Hydrogen – A pillar for achieving the EU Commission's 2050 vision

A fast and cost-efficient transition to a decarbonised society is possible if all available technologies and resources are taken into consideration. As such, GIE believes that hydrogen and the gas infrastructure have a key role to play in achieving full decarbonisation of energy supply in all sectors by 2050.

This document sets out GIE's views on the role of the gas infrastructure to support the development of hydrogen to achieve full decarbonisation and thereby supporting the EU and its Member States in achieving the climate goals set out at the COP21 meeting in Paris.

So far, decarbonisation policies have tended to focus on power generation as an easy start[1]. The focus has since expanded to include all energy-related emissions from all sectors to achieve the ambitious target reduction in GHG emissions of 80-95% by 2050.

Hydrogen has emerged then as the solution best suited to reduce CO_2 emissions in sectors where electrification seems unfeasible or relatively inefficient but even in the power generation sector to complement intermittent renewable electricity as it has recently emerged that the integration of variable renewable energy sources and increased electrification will increasingly challenge the electricity network[2].

The alert was raised in countries where the switch to renewable electricity sources were directly linked with a need to grid reinforcement to connect new generation sources with load centres (like in Germany where the wind parks are concentrated in the North whereas the load centers are in the West and South).

Whereas reinforcement of energy grids becomes crucial, the already installed and operating gas infrastructures capacity (mainly under the ground) is increasingly considered as a more appropriate way to address several infrastructure challenges:

- Providing the entry gate to Europe for renewable energy;
- Transporting energy over long distances with sufficient grid capacities;
- Balancing the energy system with seasonal storage;
- Enabling the integration of increasing shares of variable renewable energy sources into the energy system;
- Having access to areas where renewable energy sources can be cheaper or more abundant.

To achieve CO2 emissions reduction, hydrogen appears then as the appropriate solution. Thanks to its characteristics, hydrogen can be transported over long distances and stored in large quantities, making use of well-developed gas infrastructure. Based on a combination of gas assets including storage, transmission and LNG infrastructures, it enables to optimize the energy system by making use of possible synergies between the gas and electricity infrastructure (optimizing electrical grid extension through better use of existing gas infrastructures assets) while providing flexibility services under different temporal and geographical dimensions (smoothing out price fluctuations and avoiding demand curtailment).

With environmental challenges becoming increasingly significant, the interest in hydrogen-based solutions to further reducing CO_2 emissions could be characterised with a new kind of fervour. More ambitious efforts for exploring further the coupling of gas and electricity systems whilst fostering sectoral integration to decarbonise all energy sectors are needed.

Numerous of initiatives and pilot projects are initiated by GIE members, covering both blending and pure hydrogen. Considering the limited timeframe to become market-ready, short-term supporting schemes should be introduced to enable the upscaling of investment in hydrogen technologies to facilitate the market to take off. In addition, an evolving EU regulatory framework internalizing the system benefits of the gas value chain whilst promoting hydrogen-based technologies, would be beneficial in driving the transition towards EC long-term objectives in a sustainable cost-effective manner.

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[1] Increasing the production of renewable electricity by replacing stationary emission sources with lower carbon alternatives - within the same electricity network and with the same end-user appliances - was the first and obvious area to start decarbonisation in an affordable way.
[2] https://www.poyry.com/sites/default/files/zukunft_erdgas_key_to_deep_decarbonisation_0.pdf

1. *The potential contribution of low-carbon and renewable gases to decarbonising all energy sectors*

Climate targets in Europe require full decarbonisation of energy by 2050. This means that all energy sectors, including those requiring high energy density and flexibility in use, need to be decarbonised.

Given the characteristics of these market segments, an electrification-led energy transition could rapidly become challenging as electrification appears unfeasible or relatively inefficient in some market segments. Hydrogen-based technologies appear then as an appropriate solution to facilitate all energy sectors on the decarbonisation process.

Furthermore, increased renewable electricity generation as well as increased electrification of end-use markets will require an increasing need for more back-up to ensure reliable power supply.

1.1. Gases are a promising solution for market segments where electrification appears unfeasible or relatively inefficient

In industry, using gas (including hydrogen) is often the most cost-efficient solution to supply process heat and to conduct high temperature combustion processes. Furthermore, low-carbon, decarbonised and renewable hydrogen as feedstock can decarbonise polluting hydrogen-based processes (e.g. for processes in the chemical industry). Another example is in the production of steel where emissions related to current coal-based processes can be avoided by using hydrogen as raw material.

In transport, hydrogen-based solutions are a promising decarbonisation option, due to the several limitations regarding the current technology of electricity storage. This particularly counts for heavy-duty road transport and shipping with long distances and heavy loads.

