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HYDROGEN

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CEFIC VISION ON HYDROGEN

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EXECUTIVE SUMMARY

Cefic expects hydrogen to play a pivotal role in reducing the carbon footprint of Europe's energy and feedstock supply within the transition to climate neutrality. **The future of the European chemical industry – especially in the transition towards climate neutrality – will be closely intertwined with the development of a hydrogen economy,** as it is both a major producer and consumer of hydrogen. In the future, hydrogen could also become a major building block of chemical products with a low GHG footprint and could help to decarbonise the chemical industry's energy consumption.

For the vision to become reality, the European Union needs a Hydrogen Strategy, which creates legal and investment certainty, to pave the way for a successful deployment of climate-friendly hydrogen[1], which has the following aims:

- A rapid **reduction in cost** of producing climate-friendly hydrogen: the cost of hydrogen needs to be reduced to compete with current sources of energy production.
- The **right balance between promotion and affordability**: today climate-friendly hydrogen is not competitive with conventional production. Several types of incentives could be envisaged to support alternative ways of producing. These should, however, consider the need to guarantee industry an internationally competitive supply of energy.
- A solid and credible **certification framework**, including **clear and comprehensive definitions** for different types of hydrogen that can contribute to the Greenhouse Gas (GHG) abatement objective, with a technology neutral approach. An EU-wide system to certify life-cycle GHG intensity of hydrogen production and Guarantees of Origin (GOs) will need to be introduced[2].
- **A competitive market**: once the growth of climate-friendly hydrogen starts to accelerate, regulators and competition authorities will have to ensure that the hydrogen market is subject to a sufficient degree of competition. When the quantity of producers and consumers connected to the grid reach a level of competitive relevance, they should in principle be regulated in the same way as gas or electricity grids. Furthermore, Transport System Operators (TSOs) and Distribution System Operators (DSOs) should not be allowed to own and operate power-to-gas-plants, except under specific circumstances.
- **Infrastructure** should be carefully planned to safeguard **gas quality** requirements, **allow safe and efficient transport** and build on the potential of hydrogen as a storage solution.
- Strong **research and innovation support** to encourage progress on technologies which are still at low Technology Readiness Levels (TRLs) and improve or upscale existing technologies by increasing their performance and lowering their costs.
- The **statistical framework** for hydrogen should reflect the reality of the market, where it is produced as a manufactured product. It should also maintain a level playing field between hydrogen imported in a chemical plant and hydrogen produced on-site, so that the latter is not disincentivised.

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[1] For "climate-friendly hydrogen", Cefic means hydrogen produced with a low greenhouse gas (GHG) emissions compared to unabated hydrogen from natural gas with Steam Methane Reforming (SMR), e.g. with fossil-free energy or from natural gas with CO_2 emissions either captured or transformed into solid carbon.

[2] Regarding carbon accounting systems (like ETS-MRR) see Cefic position on carbon capture and use (CCU)

Introduction

Cefic expects hydrogen to play a pivotal role in reducing the GHG footprint of Europe's energy and feedstock supply within the transition to climate neutrality. The future of the European chemical industry – especially in the context of a transition towards climate-neutrality – will be closely intertwined with the development of a hydrogen economy, as it is both a major producer and consumer of hydrogen.

A hydrogen economy delivering its contribution to a climate-neutral Europe is far from reality today due to the high cost of climate-friendly hydrogen and limited infrastructure. The new European Commission (EC) will have to develop an ambitious Hydrogen Strategy that encourages very significant investments and ensures that hydrogen can fully deliver on its potential.

The European chemical industry is already a major hydrogen consumer and producer today

In the European Union (EU), it is estimated that 108 Billion Nm^3[3] of hydrogen is used as **feedstock** every year, mostly in the refining and chemical industries. Hydrogen used as chemical feedstock is produced from natural gas[4], which is converted into hydrogen via Steam Methane Reforming (SMR) and then directed to ammonia and methanol production. Hydrogen is currently not directly used as **an energy source** in the chemical industry but is commonly combusted for energy as a component of other gases such as syngas and process off-gases.

