EUROPEAN TECHNOLOGY & INNOVATION PLATFORM ON WIND ENERGY

Report on the ETIPWind Power-to-X workshop

WindEurope

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1 Context

1.1 Background

As promised in the grant agreement, the ETIPWind secretariat promised to organise meetings and workshops to strengthen synergies and alliances with other European technology & Innovation Platforms and trade associations with an invested interest in wind energy power production. This workshop report (deliverable D3.7) relates to the ETIPWind activities described in Work Package 3, task 3.3.

On 28 November 2018 the Commission presented its strategic long-term vision for a carbon-neutral economy by 2050. One of the biggest challenge in meeting this objective lies in the major harder-to-abate sectors such as steel, chemicals or cement industries. In 2016 industrial processesi accounted for 17.5% of total greenhouse gas emissions in the EU.

1.2 Objectives

The workshop organised on 21 February 2019 aimed to align efforts by various trade associations and technology platfoms on the topic of (renewable) power-to-x by informing each other on various decarbonisation pathways and to explore the potential for indirect electrification of non-energy uses (processes and products)ii in carbon-intensive industries based on wind energy.

The workshop focuesd in particular on large industrial sectors such as refineries or fertilisers where hydrogen has been used for decades and that are expected to be key early markets for power-to-hydrogen applications.

The objectives of the discussion were be to compare the technical and economic constraints for the production of renewable hydrogen, ammonia or methanol, and to identify regulatory measures that can unlock their potential.

The findings of the workshop will feed into the development of the ETIPWind Technology Roadmap, one of the thematic factsheets (2020 or 2021), the Strategic Research & Innovation Agenda as well as the reports of the WindEurope working group on electrification, which is looking at the European regulatory framework on electrification, with a particular focus on heating and industry.

1.3 Format

The 3 hour workshop was structured in four parts, which is mirrored in the report.

1. A comprehensive overview of the decarbonisation needs in Europe and the related opportunities for wind power.
2. An update on the latest state of hydrogen electrolyser technology and the challenges and opportunities related to large scale applications by experts from the hydrogen community.
3. Incentives and barriers for indirect electrification (power-to-x) by representatives from energy intensive industries.
4. Possible business cases for power-to-x from the perspective of the wind industry.

The workshop gathered 52 participants (out of 63 registrants) from a variety of sectors including the refineries, fertilizer, and metals sector as well as from the wider energy and hydrogen sectors.

Figure 1 participants at the ETIPWind Power-to-X workshop

2 Agenda

Time	Item
14.00 – 14.30	**Introduction** • Welcome address, Aidan Cronin (ETIPWind) • Setting the scene, Cédric Philibert (IEA)
14.30 – 15.15	**1. State of play and developments of Power-to-Hydrogen technologies** • Denis Thomas (Hydrogenics) • Nikolaos Lymperopoulos (FCH JU)
15.15 - 16.00	**2. Industry needs and demand for green hydrogen** • Antoine Hoxha (fertiliser sector) • Alba Soler (Concawe)
16.00 – 16.55	**3. Business cases for 'wind-driven hydrogen' and regulatory levers** • Florian Bergen (Siemens AG) • Peter Enevoldsen (Envision energy) • Zsuzsanna Szeles (DG Energy)
16.55 - 17.00	**Conclusion and next steps** • Simone Antonelli (Enel Green Power) • Aidan Cronin (ETIP Wind)

3 Introduction – setting the scene

Renewable Energy for Industry – offshore wind in Europe

By Cédric Philibert, renewable energy analyst, International Energy Agency (IEA)

Organisation

The International Energy Agency is an autonomous organisation founded in 1974 that analyses a wide range of energy issues. Its authorative analyses and publications guide energy policy on a global scale.

Direct and indirect electrification

Mr Philibert presented the opportunities for wind energy to decarbonise energy intensive sectors such as the cement, chemicals and steel (iron) industry. They will require major innovations to decarbonise, as will the shipping and aviation sectors. According to the IEA (in)direct electrification of industrial processes will be instrumental to all decarbonisation efforts and will allow renewable energy to displace fossil fuels in applications beyond the power sector.

