BRIEFING

Towards climate neutrality

European Parliament

EU hydrogen policy

Hydrogen as an energy carrier for a climate-neutral economy

SUMMARY

Hydrogen is expected to play a key role in a future climate-neutral economy, enabling emission-free transport, heating and industrial processes as well as inter-seasonal energy storage. Clean hydrogen produced with renewable electricity is a zero-emission energy carrier, but is not yet as cost-competitive as hydrogen produced from natural gas. A number of studies show that an EU energy system having a significant proportion of hydrogen and renewable gases would be more cost-effective than one relying on extensive electrification.

Research and industrial innovation in hydrogen applications is an EU priority and receives substantial EU funding through the research framework programmes. Hydrogen projects are managed by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), a public-private partnership supported by the European Commission.

The EU hydrogen strategy, adopted in July 2020, aims to accelerate the development of clean hydrogen. The European Clean Hydrogen Alliance, established at the same time, is a forum bringing together industry, public authorities and civil society, to coordinate investment.

Almost all EU Member States recognise the important role of hydrogen in their national energy and climate plans for the 2021-2030 period. About half have explicit hydrogen-related objectives, focussed primarily on transport and industry.

The Council adopted conclusions on the EU hydrogen market in December 2020, with a focus on renewable hydrogen for decarbonisation, recovery and competitiveness. In the European Parliament, the Committee on Industry, Research and Energy (ITRE) adopted an own-initiative report on the EU hydrogen strategy in March 2021.

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Climate neutrality and energy systems integration

This briefing examines the role that hydrogen can play as an energy carrier and industrial feedstock in a climate-neutral economy. In the context of the European Green Deal, the EU has set the objective to become climate-neutral by 2050. This means that emissions of greenhouse gases (GHG) must not exceed GHG removals and implies a phase-out of fossil fuels in the EU energy system.

While renewable electricity can replace fossil fuels in many uses, it cannot easily replace them completely in road freight, shipping and aviation, or in industrial activities such as steel production, where fossil fuels are used as an energy source and as a reactant. However, hydrogen can play an important role in achieving climate neutrality in these areas.

Renewable electricity generation is often dependent on the time of day, weather and season, thus some form of energy storage is needed when it is not sufficient to meet demand. This need can be met with batteries and pumped-storage hydropower, but also by using renewable electricity for producing hydrogen to serve as a gaseous energy carrier. Such conversion of energy between electricity and gas enables energy systems integration; to pave the way for coherent action, in July 2020 the Commission adopted a strategy on the subject. Studies have shown that an integrated energy system making use of existing gas infrastructure would be more cost effective than one focussed on maximal electrification and requiring costly grid upgrades and storage solutions. All climate-neutrality scenarios in the Commission's climate target plan project a growing demand for hydrogen, which would account for around 9 % of the EU's final energy demand by 2050.

Hydrogen production and transport

Hydrogen (H_2) accounts for less than 2 % of the EU's current energy consumption and is mostly used as feedstock in industrial processes, notably oil refining, ammonia and methanol production, but also as an energy carrier for space rockets. According to the 2020 Clean Hydrogen Monitor, around two thirds of hydrogen in the EU are produced on site for specific production processes.

A number of properties make hydrogen interesting as an energy carrier:

- its use for energy purposes does not cause greenhouse gas (GHG) emissions (water (H_2O) is the only by-product of the process);
- it can be stored over long periods;
- it can be used for producing other gases, such as methane or ammonia, as well as liquid fuels;
- existing infrastructure (gas transport and gas storage) can be repurposed for hydrogen, and a certain proportion of hydrogen can be blended with natural gas;
- it has a higher energy density relative to volume than batteries, making it a suitable fuel for long-distance and heavy-goods transport.

There are only around 5 000 km of hydrogen pipelines today, mainly in the US (2 600 km), Belgium (600 km) and Germany (400 km), compared with some 3 million km of natural gas pipelines. Injecting hydrogen into the gas grid could significantly reduce the upfront capital costs of hydrogen projects.

The currently dominant technology, accounting for around 96 % of **hydrogen production**, is steam methane reforming to produce hydrogen from natural gas or coal. While being cost-effective, this process generates significant CO_2 emissions. Hydrogen produced in this way is referred to as 'grey hydrogen' if the CO_2 is released, and as 'blue hydrogen' if combined with carbon capture and storage (CCS).

Hydrogen can also be produced from water and electricity by means of electrolysis. Since the capital costs for electrolysers are still very high, electrolysis will not be cost-effective unless low-cost electricity is available most of the time to allow utilisation of the electrolyser to the maximum.

