Hydrogen Europe Vision on the Role of Hydrogen and Gas Infrastructure on the Road Toward a Climate Neutral Economy

–

A Contribution to the Transition of the Gas Market

April 2019

Hydrogen Europe Secretariat, Avenue de la Toison d'Or 56-60, 1060 Brussels, Belgium
Tel: +32 2 540 87 75 I Email: secretariat@hydrogeneurope.eu I Website: www.hydrogeneurope.eu I Twitter: @H2Europe

Executive Summary

Hydrogen Europe is strongly convinced that hydrogen of low carbon footprint is a key lever for achieving deep decarbonisation in an affordable and competitive manner. As a clean energy carrier, feedstock and fuel, hydrogen can facilitate the large-scale integration of renewables, enabling grid balancing and seasonal storage as well as the decarbonisation of natural gas through innovative technologies. Hydrogen represents a pragmatic and cost-efficient solution for the decarbonisation of hard-to-abate sectors of the economy such as transport, heating and cooling, and energy-intensive industries in particular.

With a view to 2050, Hydrogen Europe considers that a significant cost-effective decarbonisation can only be achieved through an integrated sectoral approach using both the electricity, gas and heat infrastructures. We believe that hydrogen and gas integration can ease the transition towards a deep decarbonisation, thanks to the ability of the gas grid to integrate varying geographies and scales (conversion of clusters for industry zone/region/country/EU) as well as admixtures of hydrogen into the grid. Furthermore, the gas infrastructure can transport larger volumes over longer distances at a fraction of the costs when compared to the electricity grid. In a majority of studies on decarbonisation in Europe, the decline of natural gas usage suggests a subsequent reduction of gas infrastructure needs. However, with the switch to renewable and low-carbon hydrogen, among other sustainable gases, such assets can be adapted and used for a cost-effective decarbonisation across Europe. In addition, the conversion of gas grids to hydrogen is the fastest way to fully decarbonise as it can be achieved via central and decentralised actions.

The key role of gas grids is to connect a very wide range of customers and end users to a gaseous fuel supply efficiently, safely, reliably and discreetly. The key role of hydrogen as a decarbonising agent in gas grids is to reduce the carbon footprint of the gas being consumed by customers, across the various end use applications (industrial, buildings, refuelling, etc). While the overall hydrogen demand will dictate the desired extent of gas grid decarbonisation, hydrogen itself can be injected in the form of an admixture to the natural gas grid, or used to produce synthetic methane for injection, or injected directly into a hydrogen grid.

In rapidly growing markets, Hydrogen Europe views the development of hydrogen technologies evolving in differing manners, notably via: sector coupling and sectoral integration. Indeed, it is key to acknowledge the different roles that power-to-gas/power-to-hydrogen plants can have in linking the gas and electricity infrastructures by alleviating stress on the power grid thereby increasing renewable integration (sector coupling) or by efficiently integrating various sectors through the creation of increased market competition with the purpose of decarbonisation (sectoral integration).

The upcoming revision of the gas market design, currently being prepared by the European Commission, should intend to provide a clear framework for the uptake of renewable and low-carbon gases and the hydrogen market. This paper aims to inform and start the discussion with stakeholders about the key role of the gas market in the deployment of hydrogen. Furthermore, this paper will elaborate on the future role of new and existing infrastructures as EU stakeholders strive to future-proof their business and green the European gas grid, making it fit-for-purpose and in line with EU objectives. As such, this paper lays down concrete suggestions in the search for a purposeful framework for hydrogen, including definitions, market ownership models and targets.

Contents

Chapter I. Our Political Goals

The European Union (EU) has been and will continue to be the driving force of the international community in the fight against climate change. From Paris to Katowice, the EU has played a pre-eminent role in promoting and putting in place policy frameworks and legislative measures that will contribute towards the curbing of greenhouse gas emissions (GHG), leading us towards a more sustainable future. Now more than ever, the need to combat harmful climate change is pressing. Most recently, the Intergovernmental Panel on Climate Change (IPCC) urged for immediate action to radically lower emissions in order to meet the overarching Paris Agreement objective of keeping global warming well below 2°C and pursue efforts to limit temperature increase even further to 1,5°C.

Ahead of the most recent COP24 held in Katowice, the EU reaffirmed its commitment to support the energy transition towards a carbon neutral economy. Indeed, the European Commission's long-term decarbonisation strategy "*A Clean Planet for All*" published in November 2018, explores multiple pathways towards climate neutrality. These are all underpinned by increasing energy efficiency and the exponential growth of renewable energy, whilst taking into account the principles of cost-efficiency, social inclusiveness and sustainability. The role of hydrogen, among other, features prominently in a number of the pathways explored.

Hydrogen Europe is strongly convinced that hydrogen is a key lever for achieving deep decarbonisation in an affordable and competitive manner. As a clean energy carrier, feedstock and fuel, hydrogen can do this by facilitating the large-scale integration of renewables through conversion and storage into renewable hydrogen, enabling grid balancing and seasonal storage; by converting natural gas and coal to low-carbon hydrogen through gas reformation with carbon capture and storage (CCS). Hydrogen represents a pragmatic and cost-efficient solution for the decarbonisation of hard-to-abate sectors of the economy such as transport, heating and cooling, and energy-intensive industries in particular. Furthermore, hydrogen is compatible with end-users' current usage patterns and convenience.

A deep and wide penetration of hydrogen across sectors and regions will not be possible without the availability of adequate policies to drive the scale-up of hydrogen markets in the different end-use sectors (mobility, heating, industry) as well as an adequate industrial policy that delivers hydrogen production at both decentralised and centralised scale and a subsequent infrastructure that is capable of interconnecting production to customers and end-users.

The European gas infrastructure is well placed to play this role. Spurred by the third Gas Package and billions of euros of private investment, European gas infrastructure is well-spread all over Europe with 2,2 million kilometres of gas pipelines and 1,200 TWh of underground storage capacity. Today, this infrastructure provides citizens and industry with a diversified, secure and competitive supply. Indeed, the utilisation of the existing gas infrastructure, together with electricity in a hybrid system, provides a smart and cost-efficient solution for achieving the EU decarbonisation and energy transition objectives[1].

On the road to 2050, an all-electric world is neither technically feasible nor economically acceptable since it would significantly increase the energy costs for private and industrial consumers[2]. The European gas infrastructure will continue to be a strong strategic asset for Europe; gas infrastructure operators will handle less natural gas making way for more and more renewable and low-carbon hydrogen, among other renewable gases (i.e.: biomethane, synthetic methane). In the near future, the use of power-to-gas technologies will enable the transmission, distribution and the storage of large amounts of renewables in the gas infrastructure. Likewise, conversion of natural gas through gas reformation with CCS can add large volumes of low-carbon hydrogen. While dedicated infrastructure can be built to transport and store hydrogen, the adaptation, repurposing and use of the existing gas infrastructure not only for the transport of hydrogen but also as a storage medium will unlock a cost-efficient pathway towards the upgrading of hydrogen's role in the energy system along with substantial societal benefits. The existing natural gas infrastructure will act as large-scale storage provider in a climate neutral energy system while enabling a seamless integration of hydrogen

[1] See relevant studies performed by Navigant (Gas for Climate) and Poyry (Fully decarbonising Europe's energy system by 2050) report on decarbonisation
https://gasforclimate2050.eu/
https://www.poyry.com/news/articles/fully-decarbonising-europes-energy-system-2050

[2] Full electrification would require smarter, and stronger more digitalised electricity grids with associated risks undermining public acceptance of the energy transition due to rising costs and significant interference with the natural habitat, wide-spread introduction of flexibility measures and cyber-security countermeasures, and higher levels of (seasonal) storage and back-up generation capacity.

into the internal energy market through the injection of a blend and/or 100% hydrogen. The gas infrastructure can also foster broader sectoral integration: beyond synergies between electricity and gas systems, also foreseeing synergies across sectors including industry, heating, agriculture and transport.

Already today, industrial companies together with regulated and non-regulated actors of both electricity and gas markets collaborating along the hydrogen value chain are preparing themselves, their infrastructure, and new business models. Leveraging the support granted both at European and national level, they have increased their R&D efforts to address technical issues related to the injection of hydrogen, the transport of 100% hydrogen as well as regulatory and legislative barriers. Power-to-gas is currently being demonstrated across Europe to bring this technology to industrial scale with gas infrastructure operators partnering with electricity infrastructure operators, gas producers, utilities, technology providers and economic and industrial actors along the value chain. In parallel, a similar level of cooperation exists for projects involving large scale production of low-carbon hydrogen from Steam Methane Reforming (SMR) with Carbon Capture and Storage or Utilisation (CCS/CCU).