Direct electrification could have a significant impact in the heating and cooling sector. Electrification of residential energy consumption (e.g. heating and cooking) and industrial heat is technically feasible through development of new electric technologies such as electro-magnetic heating, mechanical vapour (re)compressors and next generation boilers and furnaces. These technologies also become more energy efficient and cost competitive vis-à-vis fossil fuels.

In the hardest to abate sectors like marine shipping and steel, indirect electrification or the process to create low-carbon energy carriers through electrolysis, will be needed to drastically cut emissions Renewable production of ammonia, methanol and especially hydrogen will become important and development of new electrolysis technology is making progress. So, policymakers today are discussing the possibilities of establishing a hydrogen based economy.

Hydrogen

Currently around 70 million ton of Hydrogen is produced globally. 95% is created through a process called Steam Methane Reformation. Hydrogen produced this way is called grey hydrogen. In the SMR method methane and water (steam) react to create hydrogen (H2) and carbon monoxide (CO). Inevitably the CO further reacts with the steam and forms CO2. So CO2 is a direct by-product of the SMR method. Some 10 tons of CO2 are produced for every ton of Hydrogen.

If a hydrogen economy is to have a real impact on reducing our emissions, hydrogen itself should become low-carbon. There are two possible ways. Firstly through electrolysis where renewable power from wind and solar PV farms feeds into electrolysers to produce the hydrogen. This is called green hydrogen. Secondly, by adding carbon capture and storage technology to the traditional SMR method. Hydrogen produced this way is called blue hydrogen.

According to IEA analysis green hydrogen production would remain significantly more expensive than blue hydrogen. Power prices of $30/MWh, which would be needed for green hydrogen to compete with blue hydrogen, are unlikely to materialise in light of the wider electrification of the energy system. Grey hydrogen will always be the cheapest due to the low gas prices and low carbon tax, but is of course not carbon neutral.

Ammonia

The IEA sees an important role for ammonia in the energy transition, especially for the maritime sector where it could be used as a marine fuel and the agricultural sector, where it is predominately used in the production of fertilizers. Ammonia could also be a prime vector for seasonal storage of renewable power. It is notably easier to handle and transport than hydrogen and a whole sector with a wealth of knowledge in transporting and storing Ammonia is firmly established.

Green ammonia could be produced wherever hydrogen is available, but the IEA expects the most cost effective way would be to produce green ammonia outside the EU in areas with good wind and solar resources such as Argentina, Chile, Morocco and Australia. This is primarily due to the expected lower electricity prices (40 EUR/MWh vs 100 EUR/MWh). In time, green ammonia produced there with renewable energy would be more than 33% cheaper than ammonia produced locally in the EU.

Hence the IEA expects a large international trade of ammonia driven by globally dispersed renewable energy sources. Ammonia production would relocate to areas with excellent wind and solar power resources and then shipped to where it is needed. Hydrogen production on the other hand would naturally develop around existing natural gas infrastructure as blue hydrogen will remain significantly cheaper than green hydrogen production.