Depending on its production process and the resulting GHG emissions, hydrogen is commonly classified as follows (although this classification is somewhat simplified and not comprehensive):

Clean hydrogen ('renewable hydrogen' or 'green hydrogen') is produced by electrolysis of water with renewable electricity, at a cost range of about €2.5-5.5/kg. No GHG is emitted during the process.

Grey hydrogen is produced from natural gas by steam-methane reforming at a cost around €1.5/kg, depending on the price of gas and carbon emissions. This production process results in emissions of about 9.3 kg CO_2 per kg of hydrogen.

Blue hydrogen uses the same production processes as grey hydrogen, but the CO_2 is captured and stored permanently. Its production costs around €2/kg, making it more expensive than grey hydrogen but cheaper than green hydrogen. Where CO_2 storage capacity is available, existing hydrogen production facilities could be converted to blue hydrogen, thus reducing investment costs.

Turquoise hydrogen is produced by pyrolysis of natural gas, with pure carbon as a side product that can be sold on the market. It is still at an early stage of development but has the potential to become a cost-efficient process.

The Commission's EU Hydrogen strategy (see below) characterises **low-carbon hydrogen** as encompassing blue hydrogen and electricity-based hydrogen with significantly reduced full life-cycle GHG emissions compared to existing hydrogen production.

Hydrogen for a climate-neutral economy

Clean or low-carbon hydrogen can help to cut GHG emissions by substituting fossil fuels as energy carriers or chemical feedstock, and thereby contribute to achieving a climate-neutral economy.

Energy system integration

The future climate-neutral energy system is expected to rely largely on renewable electricity, where biomass and nuclear energy play a more limited role. Many energy uses that rely on fossil fuels today, for example battery-electric vehicles for transport or electric heat pumps for heating and cooling, can be electrified. However, electrification is not practical for certain uses such as heavy goods transport, steel production, or high-temperature industrial heat. For these applications, clean hydrogen provides an indirect way to use renewable electricity. For other uses, such as passenger cars or space heating, there is a choice between electrification and the use of hydrogen, although using electricity directly is more energy efficient than using it to produce hydrogen. Extensive electrification would require a massive expansion of electricity generation capacity and the electric grid, while the clean hydrogen option would also require increasing the supply of renewable electricity as well as investment in hydrogen transport and storage infrastructure. Repurposing the existing gas transport and storage infrastructure for hydrogen can diminish the need for investment.

Hydrogen can help address the challenges posed by the increasing share of variable renewable energy sources in electricity generation, according to an analysis by the Congressional Research Service. Surplus renewable electricity, now often curtailed, can be used to produce hydrogen by electrolysis. This hydrogen can be stored and converted back to electricity when demand peaks, by combustion in modified gas turbines or by electrochemical reaction in fuel cells. The efficiency of fuel cells is up to 60 % and of fossil power plants 35-60 %. Electrolysis of water has an efficiency of 60-80 %, meaning that more than half of the energy is lost by converting electricity to hydrogen and back again to electricity.

Industry

Scenarios for the decarbonisation of industry generally rely on the electrification of industrial processes with low-carbon electricity and on the use of clean or low-carbon hydrogen as an energy carrier and feedstock, for processes that cannot be easily electrified.

In iron and steel production, the use of hydrogen as a fuel and reactant is still at the demonstration stage, with commercial application expected to start in the mid-2020s. With the use of clean hydrogen, this can enable the production of steel without GHG emissions. Due to its relatively higher cost, a dedicated market for such emission-free steel would be required.

In the chemical industry, hydrogen is a key energy source and feedstock for most low-carbon technologies. Full decarbonisation of the chemical industry would require a massive supply of low-carbon energy electricity, clean hydrogen and CO_2. Supporting measures would be required to enable the necessary investment and keep the industry's production costs competitive.

Transport

The EU transport sector has failed to cut its GHG emissions, due to increased transport demand and the continued dominance of fossil fuels. Batteries are a suitable technology for light-duty road vehicles or urban buses, but their lower energy density, compared to fossil fuels, limits their use for long-distance road transport, shipping or aviation. Clean hydrogen is a promising fuel for transport applications because it offers a higher driving range than batteries and quick refuelling. Hydrogen-fuel cell vehicles convert hydrogen to electricity to power their engines. To support wider adoption, the current network of 144 hydrogen refuelling stations in Europe would need to grow considerably.

Clean hydrogen produced from renewable electricity and CO_2 can also be used to produce synthetic gaseous or liquid transport fuels (Power-to-X). These so-called powerfuels can help decarbonise maritime shipping and aviation. However, the conversion from electricity to synthetic fuels entails significant energy losses, whereas battery-electric vehicles use energy much more efficiently.