Finally, it is necessary to point out that the relevance of developing a hydrogen economy is fundamental for Europe's global leadership. Within this context, Hydrogen Europe welcomes the European Commission's recent decision to grant hydrogen value chains with the status of Important Projects of Common European Interest (IPCEI). A recent study found that more than 5.4m direct jobs can be created by 2050, contributing to a €820 billion annual revenue for the hydrogen and equipment-related industries[3]. Security of supply will also be positively affected as the use of domestically produced and imported hydrogen would decrease Europe's fossil fuel imports dependency while positively impacting the EU's trade balance.

The upcoming revision of the gas market design, currently being prepared by the European Commission, should intend to provide a clear framework for the uptake of renewable and low-carbon gases and the hydrogen market.

Chapter II. Creating a Market for Hydrogen

A "colour-blind" approach: Hydrogen will have a key role to play on the pathways to carbon neutrality

Hydrogen, from both low-carbon as well as renewable energy sources, will have a key role to play along the journey towards carbon neutrality. Hydrogen has a central role in each of the strategic building blocks[4] the European Commission foresees for paving the road to a net zero greenhouse gas economy by 2050.

Hydrogen is at a crossroads of several key technologies relevant to the energy transition: it can be produced via water electrolysis with low carbon or renewable power, and Steam Methane Reforming (or auto thermal reforming and/or methane cracking) with CCS/CCU. Biogas/biomethane reforming and biomass gasification/pyrolysis are other ways to produce hydrogen using renewable gases or wastes[5].

Electrolysis will play an important role in the future hybrid system. While Europe currently boasts a strong presence and role as a frontrunner in the electrolysis market (integrators, component providers, OEMs), this technology remains relatively expensive at this stage due to the high capital costs of the technology which require larger markets and further development to reach industrial scale-up and bring costs down. The current absence of an adopted policy and regulatory framework for electrolysis is inhibiting market development[6]. However, costs are expected to decrease dramatically with the uptake of power-to-gas/power-to-hydrogen. Furthermore, with the forecasted increase in wind energy generation for example (per IEA it is expected to reach around 40% of EU energy generation, becoming number 1), electricity costs are also expected to decrease, enabling a cheaper hydrogen production through renewable energy sources. By

[3] Hydrogen Roadmap for Europe, Fuel Cell and Hydrogen Joint Undertaking, 2019.
[4] See COM(2018) 773 final – A clean planet for all – A European strategic long term vision for a prosperous, modern, competitive and climate neutral economy.
[5] Furthermore, where renewable energy sources are used to produce hydrogen and where carbon capture and storage in combination with biogenic carbon feedstock is applied, the resulting hydrogen could be considered as having a carbon negative impact.
NOTE: natural gas can be used for hydrogen production via (steam) methane reforming or methane cracking (IV-H_2). In order to avoid GHG emissions, the CCS and CCU technology becomes an intrinsic part of the production processes. Similarly, coal gasification and subsequent carbon capture and storage delivering hydrogen (IV-H_2) is a relevant option here.
[6] See IRENA (2018), Hydrogen from renewable power: Technology outlook for the energy transition, International Renewable Energy Agency, Abu Dhabi.

combining renewable energy resources available to our continent and our vast geological hydrogen storage capacity, Europe can further strengthen its global leadership in hydrogen.

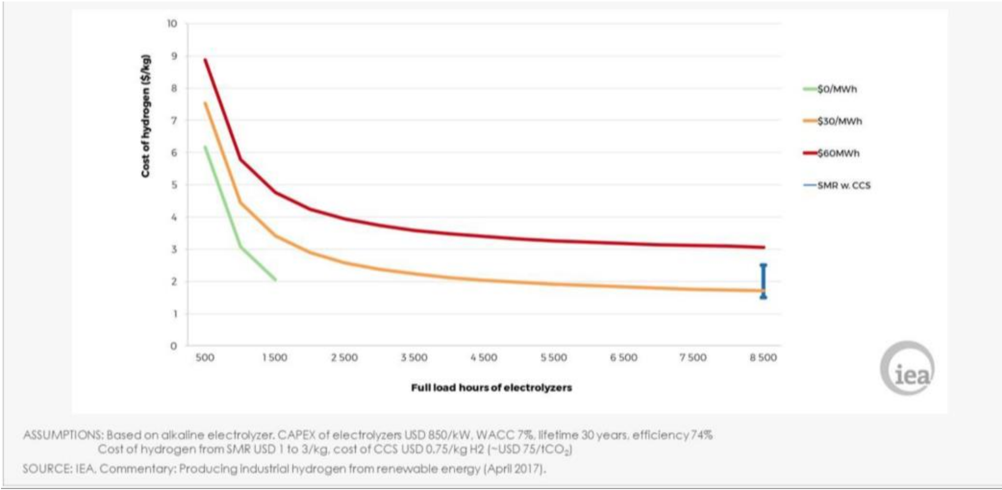

Figure 1 - Cost of hydrogen from electrolysis for different electricity costs and load factors ($/kg) - Energy Transitions Commission (2018)

Conversely, Steam Methane Reforming (SMR) technologies, which are today mature and widely used, when combined with Carbon Capture and Storage or Usage (CCS/CCU) could enable a fast and cost-efficient scaling up of low carbon hydrogen into the energy system, contributing to economies of scale.

Low carbon hydrogen projects can facilitate a wider deployment of hydrogen and contribute to the upscaling of the market for hydrogen. In the longer term, one could envisage a full switch to renewable and/or low carbon hydrogen in the gas grid to achieve deep decarbonisation. An infrastructure accommodating high shares of hydrogen was the reality in a number of European cities during the 19^{th} and 20^{th} century, when town gas was widely used. The United Kingdom, for example, is a leading country in terms of hydrogen developments, with their grid conversion analyses for Leeds, Manchester and Liverpool. By combining natural gas resources available to our continent and our vast geological CO_2 storage capacity, Europe can further strengthen a global leadership in hydrogen as well as carbon management and abatement technologies.

For the reasons above mentioned, renewable and low carbon hydrogen go hand in hand in European in the efforts to deliver on the Paris Agreement.

Hydrogen can be injected into the existing gas infrastructure, provided that the resulting gas complies with the gas quality requirements. It can also be combined with CO_2 to form synthetic methane through methanation, at the expense of additional capex and loss of efficiency. While synthetic gas as well as low concentration admixtures can be transported, stored and distributed in the same way as natural gas (i.e.: without changes to the system), the injection of high hydrogen concentrations requires adaptations at the level of the infrastructure, the downstream facilities and the end-user appliances, since hydrogen and natural gas have different chemical and physical properties.

Defining the contribution of hydrogen to decarbonisation has become an overarching priority. An increasing number of organisations are using different definitions for renewable, green, low-carbon, decarbonised, blue, etc. hydrogen. In order to harmonise the different types of hydrogen in line with the current European legislation and technology level, Hydrogen Europe suggests a clear set of definitions in Part V of this document.

Chapter III. Vision on the Role of the Gas Infrastructure

The gas infrastructure will play a central role in bringing the following three contributions of hydrogen to the fore:

- its role in supporting the upscaling of renewable energy sources in the energy system;
- in providing cost-effective options for transport, for long-term and seasonal energy storage, for the balancing of the energy system and for security of supply; and
- the decarbonisation of the gas infrastructure and gas end-uses.

We believe that the integration of hydrogen into the gas grid eases the transition towards a deep decarbonisation, thanks to the ability of the gas grid to integrate varying geographies and scales (conversion of clusters for industry zone/region/country/EU) as well as admixtures of hydrogen into the grid.

1. Gas infrastructure is key to unlocking the systemic role of hydrogen

Balancing the supply and the demand, time wise, geographically and across sectors is a growing challenge for the European energy system where decentralised and intermittent renewable electricity generation is taking an increasing role.