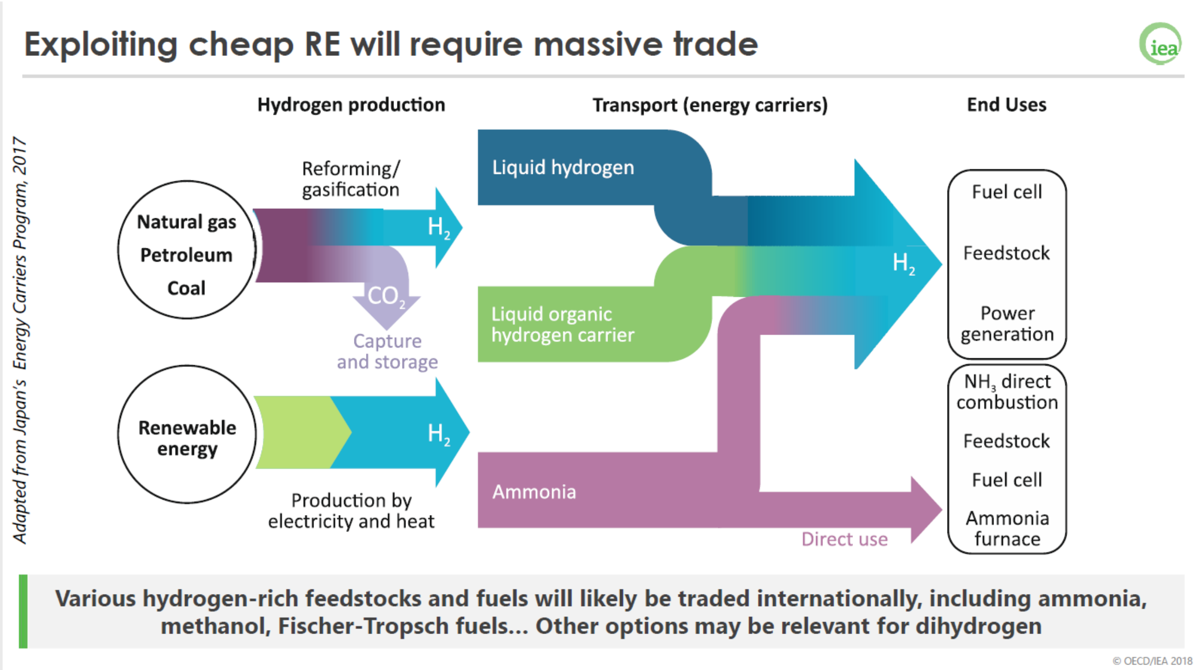

Figure 2 schematic representation of a hydrogen economy

4 State of Play and developments of Power-to-Hydrogen technologies

4.1 State of Play and developments of Power-to-Hydrogen technologies

By Denis Thomas, EU Regulatory Affairs & Business Development Manager, Hydrogenics

Organisation

Hydrogenics is a global leader in electrolysis and fuel cell technology with production sites in Europe and North America.

Overview of electrolysis technology

Mr Thomas presented the state of play in green hydrogen production technologies. Whilst there are a number of ways of producing hydrogen through electrolysis, the presentation focused on the two most advanced methods. These technologies are also commercialised by Hydrogenics.

- Alkaline electrolysis: a proven technology that builds on almost 60 years of experience. Models range mostly from 80 to 500 kW, but MW scale electrolysers are also available.
- Proton Exchange Membrane (PEM): developed 20 years ago with strong potential for upscaling to 10-25 MW. Currently there are models of 1.5 MW.

The efficiency of hydrogen production using existing PEM technology is about 50% and 16 kWh is needed to produce 1 kg of Hydrogen. With alkaline electrolysis some 55 kWh is needed to produce 1 kg of hydrogen. A 1 MW alkaline electrolyser at full capacity could thus produce 18 kg of hydrogen per hour.

The versatility of Hydrogen

Hydrogen an interesting energy carrier due to its versatility and wide application range. When deployed on a large scale it could help to decarbonise the whole energy system and the mobility and power sector in particular. Green hydrogen could fill up fuel cells for cars, trucks and buses or even MW scale fuel cells to store and re-dispatch excess renewable energy at times of overproduction. Hydrogen could also be injected in the gas grid to store renewable power over a longer period of time (i.e. seasonal storage). In the European Commission's recent EU 2050 long term strategy there's a very ambitious hydrogen scenario which sees the hydrogen production capacity rise from 150 MW today to 50 GW by 2050.