Market and technology development

Developing the hydrogen economy will depend on a number of factors: creating a market for clean hydrogen, cutting its production costs and creating an infrastructure for its transport and storage.

The cost of clean hydrogen is determined by the capital expenditure for electrolysers and the cost of renewable electricity, which is expected to continue dropping. According to an extensive study by the Florence School of Regulation, a key challenge to the cost-effective design of energy innovations is finding an optimal balance between research, development and demonstration of new technologies ('technology push'), ensuring support for key infrastructure projects and creating demand through production subsidies, public procurement and mandates ('market pull').

The International Renewable Energy Agency (IRENA) expects electrolyser prices to drop with mass production and economies of scale. Bloomberg New Energy Finance estimates that US$150 billion of government funding worldwide would be needed over the next 10 years to halve the cost of producing clean hydrogen. A Sciences-Po study proposes carbon contracts-for-difference as a support scheme based on long-term contracts between an investor and a public body, which would compensate the cost difference between fossil-based and clean hydrogen production by paying the difference between a mutually agreed CO_2 strike price and the carbon price in the EU ETS.

For clean hydrogen to become a tradeable commodity, guarantees of origin are needed to prove the GHG emissions during its production. The CertifHy project works to establish harmonised guarantees of origin schemes that are to be applied by national certification bodies across Europe.

Given the limited supply of clean hydrogen in the initial phases, it should be utilised first of all where low-carbon alternatives do not exist and where other advantages outweigh the higher associated costs. As long as clean hydrogen is only available in limited quantities and at a high cost, low-carbon blue hydrogen can play a transitional role in ramping up the hydrogen economy. Energy analysts warn that pushing for too much green hydrogen in the early stages of development would increase the operating cost, because electrolysers would be required to run at times of high electricity prices.

Domestic production of clean hydrogen in the EU will likely not be sufficient to meet the growing demand. A recent IRENA study on green hydrogen suggests that imports of clean or low-carbon hydrogen could fill this gap and offer opportunities for new trade and technology partnerships with countries that still depend on fossil fuel exports or have abundant renewable energy resources. However, if pipeline transport is not possible, hydrogen must be liquefied for transport, with high energy costs, or converted into other carriers such as ammonia or methanol, with high losses.

EU policy and initiatives

The Renewable Energy Directive (EU) 2018/2001 lays down a legally binding definition of renewable liquid and gaseous transport fuels of non-biological origin. This definition also includes hydrogen for the purposes of calculating compliance with the targets set out in the directive (32 % share of renewable energy in EU gross final consumption and 14 % renewables share of transport energy by 2030). The Alternative Fuels Infrastructure Directive 2014/94/EU establishes a common framework and sets out minimum requirements for the roll-out of alternative fuels infrastructure in the Member States, including refuelling points for hydrogen. Both directives are to be revised by the second quarter of 2021, under the Fit for 55 package, with a view to increasing their climate action ambition.

The Fuel Quality Directive 98/70/EC indirectly promotes the use of hydrogen, by requiring fuel suppliers to reduce the life cycle GHG emissions per unit of energy by 6 % by 31 December 2020. It is complemented by Council Directive (EU) 2015/652 (laying down the calculation methods and reporting requirements), which sets the efficiency factor of the hydrogen fuel cell electric powertrain to 40 % and fixes the GHG intensity of clean and fossil-based hydrogen and of hydrogen-derived methane. In addition, the HyLaw project identified more than 50 EU legislative acts in wider regulatory areas that impact hydrogen technology development indirectly and would need to be considered, among them health and safety, environment, labour, and transport.

The EU supports research and innovation projects on hydrogen through the research framework programmes, Horizon 2020 and Horizon Europe (2021-2027). Projects are managed by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), a public-private partnership supported by the European Commission. Over the past 10 years, more than €1 billion has been invested in hydrogen projects. The second phase of the FCH JU (2014-2024) is expected to benefit from €665 million in EU support, which, complemented by private funding, will bring investments to a total of over €1.3 billion.

The European Hydrogen Valleys Partnership initiative under the Commission's Smart Specialisation Platform has the objective to facilitate cooperation between European regions that want to develop the production and utilisation of hydrogen.

Member States can collaboratively support specific innovation projects as important projects of common European interest (IPCEI), subject to the criteria defined by the European Commission. In December 2020, 22 EU Member States and Norway signed a manifesto to establish an IPCEI on hydrogen. This would be the third IPCEI, after those on microelectronics and batteries.