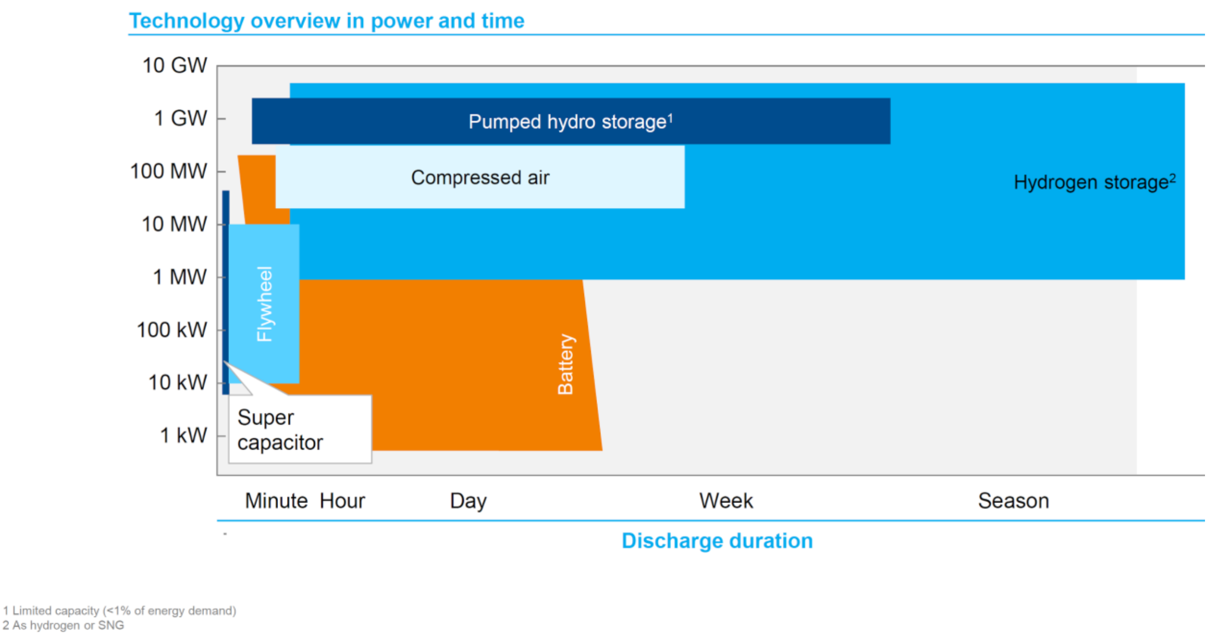

Figure 2 - FCH JU, Hydrogen Roadmap for Europe (2019)

- Firstly, the gas infrastructure can transport large volumes over long distances at a fraction of the costs when compared to the electricity grid. As an illustration, one could compare the BBL natural gas interconnector and the BritNed high-voltage direct-current submarine power cable. Both projects required roughly the same investment for their construction and both connect the Netherlands and the United Kingdom. However, BritNed only possesses a capacity of 1 GW, whereas the BBL pipeline has a total capacity of more than 20 GW, highlighting the comparative advantage of the gas infrastructure:

<u>*Cable versus pipeline*</u>

Name	Cable (BritNed)	Pipeline (BBL)
Capacity	1GW	20GW
Construction costs	EUR 600M	EUR 500M
Distance	260 km	230km
Volume (year)	8TWh	120TWh

<u>*Cable versus pipeline*</u>

Name	Pipeline (IUK)	Cable (NEMO)
Capacity	FWD (import BE): 27 153 MWh/h REV (export BE): 33 476 MWh/h	1000 MW
Construction costs	EUR 713M	EUR 690M
Distance	235 km	140km
Volume (year)	240TWh	8TWh

- Secondly, the existing gas infrastructure can provide large seasonal storage capacities. Figure 3 underlines the storage potential of, by way of example, Belgium, Denmark, France, Germany, the Netherlands, Sweden, Switzerland and the Czech Republic. Their gas storage volume amounts to 1,200 TWh of natural gas enabling it to cover today's average EU gas demand for more than three months. Whereas total electricity storages of 1.5 TWh suffices solely to meet the average electricity demand for fewer than ten hours. A high-renewable energy source-based electricity system will therefore need to depend on the gas system to provide energy storage.
- Thirdly, the gas infrastructure enjoys cross-border transmission capacities which are significantly higher than the equivalent existing electricity cross border capacities, as shown in Figure 4.

Figure 3 - Gas storage volume is more than 350 times larger than **electricity storage volume in GGI countries plus CZ**

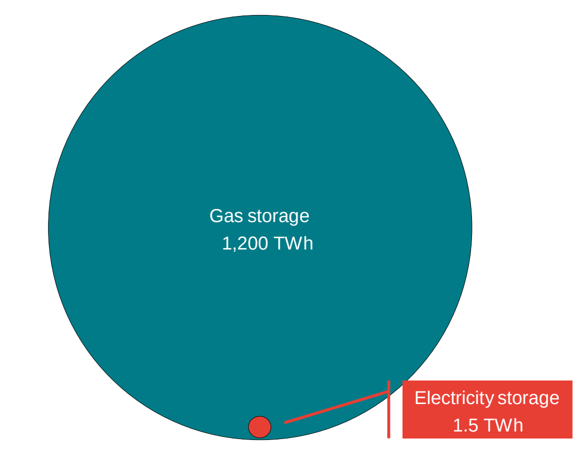

Figure 4 - Cross-border transport capacities for gas far exceed those of electricity

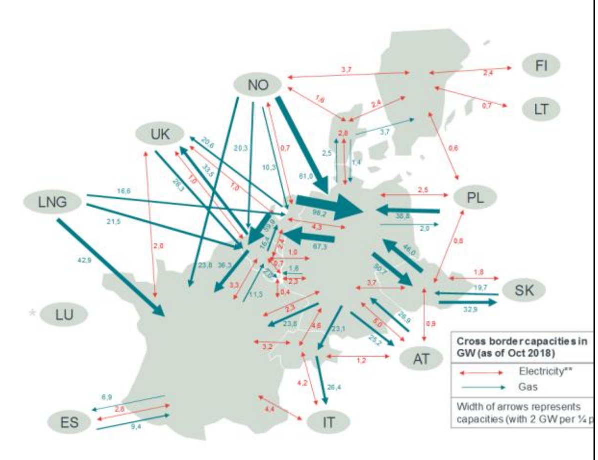

Figure 3 - Frontier based on Gas Infrastructure Europe, Entso-E and DOE & Figure 4 - Frontier Economics, GGI-Study, based on Entso-E and Entso-G

*Note: ** In some cases published capacities vary slightly between flow directions. In that cases, the higher figures are depicted.*

Power-to-gas can support the upscaling of renewable electricity sources into the energy system. As highlighted by the IRENA study[7], electrolysers can help integrate variable renewable energy into power

[7] See IRENA (2018), Hydrogen from renewable power: Technology outlook for the energy transition, International Renewable Energy Agency, Abu Dhabi.

systems, as their electricity consumption can be adjusted to follow wind and solar power generation, where hydrogen provides a source of storage for electricity as well as an alternative to its injection into the electricity grid.

Electricity markets in Europe have to deal with the rapid rise of renewable power generation. In some places the power generation of renewables exceeds the total demand in the electricity grid which often leads to the need to curtail output, costing €143 million (£M127) to the UK in 2018 alone[8] and €412 million to Germany in 2015 alone[9].

As such, power-to-gas constitutes the missing link for the coupling of the gas infrastructure and the electricity grid. The capacity of the electricity system to manage high shares of intermittent renewable energies – having in mind the gradual closure of conventional power plants - depends on the flexibility available in the system.

Hydrogen enabling the continued use of gas infrastructure

With a view to 2050, a number of recent studies have highlighted the significant cost savings that can be achieved through an integrated sector-coupling approach that embraces the above-mentioned advantages of the existing gas infrastructure compared to full-electrification scenarios[10]. Indicative calculations show for example that Germany alone can easily save €12 billion per year by 2050 through the continued use of gas networks[11], compared to an electrification-led scenario where gas is only used for seasonal storage. If, for simplicity, a linear development path between today and 2050 was assumed, these would elicit total cost savings of €200 billion[12] to €535 billion[13] between today and 2050 assuming a 95% decarbonisation target. With respect to savings for avoiding investments in additional electricity transmission lines, the estimates amount to €113 billion[14] to €121 billion[15] accumulated until 2050.

These large cost savings can be attributed both to the continuing use of gas-based end-user appliances in heating, industrial processes and the transport sector (e.g.: low (2 Vol. %) to intermediate (10-15 Vol.%) admixture of H_2 to hydrogen) and to the continuing use of the gas grid for transportation and storage by avoiding investments in the electricity transmission grid extension.

While the future unabated use of natural gas is inevitably limited in a climate-neutral energy system, the transformation of natural gas to hydrogen through gas reformation with CCS and the transformation of renewable electricity into hydrogen through electrolysis enable today's and tomorrow's energy consumers to harvest substantial cost savings thanks to the extensive transportation and storage capacities of the existing gas infrastructure.