Hydrogen and wind energy sector

Hydrogenics is involved in a number of projects that combine hydrogen electrolysis with wind power. One project is the EGAT Lam Takhong project in Thailand where they produce hydrogen when the nearby 24 MW windfarm gets curtailed. The project includes a 1 MW PEM electrolyser and a 300 kW fuel cell. In addition there is a storage tank where they can store the equivalent of 3MWh of power by compressing hydrogen at 250 bar.

The business case for green hydrogen

Today the fertilizer and refinery industry make up 93% of the global hydrogen market. For these sector hydrogen prices range from 1 to 2 EUR/kg. This is because 96% of the hydrogen is produced according to the SMR method using cheap gas. If green hydrogen is to compete with these technologies on cost alone (no carbon taxes), electricity prices would need to drop to 20 EUR/MWh as 80% of the green hydrogen production cost is the electricity cost.

The dropping prices of solar PV, onshore and offshore wind and rising carbon tax greatly improve the business case but more is still needed. Reducing the weight of axes, levies and distribution costs on the electricity bill will also be essential to ensure a shift towards green hydrogen.

4.2 Fuel Cell and Hydrogen Joint Undertaking (FCH JU) support to electrolysis in view of 2050 decarbonisation targets

By Nikolaos Lymperopoulos, policy officer, FCH JU

Organisation

The FCH JU is an EU Institutional Public Private Partnership that brings together the European Commission, the hydrogen and fuel cell industry and academia. The overall objective of the FCH JU is to bring green hydrogen technologies to market readiness by 2020.

FCH JU levering support for hydrogen

So far, the FCH JU supported more than 240 projects totalling a budget of just under 900 million Euro. Almost half of the budget, 418 million Euro, was spent in support of hydrogen deployment in the power system. 154 million Euro was spent supporting large scale demonstration projects linking renewable energy sources and hydrogen production with the aim to facilitate the integration of the former in the energy system.

Some of the projects supported by the FCH JU were H2Future, where green hydrogen is injected into a steel manufacturing plant, Demo4Grid, where hydrogen is used to decarbonise industrial boilers in the food industry and RefHyne, where a 10 MW on-site electrolyser is connected to a refinery.

Hydrogen roadmap for Europe

The FCH JU also developed a Hydrogen Roadmap in close collaboration with a wide range of energy stakeholders.[iii] According to this roadmap renewable energy capacity will quadruple. To managing this increase in variable renewable energy and help decarbonise the energy system, hydrogen presents itself as a key vector for sector coupling, seasonal storage and providing new links between power production and consumption areas.

By 2050 FCH JU believes that in a European hydrogen economy the hydrogen sector could provide up to 24% of the EU final energy demand, bring annual revenue of more than 800 billion Euro and employ around 5.4 million people in its entire supply chain.

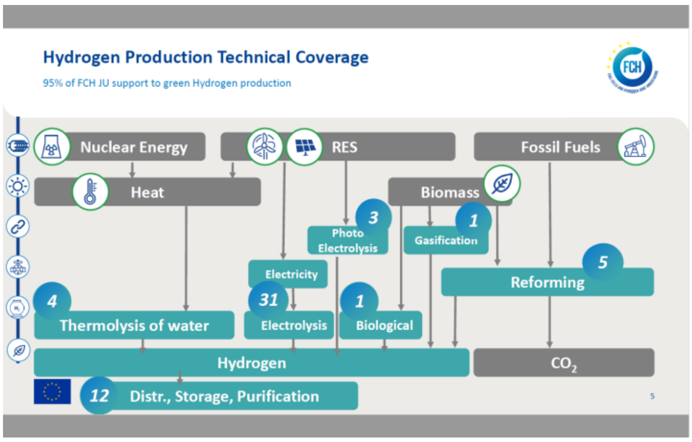

Figure 3 hydrogen prodcution techniques supported by the FCH JU

5 Industry needs and demand for green hydrogen

5.1 Hydrogen, green ammonia and fertilizers

By Antoine Hoxha, expert in fertilizer production technology

Mr Hoxha held a presentation under Chatham house rules on the opportunities of green ammonia and hydrogen for decarbonising the fertilizer sector in Europe. Decarbonisation is an important topic for the fertilizer sector in Europe. Through increased energy efficiency the sector has already been able to reduce emissions, but new technologies will be needed to complete the transition to a low-carbon fertilizer sector.