EU hydrogen strategy

The goal of the European Commission communication on a hydrogen strategy for a climate-neutral Europe, adopted on 8 July 2020, is to accelerate the development of clean hydrogen, ensuring its role as a cornerstone of a climate-neutral energy system by 2050. To reach this goal, the strategy envisions a gradual trajectory, initially including blue hydrogen projects. Several key actions are to be implemented over the course of three strategic phases between 2020 and 2050. The strategy points to the existing status quo, concluding that hydrogen (and in particular renewable hydrogen) plays only a minor role in the overall energy supply today, with challenges in terms of cost-competitiveness, scale of production, infrastructure needs and perceived safety.

According to the Commission, cooperation across the entire supply-chain and across the public and the private sector is essential to delivering an enabling regulatory framework and the critical mass in hydrogen research and deployment investments, deemed necessary to ensure the scale-up.

With the launch of the European Clean Hydrogen Alliance, a forum has been established, bringing together industry, public authorities and civil society, to coordinate investments for scaling up production and increasing demand. The strategy has a clear focus on ensuring the appropriate priority and proper access to finance for clean hydrogen projects, mentioning the need for coherence across EU funds and EIB financing. The alliance is expected to deliver an investment pipeline and ensure adequate policy coordination.

On the policy side, the strategy points to the necessity of providing certainty on policy direction and clarity on the investments needed. The Commission intends to propose a low-carbon threshold/standard and a certification scheme by June 2021, likely based on ETS benchmarks and the CertifHy project mentioned above.

The three strategic phases lay out a step-by-step approach where initial deployment, towards 2024, is located close to demand centres, e.g. industry or refuelling stations, thus limiting the infrastructure needs. The focus in the **first phase** is on scaling up manufacturing of large (up to 100 MW) electrolysers, decarbonising existing hydrogen installations and facilitating the take-up of hydrogen in end-use applications. Planning for transport infrastructure and laying down regulatory frameworks to ensure a well-functioning hydrogen market are key policy actions.

In the **second phase** (2024-2030), infrastructure will be increasingly deployed, starting with local networks on islands, remote areas or local hydrogen clusters, where hydrogen would be used not only for renewable energy balancing but also in industry and transport applications and for residential and commercial heating. This phase also envisages developing the EU-wide logistical infrastructure (initially networks of refuelling stations), establishing larger-scale storage facilities and planning a pan-European hydrogen network, possibly including the repurposing of existing gas infrastructure. Research and innovation funding is expected to play a significant role in the coming decade to boost efficiency and scale, delivering cost-effective electrolysers in gigawatt (GW) scale and reaching cost-competitiveness of renewable hydrogen by 2030. Beyond 2030, renewable hydrogen technologies would reach maturity with large-scale deployment and demand expected.

In terms of installed production capacity in the first two phases, the strategic objective for 2024 is at least 6 GW of renewable hydrogen electrolysers producing 1 million tonnes renewable hydrogen, climbing to 40 GW in 2030 with 10 million tonnes of renewable hydrogen production.

On 11 December 2020, the Council adopted conclusions entitled 'Towards a hydrogen market for Europe', calling on the Commission to further elaborate and operationalise the EU hydrogen strategy. In the conclusions, the Council puts a particular focus on renewable hydrogen for decarbonisation, recovery and competitiveness. It calls on the Commission to develop the EU potential for hydrogen production from cost-effective renewable electricity sources, while respecting the energy-efficiency-first principle and direct electrification options, and to develop approaches to safeguard the transition by avoiding lock-in and sunk investment cost. Furthermore, it identifies the opportunity to improve the EU's energy security by reducing import dependency and diversifying import opportunities. The last part ties in well with the 2x40 GW initiative of the industry association Hydrogen Europe, which is to install 40 GW renewable hydrogen capacity in the EU and another 40 GW across Ukraine and North Africa.

Member State policy and initiatives

According to a study contracted by the FCH JU and looking at the Member States' final national energy and climate plans (NECP) submitted by April 2020 (or draft NECPs submitted by those that missed the deadline), all but two plans mention hydrogen and its potential role in decarbonisation. However, only half of the plans lay down explicit hydrogen objectives; others are technology-neutral, supporting Power-to-X demonstration projects, which often implicitly support hydrogen. Transport is the first area of application for hydrogen in most of the plans, with industry following as the second. The study concludes that 2021-2030 is considered primarily a preparatory phase with hydrogen viewed as a medium/long term option. Using electrolysers and renewable energy for the production of hydrogen is the main focus of the plans, although there is some focus on low-carbon blue hydrogen; Poland specifically mentions coal-gasification hydrogen. The entire value chain (generation, storage, transport, distribution, supply, end use) is only rarely addressed in the plans.

