European Association for Storage of Energy

Power-to-Gas Business Cases:
Revenue Streams, Economic and Regulatory Barriers, Business Opportunities

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Introduction

The European Commission (EC) has set out a European Green Deal that aims to tackle climate and environmental challenges, among others the energy transition. A key aspect of this Green Deal is the decarbonisation of the Gas sector and market. To achieve this decarbonisation, the EC has launched different studies identifying and assessing the regulatory barriers that could potentially limit sector coupling and deployment of renewable and low-carbon gases.

In response to the EC initiative, EASE has decided to develop a paper outlining the main business opportunities for Power-to-Gas, as well as the barriers that could obstruct the wider deployment of Power-to-Gas in the EU. EASE also provides a set of recommendations for policymakers to support the Power-to-Gas business case.

Background

Hydrogen and Power-to-Gas (PtG) are chemical energy storage technologies, one of five energy storage technology 'families' identified by EASE[1]. Electricity-produced hydrogen can be used for transport (fuel), for heating (fuel), as a raw material (chemical feedstock); to balance electricity demand & supply and to support the management of the electricity grid (through storage).

Power-to-gas technologies could bring the following key advantages:

- By absorbing renewable or low carbon electricity and converting it to a versatile energy carrier, Power-to-Gas (PtG) and Power-to-Liquid (PtL) technologies have the potential to secure a supply of clean energy through the seasons (e.g. renewable energy produced in spring could be stored until the winter).
- PtG and PtL are key technologies for smart sector integration, able to decarbonise key sectors of the European economy, especially the ones which cannot be decarbonised by just electricity.
- PtG and PtL facilities contribute to a more stable and flexible electricity system, supporting the further integration of variable Renewable Electricity Sources (RES) both in the short and in the long term. It can avoid costly electricity grid extension when gas infrastructure is in place to absorb and transport the hydrogen.
- PtG and PtL are energy storage technologies[2] and therefore can contribute to increasing the share of renewable electricity used in the energy mix by reducing or avoiding curtailment (spillage) of renewable electricity generation. By shifting the use of excess renewable electricity forward in time to periods of deficit, RES essentially become dispatchable, which greatly facilitates their integration into the energy system, and ensures optimal use of installed RES capacities. Additionally, when optimally located, it could enhance the optimal use of the transmission grid avoiding congestions.
- Finally, it can be used to produce renewable or low-carbon fuels (e.g. synthetic methane, methanol) or chemicals (e.g. ammonia).

Hydrogen could be stored in different ways, e.g. in salt caverns (in gaseous form) or small tanks (in liquid form) or as a chemical like ammonium. Under certain conditions, it can be transported over long distances through the existing natural gas pipeline system or by other transport means such as trucks, trains, or maritime vessels in a compressed or a liquid form, or hydrogen pipelines.

EU policymakers have recognised the promising role that hydrogen can play to decarbonise high-value end-uses, such as part of the industrial applications and very heavy-duty transport. Seasonal storage could be another key driver.

In this document, we will focus solely on hydrogen produced through Power-to-Gas, i.e. by electrolysis. Other technologies to produce hydrogen are not considered.

[1] EASE, Energy Storage Technologies, 2019.
[2] As defined by the Clean Energy Package, Directive (EU) 2019/944, Art 2§59): "energy storage [...] means 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".

1. Overarching Issues

Operation of Power-to-Gas Facilities in the Electricity Market Design

Unbundling, i.e. the effective separation of networks from activities of production and supply, is fundamental to achieve a well-functioning energy market.

Recommendation: Power-to-X should be used by market operators to provide market services in order to avoid distortions and inefficient market outcomes, when appropriate market conditions are given. With this goal in mind, the regulatory framework should allow PtG technologies to compete on the market on a level-playing field with other technologies.

Definition of Renewable Gases and Other Gases

To support investment, clear definitions of renewable and low-carbon gases (including hydrogen and Power-to-Gas fuels) are necessary.