In heating, the sector is dominated by oil and gas to respond to fluctuating seasonal demand in most countries. Despite assumed continued energy efficiency gains, deep electrification of the heating sector would lead to a substantial and inefficient expansion of the electricity grid, increasing subsequently the costs for end users. This calls for gas as a complement to mitigate peak demand and thus to avoid inefficient expansion of the electricity grid. In fact, the ability of gas boilers to provide large heating power (even during cold spells) and their comparably low investment costs makes it unnecessary to promote any different heating solution. Gas heating is prevalent in most countries, mainly allowing seasonal heat to be covered. In the future, it will remain a valuable energy carrier based on its comparably low capacity costs and high flexibility.

Gas as an energy carrier, due to its versatility, appears then as the cost-efficient solution, having comparable physical and chemical properties with other fuels while complementing renewable electricity sources.

Whereas a fuel switch from oil/coal to natural gas enables to reduce CO_2 emissions, hydrogen will be a key enabler for reaching Europe's climate targets by making full use of the advantages of existing infrastructure.

1.2. There will be an increasing need for back-up power generation capacity to ensure reliable power supply provided by gaseous energy carriers including H_2

In electricity production, gas-fired electricity serves as a reliable back-up generation for intermittent renewable electricity.

In the past, nuclear considered as base-load and fossil fuels as base or peak-load, were important dispatchable sources that could be adjusted to demand. These have been progressively replaced by intermittent renewable electricity sources. Thus, less dispatchable sources are becoming available whereas the electricity grid requires additional flexibility to cope with intermittent renewable electricity sources[3].

Gas-fired power plants are, based on their comparably low capacity costs and high flexibility, best placed to provide this back-up service. In order to secure adequate availability of gas and in the future hydrogen to run

3 Renewable electricity provides progressively the majority of electricity generation and can even frequently exceeds power demand during certain periods, facing even the risk of curtailment.

thermal power plants during periods of high residual demand, gas infrastructure need to be adequately assessed to ensure that enough capacity will remain in the energy system[4].

In addition, increased electrification will reinforce this need as additional flexibility will be required in the electricity network to cope with high demand and peak demand risk.

2. *Rethinking the use of gas infrastructure in a decarbonised economy: gases including H2 are key for the energy transition*

2.1. Gas infrastructures enable substantial cost savings across the whole energy value chain

While electrification of some end-use sectors could be an efficient option, limitations such as low energy density, limited storability and a lack of grid capacity applies in favor of gas infrastructures for the transport and the storage of energy in a decarbonised energy system.

By saving substantial costs across the whole energy value chain, gas infrastructures contribute positively to the electricity system by providing high-capacity transmission grids and large-scale storage over long-periods. In a well-designed market, system benefits should be adequately assessed to allow transparent optimisation of the energy system.

2.2. Gas infrastructures are the adequate channel to transport and store energy as gases including hydrogen

Flexibility in the energy system has in large part been provided by the gas infrastructures, due to its inherent ability to store and transport large amount of energy.

Gas storage has been ideally suited and used for decades to match comparably constant natural supply with seasonal demand. Current electrical storage solutions cannot compete with the entire gas system in terms of handling seasonal demand patterns in a cost-efficient way. These solutions are either limited in scale or only suited for short-term durations.

By way of comparison, in Europe, gas storage is currently around 1000 times as large as the capacity from electricity storage and volume can cover energy demand for several months while electricity storage can only meet the average electricity demand for a maximum of four-five hours. Even assuming optimistic cost developments, energy storage volume in batteries is still 100 to 1000 times more expensive than energy storage volume in gas storage facilities[5].

Therefore, gas storage is the best solution for providing long-term high-volume energy storage.

In an increasing globalised market, matching supply with the pattern of energy demand, even in the case of one-off supply shortfalls and/or extreme demand situations constitutes an essential asset that will be reinforced with strong electrification, as increasing demand variation flows will accentuate demand peak and risks of price deviation.

The high interconnectivity of the European gas transportation network and LNG terminals also contribute to security of supply in providing the high capacity which is required to bridge the growing distance between energy sources and demand regions.

Transporting energy over long distances with enough grid capacity will play a growing role as it will be possible to use sources from remote areas whenever these are more cost effective than the usage of local/domestic sources. It will also facilitate to find appropriate and accepted locations (remote to populated areas), where renewable energy can be cheaper or more abundant.