Furthermore, in a majority of studies on decarbonisation in Europe, the decline of natural gas usage suggests an automatic reduction of gas infrastructure needs. However, with the switch to renewable and low-carbon hydrogen, among other sustainable gases, such assets can be adapted and used for a cost-effective decarbonisation across Europe. In addition, the conversion of gas grids to hydrogen is the fastest way to fully decarbonise as it can be achieved via central action:

8 https://www.ref.org.uk/constraints/indextotals.php
9 www.bundesnetzagentur.de
10 Dena-Leitstudie, FNB-Gas-study
11 https://www.fnb-gas.de/files/fnb_gas_wert_von_gasinfrastruktur-endbericht.pdf
12 ibid
13 https://www.dena.de/themen-projekte/projekte/energiesysteme/dena-leitstudie-integrierte-energiewende/
14 FNB Gas Study
15 Dena Study

Not convenient — Very convenient

	Decision	Switching convenience	Suitable for existing stock
Energy efficiency	Decentral	Varies significantly[2]	✓
Electric heat pump[1]	Decentral	Requires significant changes in heaters, piping and space for electric heat pump	✗
District heating network	Decentral	Significant infrastructure (piping etc.) needed to bring heat to buildings	✗
Micro CHP	Decentral	(Micro-) CHP unit needs to be installed, piping is not affected	✓
Biogas	Central	No changes for consumer	✓
Blended H_2-Natural Gas network	Central	No changes for consumer	✓
Pure H_2 network	Central	Significant changes in piping required, some upgrade of appliances required	✓

1 Electric heat pump are best suitable for modern well-insulated buildings; 2 For example, insulation is done on the outside of the house and does not affect the consumer significantly, while smart house system may require upgrade of appliances and new wiring

Figure 5 - Decarbonisation tools and their switching convenience, FCH JU, Hydrogen Roadmap for Europe (2019)
Note that it is the view of Hydrogen Europe that a pure H_2 network requires a significant upgrade of appliances

Enabling Sectoral Integration

Hydrogen is an energy carrier, a fuel and a feedstock, which if produced adequately can reduce GHG emissions, strengthen energy independence and mitigate the challenges posed by variability and intermittency of renewable energy sources as it offers a clean, sustainable, and flexible option to convert renewable electricity into a chemical energy carrier for use in mobility, heat and industrial applications. As the "gaseous form of electricity", it is an enabler for sectoral integration. The ability of power-to-hydrogen to access and integrate each sector of the energy system opens up the opportunity for deploying and utilising renewables to a much greater extent. Power-to-hydrogen systems can be implemented within the electricity grid utilising contractual obligations, guarantees of origin, in accordance with providing energy storage ancillary services for managing renewables in electricity grids and in direct combination with renewable power sources. Whereas electricity derived from renewables provides the power sector with a profound decarbonisation pathway, the heat and mobility sectors as well as industry do not yet have decarbonisation pathways of equivalent significance. The versatility of hydrogen enables these sectors to be integrated and to contribute to Europe's energy transition[16].

[16] See Hydrogen Europe's Rationale for Sectoral Integration at www.hydrogeneurope.eu

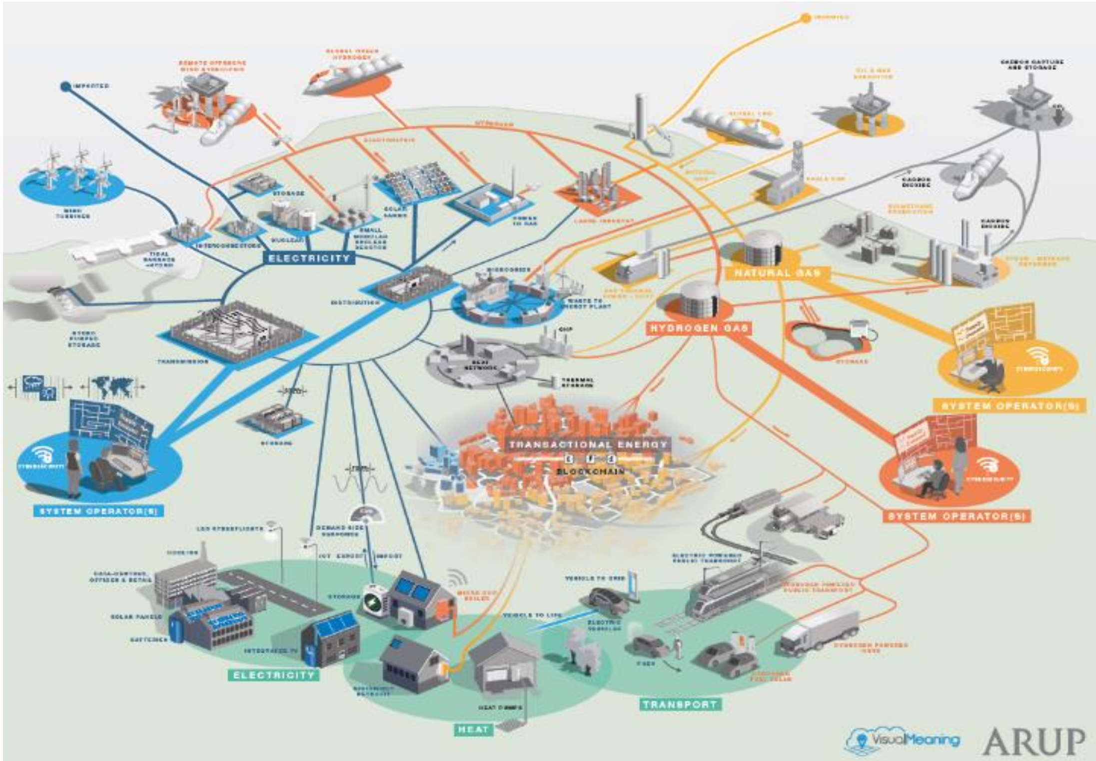

Figure 6 - Enabling Sectoral Integration, ARUP (2018)

The existing gas grids are already very well suited for the injection of biomethane and other renewable low-carbon gases. Widely spread and particularly well developed in industrial clusters and cities, the conversion of the existing gas grid to hydrogen[17] will enable the supply of renewable and low carbon hydrogen across sectors.

The gas grid will also play a pivotal role in the decarbonisation of heating for households in Europe. From today's 40% share, natural gas will gradually be replaced by renewable or low carbon hydrogen, synthetic methane and biomethane, in particular in old buildings where retrofits are costly and account for 90% of the emissions produced from buildings[18].

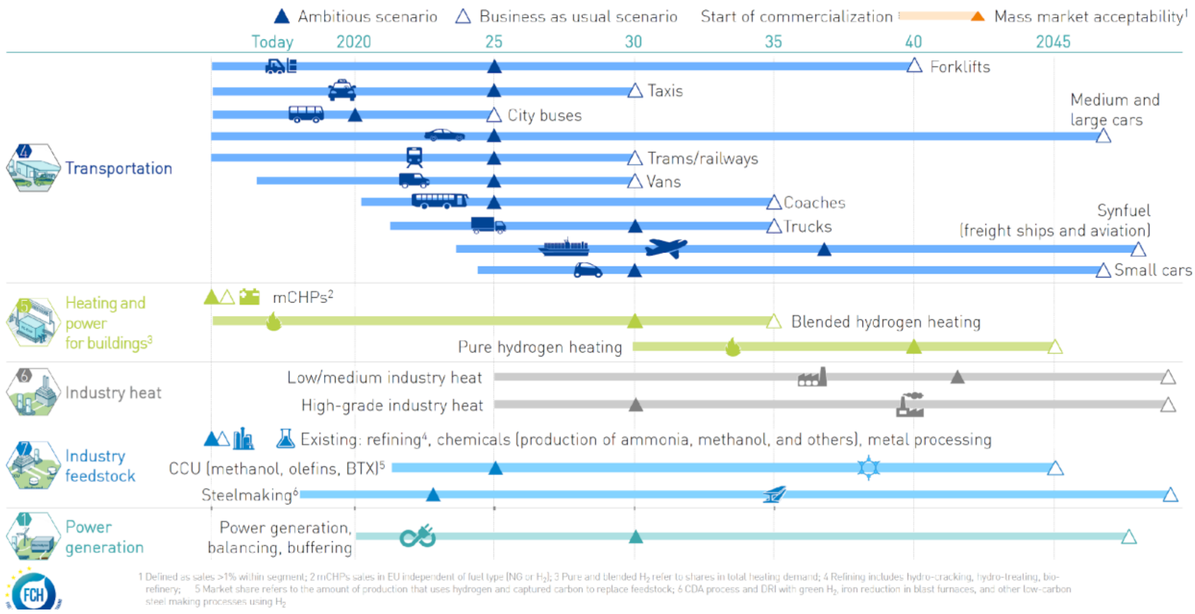

Figure 7 - Hydrogen applications and their market maturity, FCH JU, Hydrogen Roadmap for Europe (2019)

---

[17] As an alternative, where gas grid is not available the construction of dedicated pipelines for pure hydrogen can be envisaged.
[18] See FCH-JU Hydrogen Roadmap Europe 2019.

Ancillary services for the power sector

Thanks to the buffering capability provided by the gas system, power-to-gas provides flexibility which is not constrained by energy end-use [19]. Through the use of rapid response PEM electrolysers or alkaline electrolysers, power-to-gas can use cavern storage or the gas grid to offer ancillary services of high value to the electricity grid. Ancillary services are performed over different timeframes and include frequency response, voltage control, reserve and seasonal storage.