Recommendation: Hydrogen should be classified with reference to its carbon footprint and the nature of the electricity used for its production, following the CertifHy project's recommendations (e.g. certified as "renewable" if produced in a PtG facility powered entirely by renewable electricity; "low-carbon" if produced in a PtG facility powered by low-carbon electricity). EASE has published recommendations on the classification and definition of renewable and low-carbon gases.

CO_2 neutrality of Renewable Fuels and Gases

When fuels and gases are burned, the question arises of where the energy content is coming from. The source of the CO_2, which must be compatible with the provisions of the EU ETS, is not relevant as it is not an energy carrier: the energy carrier is the hydrogen-based part.

Recommendation: If it is a renewable source providing the energy content, then emissions from renewable fuels and gases should always be considered CO_2 neutral.

Deployment of a Hydrogen Infrastructure

It is important to take into account the evolution of the gas demand in the long run when assessing the investment decision on gas infrastructure, in order to ensure its economic efficiency/viability and to avoid stranded assets.

Recommendation: a stronger oversight by ACER (Agency for the Cooperation of Energy Regulators), which should set the planning methodology, and national regulatory authorities is necessary: the increasing importance of links between gas and electricity infrastructure should be reflected in a new requirement for joint grid planning/joint market activities, at both European and national levels.

Revenue Stacking

Revenue stacking allows a storage facility to provide various services to various stakeholders (generators, consumers, network operators) and 'stack' multiple revenue streams, thereby improving the business case for storage. This includes e.g. selling hydrogen to mobility/industry sectors, providing flexibility to the electricity grid. This economic strategy is explicitly allowed only in some Member States' current legislation.

Recommendation: the EU regulatory framework should explicitly enable revenue stacking to allow for market-based development of energy storage.

Hydrogen Imports

The EU should not decarbonise its energy system by increasing emissions elsewhere. Hydrogen imports should be subjected to the same requirements and thresholds for certification that are applied in the EU. Otherwise hydrogen production within the EU would be at a significant disadvantage compared to non-EU-based competitors in case these do not have to bear a comparable CO_2 cost.

Applying the standard carbon-leakage prescription (i.e. allocation of free CO_2 EU Emission Allowances (EUAs) according to BATs to EU-based producers) to hydrogen producers may not be an appropriate solution: it could cancel the incentives to resort to RES/low-carbon energy resources, hindering the energy transition.

Recommendations:

- a new system, revising existing arrangements regarding hydrogen imports, is necessary. This will pose additional challenges in terms of e.g. accountability, transparency: the EU will have to collaborate with other actors at the international level.
- Implement a strong EU Emissions Trading Scheme to better value renewable and low-carbon hydrogen.
- Develop a mutual recognition of Guarantee of Origins to facilitate cross border trade.

2. Power-to-Gas in Industry

Policy Background

In 2016, industrial processes and products use accounted for 8% of EU-28 greenhouse gas emissions and ranked as one of the five main emission source sectors[3]. Indeed, the chemical industry consumes over half of current Europe's hydrogen production. The EU acknowledged hydrogen's potential in its 2050 Long-term Decarbonisation Strategy: "The chemical and the refining sectors are a prime example where either biomass feedstock or hydrogen-based chemical production can significantly reduce process emissions".

The private sector announced the first demonstration project on that matter. Uniper, in collaboration with selected partners, aims to build and connect a 15MW-electrolyser to a refinery in Lingen (Lower Saxony, Germany). The electrolyser, powered by renewable electricity, will produce hydrogen that will then be incorporated into the conventional fuel production process. It will avoid 90% of the greenhouse gases generated by traditional processes. A Fischer-Tropsch plant is planned to be used at a later stage to produce synthetic fuels and chemical intermediate compounds (power-to-gas-to-liquid process).

Renewable and low-carbon hydrogen could also be used in other projects to replace natural gas and other fossil fuels to produce high-grade heat (>650°C) via hydrogen combustion in hydrogen-specific burners, in e.g. cement and iron production or in high-efficiency cogeneration unit to produce renewable and low carbon heat and power.

[3] European Commission, Greenhouse gas emission statistics, 2019.

