A number of EU countries – Germany, France, Italy and Spain – adopted a hydrogen strategy in 2020

They also committed around €11.5 billion to hydrogen from 2021 to 2026 in the framework of Next Generation EU, with €3 billion of spending planned in Germany, €3 billion in Italy, €2 billion in France, €1.5 billion in Spain and around €1 billion each in Poland and Romania.

Furthermore, an EU Important Project of Common European Interest (IPCEI) on hydrogen was also launched in 2020 to help accelerate the creation of a European hydrogen value chain. The level of ambition of national strategies varies but is clearly high in some cases (Table 2).

### Table 2. EU main national hydrogen strategies: targets and pledged funding

| Period | | Installed renewable hydrogen electrolysers (gigawatt) | Renewable hydrogen production (million tonnes) | Main sectorial target |
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| Phase 1 | 2020-2024 | 6 | 1 | Decarbonise existing hydrogen production in industry |
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*Source: Bruegel on national hydrogen strategies*



Germany aims to build up 5 GW of electrolyser capacity by 2030, contributing to the national energy consumption goal of 90-110 TWh by then. This is around 4% of the final energy consumption of Germany under the JRC 'Fit for 55' energy scenario. To achieve this, Germany has made €9 billion available through its national hydrogen strategy.

France's plans are even more ambitious with a target for electrolyser capacity of 6.5 GW by 2030 and with €7 billion of public funding up to 2030 to promote hydrogen applications in industry and transport.

Italy has also adopted a national hydrogen strategy, primarily targeting 5 GW of electrolyser capacity by 2030 – or 2% of final energy demand, to be scaled-up to 20% of final energy demand by 2050.

Lastly, Spain is aiming for 4 GW of electrolyser capacity, to be reached with €9 billion of public and private investment by 2030.

## United Kingdom

The UK unveiled its strategy to develop what the government defines as a *"world-leading hydrogen economy"* in August 2021, which identifies hydrogen as a key ingredient for its energy transition, especially in electricity, industry and parts of the transport sector.

On the supply side, the main target is to develop 5 GW of low-carbon hydrogen production capacity by 2030 (similar to Germany and Italy), leading to 20-35% of the country's energy consumption being hydrogen-based by 2050.

On the demand side, the target is to let hydrogen play an important role in decarbonising those sectors that currently use hydrogen based on unabated fossil fuels, such as the chemical industry and oil refineries, as well as residential heating, electricity and certain transport segments.

It is interesting to note the high expectations the UK has on the role of hydrogen in the residential heating sector. It expects around 1 TWh of domestic heating demand to come from hydrogen by 2030, which would allow 67,000 homes to switch from natural gas to hydrogen each year.

The strategy then aspires to rapidly scale up to 45 TWh by 2035, to cover 10% of domestic heating demand with hydrogen by 2035.

On transport, it is important to mention that the strategy does not envisage using hydrogen in cars, but only those segments that will be more difficult to electrify, such as shipping, aviation, trucks, buses and trains.

The strategy estimates the UK-wide hydrogen economy to be worth £900 million and create over 9,000 jobs by 2030, potentially rising to 100,000 jobs and £13 billion by 2050.

## United States

In contrast to the EU, the US will only start to develop a national clean hydrogen strategy after the passage of the bipartisan Infrastructure Investments and Jobs Act.

So far, the *Hydrogen Program Plan* and the *Hydrogen Strategy* by the Department of Energy (DoE) have offered a strategic framework to turn hydrogen into an *"affordable, widely available and reliable"* technology and *"an integral part of multiple sectors of the economy across the country."*

To fulfil its strategic vision, the US focuses on both fossil fuel-based and renewables-based hydrogen production. Hence, the US plans to utilise carbon capture and storage (CCS) to reduce emissions while still relying on production from natural gas.

The Infrastructure Investments and Jobs Act foresees the creation of at least four *"regional clean hydrogen hubs"* producing and using the fuel for manufacturing, heating and transportation. At least two would be in US regions *"with the greatest natural gas resources,"* according to the bill. One hub would produce from fossil fuels, one would use renewable power, and another nuclear power.

Coal is also listed a potential source. No target to increase the production of renewables-based hydrogen has been included in the bill. Furthermore, the legislation uses a highly debated definition of clean hydrogen, according to which a kilogram of hydrogen produced with $CO_2$ emissions of up to two kilograms is defined as 'clean'.

Similar to the EU, the US envisages the continued and increased use of hydrogen in oil refining in the short term. Additionally, the US aims to employ hydrogen as a portable power storage option.

In the medium term, hydrogen is to be applied to distributed stationary power generation, in fuel cells for medium- and heavy-duty vehicles and in the production of synthetic fuels. At the same time, hydrogen will substitute fossil fuels in industrial processes, for example in the production of steel and cement.