Below are a few headlines from Mr Hoxha's presentation.

- Ammonia has been produced on industrial scale for over 100 years.
- Production has become increasingly energy efficient, but still relies on natural gas.
- Recently new electro-chemical production methods are being developed.
- Ammonia will be cheaper and safer than hydrogen as a means for seasonal storage of variable renewable energy.
- Ammonia could also play vital role in decarbonising the maritime shipping industry.

5.2 Green Hydrogen – opportunities in the EU refining system

By Alba Soler, research associate low-carbon pathway, CONCAWE

Organisation

Concawe is the scientific body of the European Petroleum Refiners Association (EuroFuels) representing 40 member companies encompassing the entire EU refining sector.

Hydrogen use in the refinery sector

Hydrogen is an important agent in the refining process. It is mainly used to remove sulphur from final product and to maximise the conversion process. As stated before hydrogen production is mainly done using the SMR method which generates about 10 tons of CO2 for each ton of Hydrogen. Hydrogen production accounts for some 15 percent of the refining sector's CO2 emissions.

In the refining sector most of the hydrogen used is still produced on site, but recently large independent hydrogen plants have started operations. This reduces the sector's direct contribution to CO2 emissions, but displaces the problem to the wider supply chain. So a more sustainable alternatives need to be developed with and for the sector.

The role of Hydrogen in the sector's decarbonisation strategy

The refinery sector is looking to reduce CO2 emissions with 25% by 2030 and by 70% in 2050. Concawe sees three key enablers to achieve this targets of a low carbon economy: direct electrification, carbon capture and storage and green hydrogen.

Green hydrogen production techniques will abate emissions from SMR production and biofuel technologies, can be inserted in to the transport system through fuel cell technology and enable the production of e-fuels. However hydrogen electrolysers will need to scale-up dramatically, up to 100MW, and increase utilisation rates to easily integrate into the refineries, efficiency also needs to improve and electricity costs (now 80% of the Hydrogen price) needs to come down as well.

Outlook

Concawe believes the European Commission when they state electricity will be the energy carrier of the future, but it also sees a vital role for e-fuels, bio fuels and even fossil fuels in the aviation and shipping industries. Regarding energy storage the sector also believes that it can play a role in seasonal storage of renewable energy as molecules (liquids and gasses) are easier to store than electrons.