The chemical industry is also a major **producer** of hydrogen as industrial gas, with approximately 150 Billion Nm^3 produced every year[5]. In the EU, merchant hydrogen is almost exclusively produced by SMR of natural gas but it also occurs as by-product in:

- Steam cracking
- Propane de-hydrogenation (PDH)
- Chlor-alkali electrolysis[6]

What about tomorrow?

Hydrogen production will have to become less carbon intensive

The European chemical industry can be a major enabler in the deployment of hydrogen and its contribution to the EU's long-term climate ambition. Conversely, climate-friendly hydrogen will be indispensable for the chemical industry to achieve its transformation towards climate-neutrality.

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[3] Analytical report on the Strategic Value Chain on Hydrogen technologies and systems estimates feedstock demand is 325 TWh. Conversion from TWh to Nm^3 is obtained assuming a heating value of 2.,99 kWh/Nm^3

[4] Natural gas used mostly for conversion into hydrogen as feedstock was estimated at around 105 bcm (which is approximately equivalent to 1000 TWh) in 2017 according to the OECD/IEA (The Future of Petrochemicals - 2018)

[5] Eurostat prodcom 20.11.11.50 https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

[6] Yearly production is 3100 Million Nm3 (≈ 389 GWh), of which is 15% vented due to lack of economic solutions

However, hydrogen production via SMR is currently one of the largest CO_2-emitting activities[7] of the chemical industry. To be compatible with the EU's long-term climate commitments, the carbon footprint of hydrogen production will have to be significantly reduced.

CO_2 process streams resulting from SMR are quite concentrated. Therefore, applying **Carbon Capture and Storage (CCS)** to gas reforming is seen as a quite effective solution, as the cost of capture is lower compared to post-combustion CCS. Today the median cost of carbon capture in hydrogen production for chemicals (i.e. excluding transportation and storage) is estimated at around 20€/ton of CO_2 avoided[8].

Hydrogen can also be produced via **electrolysis**. The chemical industry already has a long experience of using electrolysis, as chlor-alkali is produced by the electrolysis of brine (salt dissolved in water). The chlorine industry is already exploring opportunities and business models to valorise this by-product of hydrogen in the surrounding communities, e.g. in transportation or the generation of energy.

New technologies that are not yet commercially available could also play an important role in the future:

- **Methane pyrolysis**, whereby methane is split into hydrogen and solid carbon. This methane pyrolysis process requires little energy compared to water electrolysis. If the process is based on climate neutral energy, hydrogen could be produced on an industrial scale without CO2 emissions, even when using fossil-based methane (natural gas) as a starting material.
- **Photolysis** i.e. direct utilisation of sunlight. Due to the limited availability of carbon-free electricity, the direct utilisation of solar energy via photo electrocatalysis could be a key breakthrough.

Hydrogen could become a major building block of chemical products with a low GHG footprint

The carbon footprint of chemical products such as ammonia, methanol and hydrogen peroxide[9] could be significantly reduced by the reduction of GHG emissions due to current hydrogen demand.

Hydrogen can also play an important role for the chemical valorisation of CO_2, whereby captured CO_2 (and CO from 'industrial waste gases') is used to produce methanol or other chemicals. Catalysis technologies used in the process are at Technology Readiness Level (TRL) 7 (Dechema 2017). Pilot plants are in operation (Mitsui Chemicals, Carbon recycling International, CRI) and further large-scale commercial projects are being considered.

Combining hydrogen with CO_2 would open a methanol-based chemistry that could reach a wide portfolio of high-value chemicals. It can also serve to produce alternative fuels with a lower carbon footprint, such as Renewable Fuels of Non-Biological Origin (RFNBOs) and Recycled Carbon Fuels, which are promoted under the Renewable Energy Directive.

[7] Source: European Environmental Agency
[8] The potential for CCS and CCU in Europe, report to the 32nd meeting of the European gas regulatory forum 5-6 June 2019, coordinated by IOGP
[9] Specialty chemical uses for bleaching or as rocket propellant

Hydrogen could also help to decarbonise the chemical industry energy consumption

Natural gas is the biggest energy source in the EU chemical industry, representing more than one third (34%) of its total consumption in 2016 (i.e. 203 TWh). Climate-friendly hydrogen could partly substitute natural gas consumption and represent a bigger share of the chemical industry's energy mix in the future.