Regulatory and Economic Barriers

- The recast Renewable Energy Directive (REDII) does not focus on the use of hydrogen in important sectors, such as ammonia production and steel making. The lack of regulatory incentives for a higher intake of renewable and low-carbon hydrogen as feedstock is a barrier to the further deployment of the technology.
- Article 25 of the REDII requires Member States to take into account renewable liquid and gaseous transport fuels of non-biological origin (REFUNOBIO) such as hydrogen including in cases where they are used as intermediate products for the production of conventional fuels in their calculations to reach the 14% renewable energy target in transport. However, the methodology to qualify as a REFUNOBIO (article 27, para 3 of REDII) has not been defined yet, thereby creating uncertainty. In addition, more RD&D is needed to decrease production costs and further develop the associated processes.
- Low-carbon and renewable hydrogen produced via electrolysis is more expensive than fossil-based hydrogen driven mainly by the high electricity costs. For a larger development of low-carbon and renewable hydrogen produced via electrolysis, fossil fuel externalised cost should be internalised. Internalisation of external environmental costs for fossil-based fuels would create a more balanced cost structure. In particular, Low-carbon and renewable hydrogen for high-temperature heat is more expensive than current fuels.

Recommendations

- Promote the uptake of renewable and low-carbon hydrogen generated through water electrolysis in energy-intensive industries. Specifically, an explicit exemption of the application of the Industrial Emissions Directive (IED) to hydrogen produced from water electrolysis should be considered for IED recast.
- For the refining case, clarify the methodology to qualify as a REFUNOBIO in a way that will not hinder the development of Power-to-gas.
- Increase RD&D funding for hydrogen projects aimed at scaling-up technology and decreasing production costs and further develop the associated processes.

3. Power-to-Gas in Mobility

Policy Background

To achieve the EU's ambitious greenhouse gas emission reductions targets, the EU must increase efforts to decarbonise the mobility sector.

One way to achieve this is to support the higher uptake of battery electric vehicles. However, with respect to long-distance travel, current battery constraints could mean that they are unsuitable to electrify the whole transport sector (e.g. in the case of heavy-duty vehicles). In such cases, hydrogen produced from renewable or low-carbon electricity offers the possibility to decarbonise the transport sector.

Hydrogen fuel cells are an excellent substitute for fossil fuels. Fuel cells react with hydrogen, which creates an electric current and water (H2O) as a by-product. Therefore, where the hydrogen is derived from green or carbon-neutral electricity, it leads to no CO2 emissions.

Furthermore, hydrogen could be used to produce e-fuels through a chemical process, in a manner similar to the production of synthetic natural gas. Such fuels can be used in conventional cars without the need to modify or replace the engine.

Regulatory and Economic Barriers

A necessary precondition for the wider deployment of fuel cell vehicles is the availability of the necessary hydrogen refuelling station infrastructure. The lack of refuelling infrastructure is one of the most prominent barriers to this business case.

The EU has attempted to address this through the 2014 Alternative Fuels Infrastructure Directive (AFID)[4]. Under AFID, it is up to Member states to include hydrogen refuelling points accessible to the public in their national policy frameworks - but there is no obligation on Member states to consider hydrogen refuelling points.

The recent European Commission assessment of the member state National Policy Frameworks (NPFs)[5] underlines that Member States have radically different targets and visions for the hydrogen infrastructure. The refuelling infrastructure, for example, is currently extensive in some member states, and very limited in others. This means that hydrogen-powered vehicles will likely penetrate the national markets at different speeds.

As mentioned above, hydrogen could be delivered in a decentralised fashion in the future which gives it great geographic flexibility. However, several other economic barriers will play a role in determining the economics, such as the price of the fuel cell vehicles; availability of FCEV models; the price of the hydrogen; and the cost of refuelling points.

The price of the hydrogen is expected to decrease with the increase of renewable electricity[6] and the technology curve development driven by R&I. Still, future fuel cell costs are uncertain, which may have an effect on investments.