The Hydrogen Initiative, launched by the Austrian Presidency of the Council in 2018, was signed by 24 Member States. In June 2020, Austria, Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland published a joint hydrogen declaration pushing for a key role for hydrogen in achieving climate neutrality. Several national ministries are now joining the European Clean Hydrogen Alliance. In the Hydrogen Energy Network (HyENet), an informal platform initiated by the Commission, national experts exchange experience and relay advice back to their Member States on best practices and latest developments.

Germany in particular has put strong emphasis on the role of hydrogen in the country's decarbonisation programme. The German national hydrogen strategy has a goal of 5 GW production capacity by 2030 and 10 GW by 2040. Significant funding has been earmarked for research and technology transfer from lab to market, including separate funding for industry. Recognising the limitations to producing the hydrogen needed within Germany, a budget of €2 billion has been proposed for fostering international partnerships.

On 23 September 2020, Portugal and the Netherlands signed a memorandum of understanding on their intentions to connect their respective hydrogen plans. The Dutch national plan includes producing blue hydrogen from gas with CCS; the northern Netherlands region however has opted for 100 % renewable hydrogen in its recent regional hydrogen strategy.

Expert analysis and stakeholder views

In June 2020, Hydrogen Europe released 10 recommendations, which were largely taken into account in the Commission's hydrogen strategy. The industry association welcomed the strategy and subsequently released a more specific Covid-19 recovery investment outlook.

In a letter of 15 June 2020, 15 organisations, primarily in energy-production (including nuclear) or energy-intensive industries, such as mining and steel, emphasised the importance of technological neutrality and the role of low-carbon hydrogen for a smooth transition, underlining in particular robust certification systems having guarantees of origin. Conversely, the WWF criticised the Commission's strategy for its intention to continue low-carbon hydrogen produced with gas and CCS until 2030, claiming it undermines the EU's climate neutrality ambition.

The European Science Academies (EASAC) support the phased approach of the EU hydrogen strategy and propose new regulations to accelerate the transition from fossil to clean hydrogen in chemical industries and steel production, complemented by stronger carbon pricing and an end to fossil fuel subsidies. A scale-up of renewable electricity generation would be required for the production of clean hydrogen, although the direct use of renewable electricity should have priority.

The European Committee of the Regions' opinion on a roadmap for clean hydrogen, adopted in July 2020, calls for an EU legal framework to support market development and infrastructure, comprising an EU-wide sustainability classification of hydrogen. It advocates integrating the hydrogen market with the electricity and gas markets and revising the relevant EU legislation on renewable energies, gas markets and trans-European networks. The European Economic and Social Committee adopted its opinion on this subject on 27 January 2021.

In July 2020, 11 gas infrastructure companies across nine Member States launched the Hydrogen Backbone Initiative, showcasing plans to create 6 800 km of dedicated hydrogen transport infrastructure between hydrogen valleys (75 % converted natural gas pipelines and 25 % new sections) by 2030, and ambitious longer-term goals on essential infrastructure for the hydrogen economy.

In February2021, European energy regulators published a white paper with recommendations on a gradual approach to the regulation of hydrogen networks with regard to energy system integration.

European Parliament position

The Parliament adopted its resolution on a comprehensive European approach to energy storage on 10 July 2020, underlining the potential of hydrogen for energy-intensive industries, transport and seasonal energy storage, and suggesting the inclusion of a hydrogen initiative as an Important Project of Common European Interest (IPCEI). These points are taken up and further developed in the own-initiative report on energy system integration (rapporteur Christophe Grudler, Renew, France) adopted by the Committee on Industry, Research and Energy (ITRE) on 22 March 2021.

On the same day, the ITRE committee also adopted an own-initiative report on the EU hydrogen strategy (rapporteur Jens Geier, S&D, Germany), with the Environment (ENVI) and Transport (TRAN) committees as associated committees. The report stresses the need for a common science-based classification of different types of hydrogen, based on lifecycle GHG emissions, and for European standards, certification and labelling systems that help inform consumers and should be applicable to imported hydrogen. It underlines that only clean hydrogen can contribute to climate neutrality, and calls for a swift phase-out of fossil-based hydrogen. However, it also asks the Commission to assess how much low-carbon hydrogen would be used as a transitional source, and for how long. As renewable hydrogen is not yet competitive, the Commission and the Member States should incentivise its market uptake and the development of the hydrogen value chain, focussing on sectors where hydrogen is almost competitive or that cannot be decarbonised by other technologies. The report calls for assessing the possibility of repurposing existing gas pipelines for the transport and underground storage of hydrogen, and requests the Commission to come forward with an EU strategy for clean steel, with an appropriate focus on the use of clean hydrogen.

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