Today, standard gas turbines can operate with a mix of natural gas and 3-5% hydrogen, while ensuring safety and compliance with emission standards. In the longer-term, gas turbine manufacturers have committed to deliver technologies that can operate with high shares of hydrogen: by 2020, they plan to provide their customers with gas turbines that can handle a share of 20% hydrogen and by 2030, they expect that gas turbines should be able to operate with 100% hydrogen[10].

A Hydrogen Strategy: conditions for a successful deployment of climate-friendly hydrogen

As an overall condition, a rapid reduction of the total production cost will be an absolute pre-requisite for "climate-friendly" hydrogen to become competitive with current sources of energy production. A high volume of climate-friendly hydrogen would entail a high demand for climate-neutral electricity or innovations on direct hydrogen production. The cost to produce hydrogen can therefore be reduced by ensuring low electricity prices, as well as reducing the costs of alternative technologies to produce, transport and store hydrogen.

Striking the right balance between promotion and affordability

Today there is not a sufficient economic case behind hydrogen produced with CCS or renewable electricity as an alternative to conventional production. Adding CCS to SMR plants is expected to result in a cost increase of about 50% for CAPEX and a doubling of the OPEX for CO_2 transport and storage[11]. The cost of hydrogen produced from renewable electricity is still considered to be three to six times more expensive than current production[12].

A higher EUA (European Union Allowance) price could reverse this situation but risks affecting the industry's global competitiveness. Policymakers may also envision different types of mechanisms to support the production of hydrogen. In Cefic's view, a technology-neutral approach is the most cost-effective as it would enhance competition between different innovative technologies: Life-cycle GHG emission abatement potential should be the main criterion to assess various sources of climate-friendly hydrogen eligible for support (while safeguarding other environmental objectives); too restrictive or technology-specific targets must be avoided. Support schemes should be limited in time and only benefit innovative technologies that are not - for the time being - viable without support. They should also be market-based, as well as market responsive.

In any case, additional costs related to the increased market penetration of climate-friendly hydrogen must be contained or mitigated. According to the IEA, the cost of producing hydrogen from renewable electricity could fall by 30% by 2030[13]. Economies of scale, upscaling and upgrading (i.e. higher efficiency

[10] Source: PowerTheEU - https://powertheeu.eu/
[11] IEA report on the future of hydrogen on Page 42 – June 2019
[12] See Dechema 2017 – Figure 5
[13] IEA report on the future of hydrogen – June 2019

and load factor) can reduce the cost of existing technologies. Investment support will be needed in order to stimulate market uptake of these technologies. The cost of electricity, including taxes and levies, will also be crucial for the competitiveness of hydrogen produced via electrolysis.

As far as consumption is concerned, it will be of crucial importance to secure a level playing field between the different uses of climate-friendly hydrogen. Hydrogen used for energy and hydrogen used as feedstock must be equally supported. LCA-based GHG emission avoidance should be the sole driver in case of regulatory incentives.

Certification framework for hydrogen

The EU regulatory framework should include clear and comprehensive definitions for different types of hydrogen, which can contribute to the aim of abating GHGs. Of special importance to the chemical industry, definitions of fossil-derived hydrogen and synthetic methane should also include off-gases from naphtha cracking or the gasification of plastic waste, heavy residues and LPG.

Elsewhere, consumers of climate-friendly hydrogen should be able to demonstrate their contribution to the GHG emission reduction objective. An EU-wide system to certify life-cycle GHG intensity of hydrogen production and Guarantees of Origin (GOs) will therefore need to be introduced. GOs could be an additional and market-based approach to track the developments in hydrogen production and finance climate-friendly hydrogen production, complementing other incentives while avoiding double compensation. Certification must be done by an official body to ensure the credibility of the system, including borders outside the EU (e.g. ISO).