If we aim for the long-term, decarbonising Europe's energy supply by switching to renewable energy will require a strong increase in these resources, requiring substantial additional generation capacity that may partly come

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[4] *In Artelys and Frontiers study, it has already been shown that the presence of gas infrastructures prevent unnecessary investments in electricity generation from materializing. In addition, variability of electricity prices or even risk of electricity demand curtailment situations can be reduced.*
https://www.frontier-economics.com/media/3113/value-of-gas-infrastructure-report.pdf
https://www.gie.eu/index.php/gie-publications/studies/27906-gie-artelys-study-capacity-value-of-gas-storage/file

[5] Frontiers (2018) based on IRENA (2017a) and Le Fevre, C. (2013)

from another country and even from outside of Europe. In the medium to long term, LNG terminals will be instrumental in importing and storing large quantities of renewable energy (based on hydrogen) that will be necessary to meet the energy demand and flexibility needs of the future EU energy market.

2.3. Gas infrastructures are the perfect partner to build the bridge from a fossil-dominated world to a long-term climate-neutral or even zero-emissions future

Meeting the ambitious targets set out by the EU implies a switch to renewable, decarbonised and low-carbon gases. Gas infrastructures play an important role in that transition by delivering the capacity required by the energy system. While the scale for this future requirement may be new and challenging, providing such service in itself is not.

This transition can be realised, as hydrogen-based solutions can be produced from a variety of sources - "*flexibility of generation*" - and can be used for different end-markets – "flexibility in use". As such, renewable methane as well as hydrogen-based technologies will support decarbonisation by including all energy sectors in the process. Electrification of end energy use will then be complemented by end-user appliances that can operate on hydrogen solutions when it is more efficient.

Hydrogen in a decarbonized energy system is then emerging as the key enabler for having several key competitive advantages:

- Hydrogen can be stored – "storability" in economic terms but also in terms of performance and reliability;
- Hydrogen can be produced from a variety of sources – "flexibility of generation";
- Hydrogen can be used to decarbonize sectors and end-markets – "flexibility in use";
- Hydrogen can be transported over large distances – "connecting" remote production locations and centers of demand.

Depending on the structure of the economy, its sectors and energy-mix, different solutions provided by the gas infrastructures are possible to master the challenges of decarbonisation in a cost-efficient manner. Thereby, gas infrastructures become a valuable and integral part of the future energy system. With varying relevance for the countries, it is important to keep options open to make the transition happen and to keep gas infrastructure as a valuable and integral part of this energy system and technology-mix.

3. Adapting the gas infrastructures to a decarbonised energy system

Decarbonisation of the gas system will happen in a gradual process with increasing shares of natural gas and other fuels being replaced by low carbon, decarbonised and renewable gases.

Depending on the level of hydrogen injected, gas infrastructures could facilitate the decarbonisation process. This will largely be driven by market demand but also through dialogue with producers, industry players and customers.

The development of renewable, decarbonised and low-carbon gases is dependent on political choices and decisions. The paths chosen – as well as their speed of implementation – are influenced by the overall EU climate and energy policies and will differ amongst the EU Member States.

Gas infrastructure operators will need to be ready for and able to adapt to the EU decarbonisation process. For the moment two possible options seem plausible of how the gas infrastructures will accommodate the process.

3.1. Continuing with a mixed source gas infrastructure

Under this scenario the gas infrastructure would transport blends of hydrogen with natural gas or methane up to a certain threshold. This threshold needs to be verified however based on technical condition of the network, based on operator knowledge and experience and followed by case by case analysis.

Current research shows that hydrogen could be injected to a certain extent into the transmission pipelines and storage infrastructure without significant modification of existing equipment. This injection could work together with injection of biomethane and other forms of renewable methane.

For interoperability purposes, the harmonisation in the CEN norm should be considered as a minimum threshold without prejudice to the individual Member States to extend these limits nationally or locally.

Additionally, membrane-filter technologies separating hydrogen from natural gas in H2-CH4 admixtures can constitute a possible option to respond to gas quality demands of sensitive customers.

Blending hydrogen up to a reasonable threshold can be considered as a long-term, cost-efficient solution. However, beyond a certain threshold it might become more advantageous to consider dedicated infrastructure.

3.2. *Dedicated infrastructure for hydrogen*

Dedicated infrastructure for hydrogen will progressively emerge in parallel as the market for hydrogen develops.

This could be achieved on a region-by-region basis and/or in local areas for industrial, transport use or in urban areas (with high demand densities). This will step up market integration by starting at regional level. Demand centres such as industrial clusters will have to be connected via a hydrogen backbone, most likely in relatively small amounts. With a hydrogen backbone the transmission of hydrogen can be expanded gradually, across borders and markets.

Furthermore, decentralised energy solutions will also gain in importance as gas infrastructure operators are ready to operate Power-to-gas in cities and municipalities. Thereby, infrastructure operators can contribute to an overall energy system based on sustainable, secure and locally sourced energy, supporting them in their efforts to develop and promote green energy systems in their urban landscape.

3.3. *Framework supporting the adaption of the gas infrastructures*

To facilitate the development of hydrogen-based technologies, gas infrastructures need some support in terms of adaptation of the gas infrastructures.