Electrolysers are able to respond quickly which is a key advantage for offering primary frequency control services requiring load to be directly turned up or down from the point of normal operation. This makes them suitable for providing negative reserve by increasing output or positive reserve by reducing output. From a technical point of view, electrolysers can meet the requirements of all types of control reserve without emitting CO_2. The electricity network operators could therefore rely on electrolysers to balance supply and demand on all timeframes, and thus keep electrical networks stable while reducing the CO_2 emissions of the grid balancing market.

Renewable integration and decarbonisation

Thanks to the existing gas infrastructure, power-to-gas in the context of sector coupling, can help integrate high penetration of Renewable Energie Sources (RES) into the power system and enable RES operation throughout longer periods by reducing curtailment. Non-consumption-oriented production of renewable energy can be feeding hydrogen into one or more energy sinks (e.g.: gas grid, storage tanks of hydrogen refuelling stations, and salt caverns). Stored hydrogen in the gas infrastructure can be further used in various timeframes and locations for satisfying demands for heat, transport, power or industry, achieving high utilisation and absorption of energy:

In order to successfully drive forward sectoral integration, it is necessary to

- support infrastructural coupling and create a single/harmonised regulatory framework for it;
- assess available sectoral integration technologies and recognise their key role in the energy transition and for the achievement of the climate goals, so that they are largely excluded from levies, duties or taxes related to the production, transport or consumption of energy;
- guarantee a priority use of the existing natural gas network infrastructure for sectoral integration solutions (feed-in premium);
- remove rapidly the regulatory barriers as to enable investments in the sectoral integration technologies.

How to support the upscaling of hydrogen end-use markets

Depending on the local and regional conditions and resources, different scenarios for power-to-gas development, biomass gas production, or low-carbon hydrogen production can develop. The integration of hydrogen into the networks could therefore be achieved at different points of the gas infrastructure (terminals or interconnections, transport, storage, distribution). The development of hydrogen at a large scale depends first and foremost on the development of hydrogen energy markets to be supplied by a reliable and safe infrastructure that will be able to transport and store large quantities of hydrogen connecting production areas to usages. The current gas infrastructure is well equipped to accommodate the rising need of hydrogen transportation.

The key role of gas grids is to connect a very wide range of customers and end users to a gaseous fuel supply efficiently, safely, reliably and discreetly. The key role of hydrogen as a decarbonising agent in gas grids is to reduce the carbon footprint of the gas being consumed by customers, across the various end use applications (industrial, buildings, refuelling, etc.). The desired extent of gas grid decarbonisation dictates the overall hydrogen demand, but the hydrogen itself can be injected in the form of an admixture to the natural gas grid, or used to produce synthetic methane for injection, or injected directly into a hydrogen grid.

Hydrogen Europe views the development of hydrogen technologies evolving in differing markets: sector coupling and sectoral integration. The two are depicted in Chapter V.

There is significant uncertainty about the market structure of the emerging hydrogen economy, an important backbone for the decarbonisation of Europe's energy system. Nevertheless, a number of market players are

[19] Vanhoudt, W., Barth, F. (Hinicio), Schmidt, P., Weindorf, W. (LBST), et al.: Power-to-gas – Short term and long-term opportunities to leverage synergies between the electricity and transport sectors through power-to-hydrogen; Brussels/Munich, 19 February 2016.

interested in investing into hydrogen technologies, in spite of the uncertain economic outlook due to lack of sufficient supporting policies. The integration of hydrogen and synthetic methane allows de-risking of the various technologies for production and use through the access to the internal energy market.

The development of robust markets for hydrogen for new products and services shall be encouraged. This will drive investment by the market in sources and infrastructure (including re-use of existing gas infrastructure) to supply the hydrogen needed in an efficient manner.

With a view to promoting sectoral integration and power-to-hydrogen, the gas grid would need to remain accessible to all users (producers / consumers) on a non-discriminatory basis (Third Party Access to the Network). The position of Hydrogen Europe with regard to power-to-gas plants, in the context of sector coupling, is elaborated under Chapter V below.

Chapter IV. Barriers and Hurdles

1. Injection of Hydrogen into the existing gas infrastructure: Where are we today?

Hydrogen and natural gas have distinctly different characteristics (calorific value, flow properties, density, flame speed, flame combustion properties, heat characteristics and interaction with the grid). Blending hydrogen to the natural gas stream slightly changes these characteristics, but blending can be an important early part of a 'stepped approach' towards gas grid decarbonisation.

This impacts the downstream facilities and end-users' appliances that need to be compatible with a blend which, furthermore, might be variable in composition.

Making the gas chain "hydrogen ready" translates into different adaptations and issues to tackle for each of its component, including:

1. *Gas grids*: Pipeline composition (e.g.: polyethylene vs. steel), compressors, safety[20] and admixture levels, including pipelines which are no longer needed to transport natural gas which might very well be adjusted to transport 100% hydrogen.
2. *Storage facilities*: Long-term seasonal storage of hydrogen in underground storages (UGS) is technically feasible and three pure hydrogen storage facilities are in operation.
   Salt caverns are considered to be more suitable than UGS in porous structures.
   Existing UGS have to be adapted if natural gas/hydrogen admixtures or pure hydrogen are to be stored.
3. *End-use*: Issues linked to changes of gas characteristics. For example, limits exist for the fuel supply of gas turbines. However, turbine manufacturers have started working on up to 100% H_2 capabilities for power plants[21]. Another issue that has to be addressed is billing of energy since the H_2 concentration may vary considerably due to a time-varying production profile of e.g. an electrolyser using renewable electricity. Finally, admissible hydrogen contents of 10 Vol.%, 15Vol.% or values as high as 30 Vol%, for particular appliances (cookers, boilers, etc.), are considered feasible. In contrast, some industrial branches, for instance chemical companies which employ hydrogen as a feedstock for their production, hesitate to accept H_2 concentrations exceeding 1 Vol.%. Furthermore, filter technologies are being developed to allow for hydrogen to be filtered out of the current gas mix to adapt to different end-user compatibilities[22].

The permitted concentration of hydrogen in the gas grid varies significantly between Member States (between 0.1 Vol. % up to 10 Vol.%) and in a large number of EU-countries the hydrogen injection into the gas network is generally not allowed. Neither international nor European standards define rules for admissible concentration of hydrogen in the natural gas network. The European Committee for Standardisation (CEN) standard EN 16726: 2015 summarises, "*At present it is not possible to specify a limiting hydrogen value which would generally be valid for all parts of the European gas infrastructure and, as a consequence, it is recommended case by case analysis*". The absence of regulations leads to a fragmentation of the gas market and may create problems at cross-border connection points. "A*n admissible concentration of hydrogen in the gas grid and a common Wobbe Index*[23] *have to be agreed and relevant gas quality standards have to be developed and adopted.*"

A close cooperation between legislators, investors, infrastructure operators and the hydrogen industry is needed to correctly phase the evolutions necessary in order to ensure that they are delivered in a timely manner. Germany showed that the additional costs for the transformation of the existing gas infrastructure aiming to fulfil the COP21 goals amount to at least €45 billion (2020-2050, Germany only), with a five-year delay in the transformation leading to an increase in additional costs of about 25%, showing the necessity to review relevant EU legislation accordingly.

There are fundamental legal and administrative barriers however which hinder the injection of hydrogen into the Gas grid. Hydrogen Europe is coordinating the HyLAW project which identified these hurdles and recommends a way forward.

[20] Projects: NaturalHy, Hyready, etc.
[21] http://www.mhps.com/special/hydrogen/article_1/index.html
[22] https://www.process.vogel.de/wasserstoff-aus-der-erdgasleitung-a-528677/
[23] The Wobbe index is an indicator of the interchangeability of such as natural gas, and is frequently defined in the specifications of gas supply and transport utilities.