Promote a competitive market right from the start

Industrial hydrogen production is still a “niche” market. To ensure a successful deployment, it will be important to maintain a competitive and dynamic market, including for hydrogen transmission. Early regulation in this field is important to boost investor confidence and ensure that early adopters are not penalised once the market develops. EU and Member State regulators and competition authorities should ensure from the beginning that the hydrogen market is subject to a sufficient degree of competition, where producers and consumers do not face any market abuse or foreclosure.

EU and Member State regulators should also examine whether dedicated hydrogen grids can be deemed as de facto monopolies, i.e. how much competitive pressure can be executed by other means of transport (e.g. by lorry). Once the quantity of producers and consumers connected to the grid reach a level of competitive relevance, they should in principle be regulated in the same way as gas or electricity grids (regulated tariffs, mandatory third-party access etc.) A threshold for competitive relevance has yet to be discussed.

Furthermore, TSOs and DSOs should in principle not be allowed to own and operate power-to-gas-plants, to avoid discrimination against new entrants or barriers to market entry (unbundling principle). If there is no interest in the market to invest in and operate such facilities, TSOs/DSOs might be allowed to participate in the market for a limited period (“regulatory holidays”), in order to create economies of scale. In such cases, all operators in the market should have access to the grid under the same conditions.

New dedicated network codes would probably have to be developed if Europe wants to significantly develop the public hydrogen network.

Infrastructure should be carefully planned to avoid negative consequences for end-users

Two basic types of hydrogen transport are conceivable, which would result in completely different types of supporting infrastructure:

- Injecting hydrogen into natural gas grids: system operators estimate that the infrastructure is currently capable of mixing in up to 20% hydrogen[14]
- Dedicated hydrogen infrastructures: today there is around 1,600 km of hydrogen pipeline in the EU, but most of it is in the Netherlands and Belgium (850 km) with smaller transport networks in Germany and France (390 and 303 km respectively). New dedicated hydrogen infrastructure can offer a workable option, where there are locally concentrated hydrogen sources and sinks, as well as storage facilities. Problems regarding natural gas composition could also be avoided without additional methanation. However, the cost and benefits of dedicated hydrogen grids on a large scale requires further evaluation and cannot be conclusively assessed at this point.

The increased blending of hydrogen with natural gas can have negative impacts which are three-fold:

- It will lower and widen the Wobbe band, which affects the stability of equipment. Existing gas turbines can be very sensitive to hydrogen content. Boilers and cogeneration equipment will also need to be adapted to changing burning properties. A well-developed measurement and control technology would therefore be needed to monitor the fluctuations of hydrogen content. Cefic supports a small Wobbe Index (WI) at exit points for end-use purpose, including stability criteria (WI range, rate of change) and ensuring the appropriate local WI information, and a wider WI at entry points to support a liquid gas market.
- It may render natural gas unusable as a feedstock due to downstream processes not being able to process the hydrogen (or causing upsets). Processes using natural gas as feedstock in chemical reactions are very sensitive to hydrogen (e.g. desulphurisation of natural gas[15], acetylene production). The operation, safety and efficiency of certain processes can already be corrupted by a hydrogen contents as low as 1.5%.
- Hydrogen can be better valorised for other types of applications. The increased level of hydrogen in the natural gas grid will increase the general costs of the blend without bringing tangible value-added to the consumers.

This calls for a very careful approach to hydrogen injection: for this reason, **Cefic does not consider blending obligations an appropriate method to incentivise climate-friendly hydrogen**. Gas quality fluctuations may not affect all consumers, but the hydrogen content in a given grid area needs to consider the specifications of the most sensitive consumer. On the other hand, too narrow gas specifications can hamper the liquidity of the European gas markets. As the hydrogen share in the gas market grows, greater harmonisation of national regulations for injection will be needed to avoid market fragmentation and intensify cross-border connections. At the same time, strict mandatory thresholds are inevitably required in grid areas where sensitive consumption units are located. Membrane technologies could be considered to help protect sensitive consumption units from hydrogen inflow, but the cost and methods of financing still need to be assessed. When assessing the additional costs arising for certain customers' (e.g. to maintain the required gas quality), the way these costs are borne should reflect the benefits of mixing hydrogen in providing less GHG-intensive energy source to the society as whole too.