Recommendations

- Provide further support for the deployment of hydrogen refuelling stations.
- Revise the AFID to include compulsory targets on hydrogen refuelling infrastructure based on a sound methodology and a set of criteria able to address diverse recharging needs. EASE has published a position paper on the AFID highlighting key recommendations on such methodology.

[4] European Parliament and Council directive 2014/94/EU on the deployment of alternative fuels infrastructure, Official Journal L 307, 2014.
[5] European Commission, Report on the Assessment of the Member States National Policy Frameworks, 2019.
[6] IRENA, Hydrogen from Renewable Power: Technology Outlook for the Energy Transition, 2018.

4. Power-to-Gas in the Gas System

Policy Background

As recognised by the European Commission's 2050 Long-Term Decarbonisation Strategy[7], hydrogen has the potential to replace natural gas as an energy carrier and substitute several uses of gas.

Depending on the specific situations, hydrogen can be safely blended with natural gas in pipeline systems up to 20%[8] in volume. However, the maximum percentage of hydrogen that can be allowed for end-use performance depends on appliance type/condition; and on the local natural gas distribution conditions, which could limit it to a single-digit number (in volume).

Blending limitations are avoided after a methanation process whereby hydrogen (H2) is combined with carbon dioxide (CO2), resulting in the creation of synthetic natural gas (CH4), which has the same properties as natural gas and can be freely injected into the gas grid. However, the methanation process has a much higher capital costs and lower efficiency. Careful consideration needs to be made regarding the CO2 source, which needs to be recycled CO2. Otherwise, there is no contribution to decarbonisation.

Re-use of existing natural gas pipelines could lead to an increase in social welfare by mitigating the risk of stranded assets; still, infrastructure adaptation costs must be carefully explored.

Finally, Power-to-Gas also has the potential to decarbonise the heating and cooling sector, which represents almost half of the EU's energy consumption. According to the Commission's in-depth analysis of the 2050 Long-term Decarbonisation Strategy, "*in the future, hydrogen-fuelled heating could play a bigger role, especially in off-grid areas, where there are a limited number of flexibility sources that can ensure the balance in the heating system*."

[7] European Commission, In-Depth Analysis in support of Commission Communication Com(2018) 773: A Clean Planet for all, 2018.
[8] NaturalHy Consortium, NaturalHy project final report, 2014.

Regulatory and Economic Barriers

As previously mentioned, hydrogen can be stored in underground salt caverns and possibly in depleted gas fields/aquifers. Such storage facilities may either be classified as gas storage, and fall under the scope of the Gas Directive; or as energy (electricity) storage, and fall under the Electricity Directive (recast). Therefore, Power-to-Gas facilities could be subjected to two different and potentially conflicting regulatory regimes.

Besides, while different gas qualities do not result in cross-border trade restrictions per se, according to the implementation monitoring reports of the Network Code on Interoperability and Data Exchange rules (NC INT) from ACER[9] and ENTSOG[10], cross border trade restrictions due to gas quality differences do not exist at the moment. Thus, different gas quality requirements and standards for blending across borders might create a further constraint in the future. Currently, no European standardisation on those issues exists. However, TSOs are required to cooperate at cross-border points (as defined by the NC INT).

Finally, there are economic barriers. PtG remains a relatively expensive technology due to its high capital costs and the price of electricity. Also, the injection of hydrogen into the existing gas grid above certain quantities would require adaptations of the transmission and distribution infrastructure, downstream facilities, and end-user appliances. Therefore, it is important to assess the related safety and costs concerns. Moreover, the methanation process, which avoids blending concerns, is currently expensive.

Recommendations

- Support efforts to assess the maximum blending levels of hydrogen in national and local natural gas grids as well as the impact of hydrogen on end-user appliances.
- Support efforts to assess the re-use of existing natural gas infrastructure such as transmission and distribution pipelines and underground storage facilities (salt caverns, depleted fields) for transport and storage of hydrogen, either in a blend with natural gas or in pure form.
- Based on the results of the assessments listed in the first two points, further study the possibility of an EU-wide basis for injection of hydrogen into the natural gas grid based on common technical rules, standards and blending concentration.
- Based on the result of the assessments listed in the first two points, identify and remove legal and administrative barriers that prevent the injection of hydrogen into the national gas grid. Similarly, regulatory and market distortions should be identified and addressed.
- Simplify licensing requirements and authority approvals.
- Support the development of hydrogen gas turbines.
- Tailor tariff structures so that each grid user pays a price covering the costs it induces on the grid.