Blended/pure offers most cost-effective/reliable power due to seasonal storage and grid balancing capabilities and minimizes conversion losses

	H_2-methane blending	Pure H_2 networks	Methanation[3]
Distribution infrastructure	Blending of gaseous H_2 into existing natural gas pipelines is possible up to a concentration of ~5-15%[1] – modifications to existing pipeline monitoring and maintenance practices necessary to ensure safety	Retrofitting or replacement of existing steel pipelines to non-corrosive and non-permeable materials (e.g., polyethylene, fiber-reinforced polymer pipelines) and leakage control is required for the transportation of pure gaseous H_2	No changes to distribution infrastructure required
Gas heating and cooking appliances	Utilization of H_2-methane blends in existing end-user appliances is possible up to a concentration of 5-20%[1], when calorific values are kept within tolerance bands; research even suggests 30% is possible, allowing for appropriate margin of safety	Conversion or replacement of end-user appliances (gas boilers, hot water tanks, gas cookers) required	No conversion or replacement of end-user appliances needed

Feasibility of H_2-blending in the gas network is proven: From mid-1800 to the 1950s (US) and 1970s (UK and Australia), manufactured gas ("town gas") – from coal, oil or whale oil – contained 30-60% H_2. H_2 blends are still common in some methane-poor areas (e.g., Hawaii). Hong Kong and Singapore still run on "town gas" with up to 60% H_2. H_2 blending has been restarted in countries like Germany (legal up to 10%) or cities like Dunkerque in France (H_2 blending of up to 20% in the GRHYD demonstration project) and Keele in the UK (H_2 blending of up to 20% in the HyDeploy project at Keele University in 2019)

1 The appropriate blend concentration varies by pipeline network system and local natural gas composition 2 2050 gas consumption by buildings (IEA 2DS) – underestimation of H_2 potential because the IEA 2DS projects a declining natural gas share without H_2 3 Drawback: Conversion losses

Figure 8 - Feasibility differentiation between blending, pure and methanation, FCH JU, Hydrogen Roadmap for Europe (2019)

The need for a common approach at European level on hydrogen admissible concentration and the development of technical and legal legislation from all members of the EU are essential in order to allow the injection of hydrogen into the European gas grid. The next European framework will need to focus on the following aspects:

- The framework for permitting and operating power-to-gas and power-to-hydrogen plants and grid connection/injection requirements should be included within relevant EU regulatory frameworks, including support schemes for production of electrolytic hydrogen;
- An EU-wide basis for injection of renewable and/or low-carbon hydrogen into the gas grid should be a priority to ensure a 'level playing field' and the continuing operation of trans-national interconnecting gas pipelines;
- Technical and gas composition rules should be reviewed to establish legal pathways to support power-to-gas/power-to-hydrogen operations;
- A framework for permitting and operating of gas reformation units with CCS should be established at EU level, including support schemes for production of low-carbon hydrogen;
- Safety and technical integrity limitations for hydrogen connection and injection into the gas grid should be studied in comprehensive and coordinated manner across the EU;
- Establish pricing principles covering connection fees and charges and remuneration for hydrogen supplied/injected;
- Review billing, measurement and administrative requirements with appropriate legal frameworks to allow increased hydrogen flows in European gas networks;
- An EU wide end user appliance assessment is essential to define the acceptable safety and operational threshold of end-user appliances;
- Develop the implications for refuelling infrastructure.

Finally, further research, development and deployment projects, under Horizon Europe, will be crucial to enable continued activities in order to understand and remove technical barriers to the deployment of hydrogen technologies. Hydrogen Europe therefore welcomes the common understanding between the European Institutions, reached on 27th March 2019, to include a partnership area on hydrogen and sustainable energy storage technologies with lower environmental footprint and less energy-intensive production. Furthermore, under the upcoming multiannual financial framework, increased complementarity and synergies with other EU funding mechanisms (e.g.: Connecting Europe Facility, Innovation Fund, InvestEU) but also with national and regional funding programmes and priorities will need to be maximised.

Chapter V. The Need for a Long-Term Regulatory Framework

1. Clear definitions

Clear definitions for renewable and low-carbon gases as well as, *inter-alia*, power-to-gas are needed to acknowledge their contribution to the decarbonisation and the hydrogen economy. As part of its Clean Energy for all Europeans package, the European Union agreed to the updating recast of the Renewable Energy Directive (Directive (EU) 2018/2001), aka REDII.

In addition to a new binding renewable target of at least 32% of EU final consumption in 2030, the RED II also introduces the following key changes relevant to the integration of gas from renewable energy sources into the gas system:

- Guarantees of Origin (GOs) are extended to cover renewable and low-carbon gases. This would provide a consistent means of proving to final customers the origin of renewable and low-carbon gases, including hydrogen, facilitating greater cross- border trade in such gases;
- Ensure consistency between the different GO systems for electricity, hydrogen and gas;
- Annual increase of 1.3 % of renewables' share in heating and cooling starting from the level achieved in 2020 is introduced. One of the possible measures is, according to article 23.4.a: „the physical incorporation of renewable energy in energy and energy fuel, supplied for heating and cooling";
- The Member States, where relevant, shall assess the need to extend the existing gas network infrastructure to facilitate the integration of gas from renewable energy sources and require system operators to publish the connection rules that include gas quality, gas odorization and gas pressure requirements. The transmission and distribution system operators shall publish the connection tariffs to connect production plants for renewable gases in a transparent and non-discriminatory way.

However, the RED II missed the opportunity to provide clear definitions for renewable gases, including hydrogen. At European level, clear and uniform definitions of renewable and low-carbon hydrogen, power-to-gas, power-to-hydrogen and energy storage in relation to hydrogen should be formulated and adopted, based on existing European projects, when possible. These definitions are the basis for a particular treatment of hydrogen technologies in the European and national legislations in connection to unbundling rules, trading in renewable and low-carbon gases, gas grid connection, injection into gas grid, electricity prices to be paid for and for hydrogen reconversion into electricity, tax treatment, support schemes etc.

Therefore, Hydrogen Europe proposes the below definitions:

- Renewable hydrogen is produced from renewable energy sources as defined in *article 2.1 of Directive 2018/2001*[24]
- Low-carbon and/or decarbonised hydrogen is produced from *non-renewable energy sources* with an ambitious minimum emission reduction threshold with a degressive factor[25].
- Synthetic methane is a methane gas produced from renewable hydrogen and CO_2[26].
- Sectoral integration means the integration of several sectors such as the power, transport, agriculture, the energy-intensive industries and/or the heating and cooling sectors via the use of energy carriers such as hydrogen.
- Sector coupling means the connection of the power and gas infrastructure[27].
- Power-to-gas, *in the context of sector coupling*, means the conversion, by water electrolysis, of electrical power into hydrogen or its further conversion to a gaseous energy carrier such as synthetic methane.
- Power-to-hydrogen, *in the context of sectoral integration*, means the conversion, by water electrolysis, of electrical power into hydrogen that may be used as an energy vector, a fuel and/or a feedstock.

---

[24] In accordance with a methodology to be elaborated by the European Commission based on established projects such as CertifHy. 'Energy from renewable sources' or 'renewable energy' means energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas.

[25] In accordance with a methodology to be elaborated by the European Commission based on CertifHy.

[26] With a carbon footprint in accordance with a methodology to be elaborated by the European Commission.

[27] As defined in the Gas directive 2009/73.

- Biomethane means biological methane produced as a result of upgrading biogas from the anaerobic digestion of biomass.
- Fuel cell means an electrochemical device that converts the chemical energy of a fuel, such as hydrogen, with an oxidant, such as oxygen, directly into electrical and thermal energy.

2. EU-wide hydrogen Guarantee of Origin scheme

An EU-wide Hydrogen guarantee of origin scheme is crucial for both renewable and low-carbon hydrogen. A Guarantee of Origin scheme should be developed at European level:

- Article 2.12 of the RED II defines a 'Guarantee of Origin' as 'an electronic document which has the sole function of providing evidence to a final customer that a given share or quantity of energy was produced from renewable sources';
- In parallel, non-renewable low carbon Guarantees of Origin will be needed to demonstrate the contribution to decarbonisation via gas of a lower carbon footprint. According to Recital 59 of RED II, the extension of the guarantee of origin systems to non-renewable energy sources should be an option for Member States. Hydrogen Europe supports this extension in order to be able to quantify GHG benefits of low carbon hydrogen.

The Guarantees of Origin should allow for the inclusion of additional optional information including greenhouse gas savings, the type of feedstock used and other benefits towards a circular economy. The GOs must be transferred, independently of the energy to which they relate, from one holder to another (e.g.: electricity to hydrogen or biomethane to hydrogen, etc.). Therefore, it is important that they are mutually recognised among the Member States.

According to the proposal for RED II, the extension of the GOs systems to non-renewable energy sources should be an option for Member States. There must be a clear and unambiguous distinction between renewable GOs and (non-renewable) low-carbon GOs, so that stakeholders can be confident in the GOs system.

Hydrogen Europe considers that CertifHy is the correct framework to utilise for the set-up of a hydrogen GOs scheme across Europe. However, Hydrogen Europe recommends to align CertifHy with the above-mentioned requirements for renewable and low-carbon hydrogen for injection into the gas grids[26].

This European-wide voluntary scheme would coordinate national registries, if existing, or establish itself as registry in a country lacking the capacity to have such facility until such facility is appointed by a competent authority, should the need arise.