Recommendations

Setting up research, development and pilot projects about injection of pure, blended H2 and synthetic methane into gas infrastructures and end-use applications

Supporting the development of pilot projects and demonstration plants on a larger industrial scale

Ensuring gas systems remain interoperable avoiding market fragmentation and ensuring a fully integrated market in view of the development of renewable, decarbonised and low-carbon gases

Supporting a regulatory-sandbox approach for pilot projects to ease legislative restrictions and uncertainty

4. *What design for tomorrow's European energy market?*

By adopting the Clean Energy Package, the European Union has set the bedrock for a dynamic legislative framework for the energy transition. Even if the path towards a green energy system continues to be challenging, the transition is in the right direction as decarbonisation has been initiated.

The European gas infrastructure should be recognized within the regulatory framework as a key asset for the decarbonisation of the European economy providing a sustainable and cost-efficient solution to the transport and storage challenges of a future decarbonised energy system.

4.1. *Moving from the current 'silo' approach towards a more holistic view*

Electricity and gas networks should be more closely interlinked. The next step would be to recognise the contribution of gas system to the electricity system.

Alleviating the stress on the power grid and thereby increasing renewable integration need to be internalised as part of the gas system benefits to the electricity system. An integrated sector coupling approach would facilitate the development of the electricity system as it would capture the value generated by the gas infrastructures.

At the same time, gas infrastructures can contribute to other sectors, such as industry and heating, by efficiently providing high energy density over different time frames. This contribution needs to be recognised as well. Facilitating sectoral integration would mean that further electrification of sectors such as heating would rely on gaseous energy carriers as a complement and, as such, recognise the increasing need to rely on hydrogen as an integrating agent between sectors.

Recommendations

Given the long time to implement changes in asset heavy networks, it is crucial that planning and regulation is proactive and a holistic approach is used.

Electricity and gas infrastructures planning taking place in an integrated way

Moreover, it is essential to rely on a coherent approach across multiple sectors to assess the gas and electricity system needs and flows. Without joint planning of key infrastructures across electricity and gas, there is a substantial risk of uncoordinated and inefficient investments.

Ensuring that regulation of gas and electricity operators does not create adverse incentives preventing a narrow sectoral approach.

4.2. The importance of the framework conditions to constitute the environment in which businesses can better develop

Whereas the social benefits are proven, hydrogen-based technologies are not yet profitable. The challenge today is not so much that the individual technologies are unproven, but that they need to be scaled-up in new combinations to take advantage of economies of scale and process optimisation.

This underlines the importance of the framework conditions that could constitute the environment in which businesses can better develop.

4.2.1. Supporting schemes to support the upscaling of the business case

In addition to supporting R&D and new technologies, revenue supporting schemes and contracts of difference or other mechanisms such as feed-in-tariffs could be envisaged, on a temporary basis, to accelerate the deployment of hydrogen-based technologies.

In addition, R&D on hydrogen should be done on a coordinated way between the different stakeholders to ensure coordinated action in work and planning towards the targets and to assess progress effectively.

4.2.2. Explicit support for a legal framework

- Framework for an optimised energy system

Besides these measures, the value of gas infrastructures alongside electrification should be adequately assessed and captured to ensure that they will continue delivering them. In electricity generation, the rapid deployment of renewable electricity sources is already challenging the electricity grid for requiring additional flexibility while not providing the right signal. This is due to the power market being dominated by very cheap marginal cost plants such as renewable or nuclear. Alongside the capacity market for fired electricity generation, the contribution of the gas system to the resilience of the whole energy system should also be considered.

As a minimum, strong electrification should go hand in hand with an adjustment on levies, charges and taxes to ensure that electricity system can capture the benefits generated by the gas infrastructures. A very good illustration is with P2G facilities treated as end consumers in most countries for using electricity and burdened with renewable levies whereas they enable to reduce electricity network expansion requirements or the curtailment of renewable energy sources.

Recommendations

Adjusting levies, charges and taxes to reflect societal benefits

- Framework for renewable, decarbonised and low-carbon gases

An optimised and decarbonised energy system should go along with a framework for renewable, decarbonised and low-carbon gases to provide targets and signals in favour of the development of hydrogen.

Recommendations

A viable, realistic target setting approach for the injection and supply of renewable gas and low carbon gas

A target setting approach for end consumer sectors (considering full life-cycle emissions)

Priority dispatch to facilitate injections of renewable gases into the gas grids

Establishing certificates of origin that account for the avoided $C0_2$ emissions

These swift adjustments in the regulatory framework will be needed to allow the gas infrastructure to play their central role in the scale-up of a hydrogen market in Europe where all hydrogen-based technologies can be valued in the different timeframe and thereby reflect societal expectations regarding carbon neutrality and reliability.