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[14] https://www.dvgw.de/der-dvgw/aktuelles/presse/presseinformationen/dvgw-presseinformation-vom-09042019-mehr-wasserstoff-technisch-sicher-verankern/

[15] Gas desulphurisation is required to safely operate an SMR and other reforming processes, because sulphur is a catalyst poison

In the future, if hydrogen is deployed on a massive scale, Cefic would favour the development of a dedicated infrastructure for the transport of hydrogen to safeguard gas quality. In addition, pure hydrogen can be used directly as a chemical feedstock contributing to important value chains, which is makes more economic sense than usage for combustion.

Safe and efficient transport

Hydrogen transportation represents a comparable risk versus methane transportation. Nevertheless, due to the small size of the molecule, special attention must be paid to both the containment and compression material (to avoid hydrogen embrittlement), as well as connections/joins between the containment material (to avoid leakage). Ethylene distribution pipelines can already handle up to 100% of hydrogen.

Hydrogen also has a lower density compared to methane, which means that three times more volume is needed to supply the same amount of energy as natural gas[16]. Larger or higher-pressure pipes and additional compressor capacity would therefore be needed to transport hydrogen in sufficient quantities. Alternatively, hydrogen can be transported under the form of ammonia, methanol or via liquid organic hydrogen carriers (LOHC). This would also enable transportation risks to be minimised but could raise some issues related to the cost of conversion, safety and public acceptance.

In the next decades, if other regions of the world with advantageous renewable resource conditions can produce renewable electricity at much more attractive prices than in Europe, it would make more economic sense to import energy as a product in the form of hydrogen, ammonia or synthetic fuels. Infrastructure planning must take these possible developments into account as delivery and storage choices will be of critical importance for the longer term.

Hydrogen as a solution for energy storage

Hydrogen can also act as an important enabler of the higher penetration of renewables, allowing greater flexibility through sector coupling. Scale-proven stationary storage technologies are already available in the chemical industry (industrial gas industry in particular), which operates thousands of storage locations as pressurised gas or liquid, as well as in large underground caverns (e.g. storage in salt caverns). Converting electricity into hydrogen, transporting/storing hydrogen and, in some cases converting the hydrogen back to electricity, will result in significant efficiency losses. Energy yield will progress with technological developments but will face physical limits. However, hydrogen could play a meaningful role in cases where electricity cables and batteries are not suited, e.g. to store large quantities over a long period of time (seasonal storage) and move it over long distances.

Innovation support

New hydrogen production technologies that have not yet been fully demonstrated could help significantly to reduce the cost of hydrogen production and related energy demand. Research and innovation support should encourage progress for these technologies, which are still at low TRLs like methane pyrolysis (TRL 4-5) and photocatalytic processes (TRL 2-3).

Research and innovation programmes can also support the improvement of existing technologies by increasing their performance and lowering their costs. In the field of electrolysers, efforts should focus on efficiency, high pressure membranes, lifetime as well as manufacturing costs.

[16] IEA report on the future of hydrogen on Page 77 – June 2019

A statistical framework for hydrogen

Production of climate-friendly hydrogen used as industrial gas (and not as a fuel), e.g. as feedstock in the chemical industry, should remain part of the manufacturing sector. Classifying it under the manufacture of gas would have major implications on taxation and price regulation, which would put a brake on the mainstreaming of climate-friendly hydrogen in the chemical industry.

It is also important that the statistical framework (Eurostat energy balances) maintains a level playing field between hydrogen imported in a chemical plant and hydrogen produced on-site, so that the latter is not disincentivised. In other words, if electricity is brought into a chemical site to produce hydrogen on-site for use as feedstock, it should not be considered as primary energy consumption (falling under the Energy Efficiency Directive cap) but as non-energy input.

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About Cefic
Cefic, the European Chemical Industry Council, founded in 1972, is the voice of large, medium and small chemical companies across Europe, which provide 1.2 million jobs and account for 16% of world chemicals production.