3. Harmonise fragmented regulation to inject hydrogen into the natural gas network

As mentioned earlier, the permitted concentration of hydrogen in the gas grid varies significantly between Member States (between 0.1 Vol. % up to 10 Vol.%) and in a large number of EU-countries the hydrogen injection into the gas network is generally not allowed. The absence of a harmonised EU regulation leads to a fragmentation of the gas market, which inhibits the development of the power-to-gas market and may create problems at cross-border connection points. An admissible concentration of hydrogen in the gas grid and a common Wobbe Index have to be agreed and relevant gas quality standards have to be developed and adopted.

4. A framework for power-to-gas is needed

The question of the definitions of power-to-gas and its regulatory implications

The collision of different definitions and related unbundling regimes should be clarified in relation to power-to-gas and power-to-hydrogen. Indeed, clarity should be given, at EU-level, on the different market structures in which hydrogen evolves:

Sector coupling & power-to-gas

Sector coupling means the connection of the power and gas infrastructure.

Under this structure, Hydrogen Europe sees the role of hydrogen as a coupling agent for energy storage/balancing service providers and as such recommends the following definition for power-to-gas:

Power-to-gas, in the context of sector coupling, means the conversion, by water electrolysis, of electrical power into hydrogen or its further conversion to a gaseous energy carrier such as synthetic methane.

Sectoral integration & power-to-hydrogen

As mentioned earlier, hydrogen is a molecule that should not be confined to sector coupling. Indeed, hydrogen is capable of integrating several sectors together. It is time that Europe gets away from the silo thinking of sectors. The 21st century systems need to be truly efficient and integrated. This would allow Europe not only to keep its vast and integral assets functioning but also to use this gas to decarbonise energy-intensive industries such as steel, cement or refineries and increase its energy independence:

Sectoral integration means the integration of several sectors such as the power, transport, agriculture, the energy-intensive industries and/or the heating and cooling sectors via the use of energy carriers such as hydrogen.

Under this structure, Hydrogen Europe sees the role of hydrogen as an integrating agent and as such recommends the following definition for power-to-hydrogen (PtH_2):

Power-to-hydrogen, in the context of sectoral integration, means the conversion, by water electrolysis, of electrical power into hydrogen that may be used as an energy vector, a fuel and/or a feedstock.

Such a market should be solely based on commercial agreements including Power Purchase Agreements, GOs, etc. across sectors (e.g.: Renewable Fuels of Non-Biological Origin under the REDII). Essentially, it should be treated as a commercial agreement and be kept as a non-regulated market with the typical use of regulated asset (i.e.: existing natural gas pipelines) as transport means through Third Party Access where available. This shall not prevent the development of privately-owned unregulated pipelines serving dedicated customers.

Energy storage

Clarity is needed on how the definition of energy storage relates to other classifications, e.g. industrial production activities, of Power-to-gas/Power-to-hydrogen. Indeed, the current version of the Electricity Market Design Directive defines energy storage as following:

'energy storage' means, in the electricity system, deferring the final use of electricity to a later moment than when it was generated or the conversion of electrical energy into a form of energy which can be stored, the storing of that energy, and the subsequent reconversion of that energy back into electrical energy or use as another energy carrier.

The interpretation of this definition could restrict power-to-gas/power-to-hydrogen to the sole of function storing energy, while, as demonstrated above, it could play an integral part of the new energy system (i.e.: hybrid energy system and beyond). Therefore, we recommend the European Commission to complement the definition of energy storage to ensure that power-to-gas/power-to-hydrogen is not limited to an energy storage function from the perspective of the electricity market by e.g.: defining its role in sectoral integration and sector coupling.

Power-to-gas plants Ownership Model

In the context of sector coupling and in line with EU legislation, Hydrogen Europe calls for a clear, predictable and non-discriminatory policy framework that enables and supports the roll-out of power-to-gas activities/investments, by any players, as a non-regulated activity.

It should be stressed that such a policy framework shall not distort existing and future competitive markets, in the context of sectoral integration.

Nevertheless, should the following conditions apply:

- The need for investments in power-to-gas assets have been identified within the context of decarbonisation efforts, and/or within the context of EU network development planning (as approved by European and National Regulatory Authorities (e.g. through a cost-benefit analysis);
- A subsequent gap in private investment is recognised (through, inter-alia, market tests).

Competent authorities shall:

- Launch a tendering process open to all players to enable investments through support mechanisms; the tendering process should offer the same support, at the same level and at the same moment so as to ensure that there is a level playing field between all actors[28].
- if unsuccessful, provide that Transmission System Operators/Distribution System Operators (TSOs/DSOs) can directly invest as a regulated activity until the market conditions develop significantly.

In case of investment by TSOs/DSOs as a regulated activity, an adequate regulatory oversight should be in place, ensuring transparent and non-discriminatory access to the service.

In such a regulated framework, National Regulatory Authorities (NRAs) should regularly monitor market developments. Should markets develop significantly, NRAs might prescribe how:

- Regulated entities shall transfer their respective activities and assets from a regulated to a fully commercial/non-regulated entity; or
- They shall opt to phase-out their activities in this regard.

Hydrogen Europe supports the need for power-to-gas assets, in the context of sector coupling, to be analysed in the Ten Year Network Development Plan (TYNDP) as a joint work involving ENTSO-E and ENTSO-G taking into account the input provided through relevant consultations e.g.: industrial stakeholders such as electricity and gas-intensive industries and representatives of all networks users, to define the level of investment needed.

The final aim should be to allow market players to develop long-term viable business models which can compete in the market with as little regulatory intervention as possible.

5. The role of low-carbon hydrogen in decarbonising the gas grid

In the context of plans to switch gas networks to 100% hydrogen of low carbon footprint, Hydrogen Europe calls for a clear, predictable and non-discriminatory policy framework that enables and supports investments in gas reformation plants with carbon capture and storage (CCS), by any players, as a non-regulated activity.

It should be stressed that such a policy framework shall not distort existing and future competitive markets. Hydrogen supply to end-consumers that are switched from natural gas to hydrogen (e.g. households in a concept like H21 North of England) shall be a competitive market segment.

Nevertheless, should the following conditions apply:

- The need for investments in gas reformation assets with CCS has been identified within the context of decarbonisation efforts, and/or within the context of EU or national network development planning (as approved by European and National Regulatory Authorities (e.g. through a cost-benefit analysis);
- The total hydrogen output of the gas reformation plant is fed into the regulated grid for general supply for heating and power;
- A subsequent gap in private investment is recognised (through, inter-alia, market tests)

Competent authorities shall:

- Define a regulatory scheme which takes into account the specific market conditions
- Ensure transparent and non-discriminatory access to the infrastructure.
- Limit regulatory activities and ensures it does not prevent the establishment of competitive markets in the long term.

In case of investment by TSOs/DSOs as a regulated activity, an adequate regulatory oversight should be in place, ensuring transparent and non-discriminatory access to the gas reformation plant. All interested market

[28] Hydrogen Europe considers that this level playing field should apply to all market actors, regulated and non-regulated players alike, in particular with regard to a national support scheme for non-regulated players which should equal the corresponding regulated players' ability to recover their investment.

parties should be given the opportunity to acquire capacity at the plant and have their gas transformed to hydrogen through open and non-discriminatory capacity auctions.

In such a regulated framework, NRAs should regularly monitor market developments. Should markets develop significantly, NRAs might prescribe how:

- Regulated entities shall transfer their respective activities and assets from a regulated to a fully commercial/non-regulated entity; or
- They shall opt to phase-out their activities in this regard.

The final aim should be to allow market players to develop long-term viable business models which can compete in the market with as little regulatory intervention as possible.

6. EU Network Development Planning

The mapping of potential interactions between electricity and gas systems in relation to hydrogen is crucial for the development of future policies for the decarbonisation of the energy sector and achievement of EU climate goals.

Closer cooperation and coordination between electricity and gas systems in the context of renewable and low-carbon hydrogen technologies can contribute to achieving the climate goals in a more cost-efficient way.

According to Regulation (EU) 347/2013, by the end of 2016, ENTSO-E and ENTSO-G have submitted for approval to the Agency for the Cooperation of Energy Regulators (ACER) an interlinked electricity and gas market and network model, including both electricity and gas transmission infrastructure as well as storage and LNG facilities. ACER required further investigations concerning: gas and electricity prices, interaction (potential competition and synergies) of electricity and gas infrastructure developments, cross-sectoral influence of gas and electricity projects.

Therefore, it is crucial to emphasise the capabilities of hydrogen technologies to transport and store energy and their importance for the long-term decarbonisation of the energy sector through integration of significant quantities of renewable energies and to identify and assess all possible interactions between electricity and gas systems in relation to low-carbon and renewable hydrogen, existing and planned electricity and gas networks, electricity and gas storage capacities, demand-respond capacities, electricity and gas prices etc.