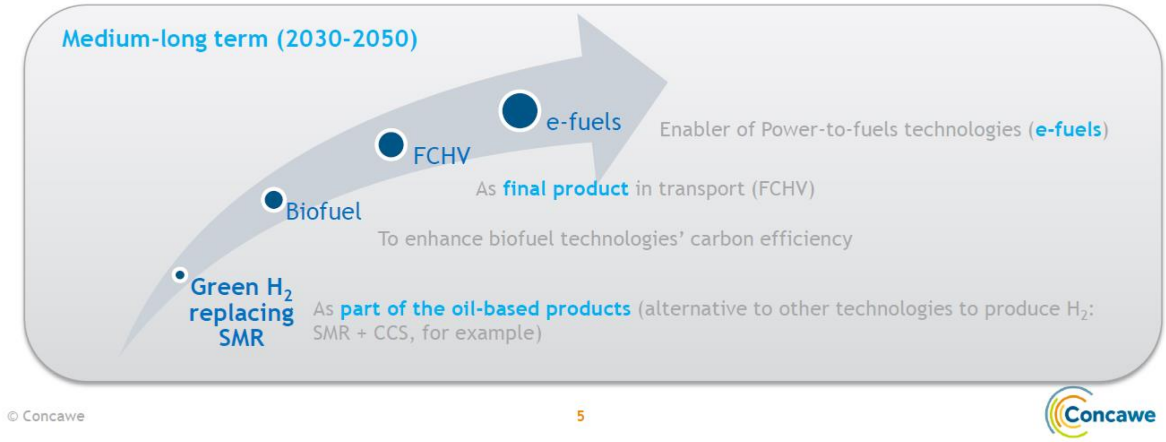

Figure 4 Green hydrogen pathway to decarbonise the refinery sector

6 Business cases or 'wind-driven-hydrogen' and regulatory levers

6.1 Electricity-based fuels as a link between the electricity and transport sectors. Business cases for 'wind driven hydrogen'

By Florian Bergen, project development director, Siemens AG

Organisation

Siemens AG is a global industrial manufacturing company with headquarters in Germany. It has an extensive energy division active in technology for power generation, distribution and services.

The case for hydrogen

The search for green hydrogen is driven by the understanding that a) 60% of the global CO2 emissions come from industry, heating and transport and that b) direct use renewable energy in those sector is difficult. In addition the energy system of the future will see a stronger decoupling of power production and consumption because the higher shares of variable renewable energy will increase the system's residual load.

Siemens AG is active in a number of hydrogen projects of which a number were presented. Firstly two electrolyser systems: the 5 MW Silyzer and the 17.5 MW Silyzer 300, followed by a German power-to-methanol project and the GreenHydroChem real world lab.

Hydrogen and sector coupling

GreenHydroChem is a cross-sectoral project linking the chemical feedstock, transport and building sector. Renewable energy, CO2 form a nearby refinery and chemical by-products are used, via a number of interlinked processes, to create new e-fuels for the chemical sector, hydrogen mobility via fuel cells and urban heating. According to Mr Bergen, e-fuels are today more expensive than fossil and biofuels, but their production is on a lifecycle basis almost emission free.

So Siemens is developing a large scale power-to-methanol project in Patagonia, Argentina. In this project wind power driven electrolysers would create hydrogen which would be fused with imported CO2 to create methanol. This methanol would then be shipped to Europe to feed into the refinery and car fuel industries. The total estimated production cost is 700-750 dollar per ton, with an estimated market price of 800-1000 dollar per ton (up from 760 dollar per ton today).

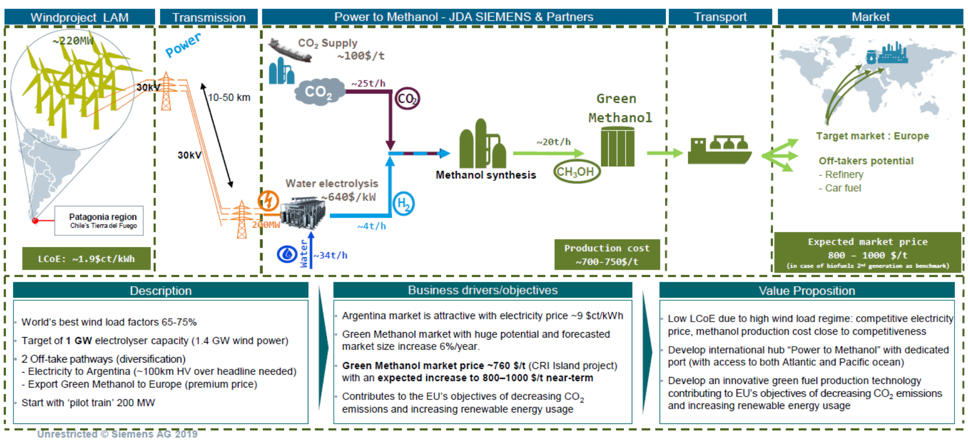

Figure 5 Power-to-methanol on a global scale

6.2 Examining the business incentives for investments in coupled wind-storage systems

By Peter Enevoldsen, product owner, Envision Energy.

Organisation

Envision Energy is a global wind energy company headquartered in China. Envision manufactures wind turbines, but also provides energy management and energy technology services.