In the long term, hydrogen is expected to be integrated into energy systems, providing mid- to long-term storage, stabilisation services and the coproduction of hydrogen for end-uses other than electricity.

The US notably aims to utilise research and development investments to overcome technical barriers and validate hydrogen prototype applications by providing grants to research and development and demonstration projects.

While public hydrogen investments by the DoE were limited to about $150 million per year in 2017, the Infrastructure Investments and Jobs Act introduces future investments of up to $9 billion from 2022 to 2026. Hence, US investments are similar to the ones in the Next Generation EU programme.

Out of the $9 billion, $8 billion will go to the development of the regional hydrogen hubs using the fuel for manufacturing, heating and transportation. The additional billion will be assigned to research and development and demonstration projects for electrolysers.

If the US can keep up with its ambitions, the DoE estimates a four- to six-fold increase in hydrogen consumption by 2050. This increase would translate into hydrogen potentially accounting for up to 14% of US total energy demand by 2050.

## China

China currently is the world's largest hydrogen producer but not of green hydrogen, as most is based on coal. In addition to more common uses of hydrogen such as feedstock for oil refining or ammonia production, the country also has targets for hydrogen applications in the transport sector.

As part of the recently released 14$^{th}$ Five-Year-Plan, hydrogen has been identified as a prioritised emerging industry in China, with an aim to increase the share of renewables-based hydrogen to 50% of total hydrogen production by 2030.

This represents a significant commitment, considering the country's current reliance on coal for hydrogen production. CCS technologies are also envisioned to play an important role in the decarbonisation of hydrogen production, similar to the approach followed by the US.

Future applications of hydrogen are expected to be specified in a national hydrogen development strategy, still to be published. At the provincial level, Shandong, for example, is aiming to develop industrial hydrogen clusters, in which the different application opportunities of hydrogen are intertwined. Pilot programmes to produce steel using renewables-based hydrogen have also been launched.

Moreover, the provincial plans include accelerated hydrogen refuelling station construction and continued fuel cell vehicle subsidies. Additionally, market observers expect current subsidies and investment programmes in the transport sector to be extended to hydrogen delivery and storage infrastructure as well as to CCS and electrolysis technology. However, the extent of these investments also remains unclear until the national hydrogen development strategy has been outlined.

## Japan

Japan adopted its *Basic Hydrogen Strategy* in 2017. This strategy envisions using hydrogen in both households and in industrial applications. Moreover, hydrogen is integrated into 10 of the 14 priority technology areas in the Japanese *Green Growth Strategy* published in 2020. Japan's hydrogen strategy is part of the country's desire to become independent of imported fossil fuels.

Japan aims to increase its hydrogen consumption twenty-fold till 2030, from around 300,000 tons currently, to 6 million tons. This rapid expansion reflects a rise in the share of hydrogen in current primary energy consumption from 0.2% to about 4.5%.

The increased demand is supposed to be covered by 300,000 tons of domestically-produced renewable hydrogen in 2030 and 5-10 million tons in 2050. The remaining demand will be met by imports of natural gas-based and renewables-based hydrogen.

While the share of renewables-based hydrogen in the imports is so far not subject to a quantitative target, domestic production is aimed to be 100% renewable-based by 2030.

Similar to China, Japan has been pursuing the application of hydrogen in the transport sector since the 2000s. By 2030, Japan aims to have 800,000 fuel cell vehicles, representing about 1% of currently registered vehicles.

Interestingly, Japan also foresees the use of hydrogen in the residential sector. By 2030, 5.3 million fuel cell units are expected to supply local power and heat households and power the industrial sector.

To achieve this wide-ranging application of hydrogen in the economy, Japan pursues quantitative targets for cost reductions and power efficiency increases, with significant research and development programmes being linked to these milestones.

Supported by significant public investments, Japan is working on the development of hydrogen infrastructure in the country, accompanied by relevant regulatory reforms, subsidies as well as the establishment of an international hydrogen supply chain, currently being envisioned in two demonstration projects in Australia and Brunei.

## Conclusions

The EU, the UK and Japan currently have the most detailed hydrogen strategies, while, despite starting early, China's national strategy remains undefined and unfocused on renewable hydrogen. The US, however, is in the process of formulating its strategy which will be published soon.

When looking at planned investments, Japan, the US, and the EU all project similar levels of per capita public investment. In terms of future applications, all countries aim to deploy hydrogen in industry. The UK focus on residential heating is peculiar compared with other strategies.

All players envision a gradual transition to low-carbon hydrogen, be it by focussing on renewable hydrogen, in the EU and the UK, or CCS technologies, most notably in the US. Japan takes on a special role as it plans an international hydrogen supply chain given the country's limited domestic resources.

All in all, and notwithstanding these differences, it is clear that all players want hydrogen a significant role in the decarbonisation of their economies. ■

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