Examples for such interactions are:

1. Power to hydrogen/gas for direct use
2. Power to synthetic methane
3. Power to hydrogen/gas to power (F-Cell, Gas turbine)
4. Ancillary services in electricity grid
5. H_2/CH_4 injection into gas grid

Criteria for eligibility for Projects of Common Interest status should be adapted to make the contribution to decarbonisation a decisive criterion (i.e.: hydrogen-ready transport grid). This would ensure the long-term relevance of future investments while avoiding the risk of stranded assets. Furthermore, projects that promote the connection of renewable and low-carbon hydrogen to the grid, thereby contributing to the achievement of European decarbonisation objectives should be included.

Acknowledge the role of power-to-gas in providing ancillary services

There are different market arrangements in place throughout Europe regarding ancillary services procurement and balancing market design, including energy storage and demand response at TSO and DSO levels.

The Commission Regulation (EU) 2017/2195 provides a detailed guideline of electricity balancing including the establishment of common principles for the procurement and the settlement of frequency containment reserves, frequency restoration reserves and replacement reserves and a common methodology for their activation.

The integration of balancing electricity markets should be facilitated with the establishment of common EU platforms for operating the imbalance netting process and enabling the exchange of balancing energy from frequency restoration reserves and replacement reserves. In order to allow an exchange of balancing services, it is necessary to create a common merit order and to regulate the standardisation of balancing products. The Regulation lists the minimum set of standard and additional characteristics defining standard products.

When a TSO uses a European platform, it shall use only standard and, if justified, specific balancing products in order to maintain the system's balance.

According to ENTSO-E, the guideline creates a level playing field for all potential providers of balancing services, including demand side response and energy storage. Therefore, it is important that the capabilities of power-to-gas and related energy storage to provide ancillary services and to meet the requirements for standard products will be recognised and the participation of power-to-gas and hydrogen energy storage in balancing markets for ancillary grid services will be promoted.

Power-to-gas instead of curtailment

At present, renewable energy producers are usually partially compensated for not being able to inject their production into the grid due to limited grid capacity or limited demand. By creating a legally binding merit order, compensation for curtailment should only be paid if no alternative exists.

This would result in the avoidance of curtailment, with hydrogen being produced if a power-to-gas plant nearby can remove the bottleneck in the electricity grid or can utilise the power currently not being demanded in the electricity market. 'Compensation' should only be paid if there is no power-to-gas plant available.

This would allow the full potential of electrical renewable production to be integrated in the electricity and gas grids, maximising the EU social welfare by reducing funding support for "non-production". Power-to-gas would allow the maximisation of RES potential and RES would not be limited by the size of the electricity market. Moreover, by providing a solution to an excess of renewable electricity production, power-to-gas will reduce negative/very low prices on the electricity wholesale market. Power-to-gas will support the wholesale electricity prices enabling the development of additional market-based RES generation without any subsidies.

Remuneration Mechanisms

A power-to-gas plant which provides response services, reserve services or congestion management services to the electricity grid is helping to manage the variability caused by renewables, helping to integrate more renewable energy by reducing curtailment and helping to reduce the CO_2 emissions of conventional grid balancing techniques. Use-of-system grid fees for such power-to-gas systems should be waived and the hydrogen they produce classified as renewable hydrogen.

Even if the production costs of renewable energies have significantly reduced, the level of investments in infrastructure (electrolyser, storage, etc.) and the cost of electricity are such that renewable hydrogen is not yet competitive.

Some measures have to be implemented to avoid market failure and accelerate the deployment of power-to-gas to decarbonise the gas grid sector; in addition to supporting R&D and new technologies, it would be appropriate to:

1. Set up, on a temporary basis, revenue supporting schemes, contracts of difference or other mechanisms such as Feed-in-Tariffs, to bridge the gap between conventional and renewable/low-carbon solutions in order to enable the take-off of renewable and low-carbon hydrogen. The legally appropriate pathways should be investigated at the national level and identified barriers, if any, removed.
2. Increase visibility on the electricity price and grid services income. Electricity can account for a large portion of the total costs; moreover, visibility of the electricity market price is on a short-term period only (usually 3 years), while electrolysers are usually depreciated over a long-term period (approximately 20 years).
3. Obtain an adequate internalisation of CO_2 price and ensure hydrogen injected into the gas grid possesses a carbon footprint that is below an agreed carbon-intensity threshold.

State Aid Guidelines

Electrolysers require significant amounts of electricity and the latter's price represents one of the most important cost factors for the conversion of electricity into hydrogen. Therefore, it is important to reduce the price of the electricity used in the electrolysers process, provided that it comes from renewable energy sources. Considering the potential of renewable hydrogen for decarbonising the gas, mobility and industry sector, *its production by electrolysis, regardless of the capacity of the power-to-gas/power-to-hydrogen plant, similar to the production of industrial gases, has to be included in the list of electro-and trade intensive sectors in order to reduce the charges in the electricity price associated with the use of renewable energies.*

The list of electro-and trade intensive sectors in Annex 3 of the Guidelines for which an aid in the form of support of renewable energy can be granted should be extended with production of renewable hydrogen. In order to ensure the necessary investment security in the market introduction phase of electrolysers, it is advisable to design the approval for the reduction of the apportionment for the electricity purchased from the grid for electrolysis on a multiyear basis.

In its current guidelines, the European Union defined (art. 1.3.11) energy from renewable energy sources as "energy produced by plants using only renewable energy sources, as well as the share in terms of calorific value of energy produced from renewable energy sources in hybrid plants which also use conventional energy sources and it includes renewable electricity used for filling storage systems, but excludes electricity produced as a result of storage systems;"

In order for electrolysers to play their key role in renewable integration across sectors as well as contribute to the decarbonisation of the power sector through ancillary services, *Hydrogen Europe recommends that the guidelines should be reviewed keeping in mind that electricity produced as a result of such storage systems should be considered renewable*.

EU-wide targets for renewable and decarbonised gases in the gas markets

A target setting approach for the injection and consumption of renewable and low-carbon gases will send clear signals to investors and businesses alike to act and work effectively towards the greening of the gas infrastructure and the scaling up of hydrogen and other forms of renewable and low carbon gas.

The objective should be to decarbonise the existing and new gas markets and not just the gas grid. It would otherwise encourage production for the sole purpose of injection and decarbonisation of gas grid, leading to divert volume from other higher value markets.

An EU wide target as opposed to national targets is the preferred option as this would allow more flexibility, thus recognising and respecting the varying national and geographic specificities of the different Member States.

In view of the EU's long-term climate objectives, the maturity and scaling up of renewable and decarbonised gases would be further supported by targets linked to specific timeframes[29]:

- ✓ 2030: minimum of 7% of natural gas by volume is replaced by hydrogen
- ✓ 2040: minimum of 32% of natural gas by volume is replaced by hydrogen
- ✓ 2050: 100% renewable and decarbonised gases of which a minimum of 50% is hydrogen

The targets should contribute towards the achievement of the EU's objectives for renewable energy, as a sub-target to the Renewable Energy Directive (REDII). As such, contributions of EU Member States towards the achievement of their renewable targets and the role envisaged for renewable and decarbonised gases should form part of the National Energy and Climate Plans submitted by governments to the Commission in accordance with the EU Energy Governance Regulation.

Hydrogen market design

Hydrogen Europe commends the initiative by the European Commission to look at the future role of gas in Europe and that hydrogen is considered as an integral part of the pathway to decarbonisation.

However, we would stress that, in order to grasp the full potential of hydrogen as a decarbonisation enabler, a specific hydrogen market design be created, in line with the electricity and gas market designs in such a way

[29] Based on Hydrogen Roadmap for Europe, FCH JU (2019)

that it gives full flexibility to the markets so as to integrate fully in the most efficient and cost-competitive manner.

Indeed, due to its versatility, the potential for hydrogen to play a key role across sectors needs to be tackled in a systemic manner, realising a true sectoral integration.

Therefore, *Hydrogen Europe calls on the European Commission to integrate a review clause, subject to a significant market development, within a new gas package*.

Although hydrogen does not yet account for a significant proportion of European energy consumption, it is the view of Hydrogen Europe that by the mid-2020s, the European Commission should launch a consultation process with stakeholders on a possible hydrogen market design target model as part of a review clause in any upcoming gas legislation proposal, providing that significant market developments have been realised, including sufficient volumes.

***

Hydrogen Europe represents the European Hydrogen and Fuel Cell sector, including 110 industry companies representing the whole value chain, including OEMs and end-users, 67 research organisations and 16 national associations. We bring together diverse industry players, large companies and SMEs, who support the delivery of hydrogen and fuel cells technologies. We do this to enable the adoption of an abundant and reliable energy which efficiently fuels Europe's low carbon economy.

We partner with the European Commission in the innovation programme Fuel Cells and Hydrogen Joint Undertaking (FCH JU).

For more information, please visit www.hydrogeneurope.eu.
Contact: Nicolas Kraus, n.kraus@hydrogeneurope.eu.