The benefits of coupling wind farms and electrolysers

There are numerous ways how hydrogen electrolysis can help to mitigate the variations in renewable power production. Firstly electrolysis is a flexible load. Secondly hydrogen can be used to store excess renewable energy. Thirdly, hydrogen is a versatile agent and there is or will be a strong market on which to sell the hydrogen produced.

Analysing the wind driven hydrogen business case

Whilst there is a wealth of research on storage applications Mr Enevoldsen research focused on the differences in the business cases depending on the final application of the stored energy. He researched three configurations: one where hydrogen is produced for electricity market arbitrage, one where the hydrogen is produced to be sold on the hydrogen market and one where excess wind power flows into a battery for electricity market arbitrage.

From his analysis it is clear that with a robust hydrogen price of 9 EUR/kg wind driven hydrogen production makes business sense with a full return on investment in less than 3 years. With a hydrogen price of 5 EUR/kg, hydrogen electrolysis is still more profitable than investing in batteries, particularly as the use of electrolysers increases the profits from electricity market arbitrage. Batteries and hydrogen are equally profitable at a hydrogen price of 2 EUR/kg, which is close to the current price.

Hydrogen outlook

Envision sees a big future for hydrogen in medium long distance goods transport on land. Most trade happens on a regional level and is land based. Road transport, in other words trucks, will still play an essential role in the near and medium term future. Hydrogen trucks with fuel cell technology have currently more autonomy than electric trucks.

The uptake of hydrogen trucks will be a boost for the hydrogen sector. They believe demand would increase quickly in a short term so that hydrogen prices of 9 EUR/kg could become a reality as production capacity is still low. Indeed German prices for hydrogen already exceed estimations on certain days last year.

6.3 Study on sector coupling. The potential of linking the EU electricity and gas sectors

By Zsuzsanna Széles, policy officer, European Commission DG Energy

Organisation

The European Commission is an institution of the European Union, responsible for proposing new legislation, implementing decisions and managing the day-to-day business of the EU.

The 2050 long term strategy – a clean planet for all

In November 2018 the European Commission presented its long term strategy for a climate neutral Europe by 2050.[iv] The strategy outlines the various polices and technologies that could be employed and developed to ensure the EU will compliant with the Paris Agreement (keeping global warming below 2° Celsius and striving towards just 1.5°).

All scenarios of the 2050 long term strategy expect a strong decline in the consumption of natural gas by 2050. The consumption of hydrogen is expected to increase in all scenarios, but most in the scenario called 'hydrogen economy', but also in those scenario that have a greenhouse gas emission reduction target of 90% or more.

Sector coupling study

DG Energy commissioned a study that focuses on the regulatory framework for integrating renewable and/or low carbon gases. It will contain a qualitative assessment of the possible future energy mix, the role of gases therein and identifying the barriers for linking the gas and electricity markets and networks. Finally the study will formulate some policy recommendations for the renewed Gas package which is under revision at the moment.

The study will especially focus on key member states and their national regulatory frameworks. As well as the various technical specifications and political priorities (e.g. security of supply).

Hydrogen in the gas networks

Currently there is no regulatory framework for the injection of hydrogen into the gas network. So policymakers should either create a hydrogen framework or adapt the current regulation to accommodate the possible role of hydrogen in the future. The latter option is maybe preferable as there is still no large scale hydrogen economy and market. In any case regulation should look into:

- Not discriminating hydrogen against other gases (unless for safety reasons).
- Revising gas quality standards to suit other and renewable gases.
- Including some form of guarantees of origin scheme.

7 Participants list

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[i] By-product or fugitive emissions of greenhouse gases from industrial processes. This doesn't include emissions from fuel combustion e.g. for heat provision.

[ii] Energy uses are not included e.g. replacing natural gas and other fossil fuels with hydrogen to produce high-grade heat via hydrogen combustion

[iii] https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[iv] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-long-term-strategy