[9] ACER, First Implementation Monitoring Report of the Network Code on Interoperability and Data Exchange, 2017.
[10] ENTSOG, Interoperability and Data Exchange Rules Network Code Second Report on Implementation Monitoring, 2017.

5. Power-to-Gas in the Electricity System

Policy Background

The cost of large-scale, long-term storage of hydrogen (and related chemicals) is already very low[11], making it one of the most cost-efficient technologies for long-term storage of clean energy. To complement the variable power supply from wind and solar energy installations at times when they are not generating electricity, hydrogen can play a key role. Through Power-to-Gas, intermediate storage, and subsequent re-electrification (Gas-to-Power), hydrogen can provide the necessary flexibility.

In Europe, there is potential for hydrogen storage, primarily in salt caverns but potentially also in depleted gas fields and aquifers. The stored hydrogen can then be used to power fuel cells that (re-) generate electricity at an efficiency of up to 60% if using pure hydrogen[12] comparable to the combined cycle gas power plant efficiency. It can also be burned in adapted combined cycle gas power plants with efficiencies close to 60% and in high-efficiency cogeneration. In current natural gas-fired power plants, hydrogen can be blended in small quantities only (depending on the manufacturer of the plant and burner technology). However, gas turbines that can handle pure hydrogen are being developed and rolled-out. Hydrogen can be stored locally in the gas turbine power plant premises and utilised by the gas turbine at higher concentrations than the injection in the natural gas network would allow.

[11] European Commission, Energy storage – the role of electricity, 2019.
[12] IEA, Technology Roadmap Hydrogen and Fuel Cells, 2015.

By reducing curtailment, PtG – being an energy storage technology - can enable a higher intake of renewable electricity into the energy system. Renewable energy curtailment costs can be substantial: in Germany, for example, they reached a new high of 5,518 GWh in 2017, which cost system operators €610 million in 2017[13]. This represents an increase of 47% compared to 2016.

PtG can also compensate for the difference between expected and actual vRES production at much shorter timescales (even seconds), providing balancing/frequency control services.

Regulatory and Economic Barriers

As is the case with other energy storage technologies, Power-to-Gas re-electrification facilities (Power-to-Gas-to-Power) often face double taxation. Once for their "consumption", i.e. making the gas, and a second time for the consumption by the final customer of the re-generated electricity. The question of double grid costs must be assessed in the cases PtG may provide added value to the grid. In this case the added value must be balanced towards the grid usage. Importantly, a level-playing field between PtG and other technologies for the supply of flexibility services to the grid must be insured.

Additionally, PtG facilities are subject to a wide array of regulatory schemes: in some member states levies differ if an electrolyser is connected to the grid or if the device is coupled to a wind park, the reason for this being not entirely clear. There is also legal uncertainty regarding PtG plants and the recognition of PtG facilities as a grid service/flexibility service provider. The classification of a Power-to-Gas facility as constituting "demand" leads to various charges and allocations[14], which is not necessarily the case if one provides grid services.

Recommendations

- Ensure that the structure of electricity grid fees reflects the costs that each user induces on the grid: in other words, when Power-to-Gas facilities provide flexibility services that have value in terms of increasing the efficient operation of the grid, these facilities should not be penalised with unfair grid fees/tariff, and be treated in a level-playing field as regards other substitute technologies.
- Ensure Power-to-Gas facilities are able to participate in different markets on a level-playing field with other flexibility providers.

[13] Bundesnetzagentur, Monitoring Report, 2018.
[14] HyLaw, Electricity grid issues for electrolysers, 2019.

Note

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About EASE:

The European Association for Storage of Energy (EASE) is the leading member - supported association representing organisations active across the entire energy storage value chain. EASE supports the deployment of energy storage to further the cost-effective transition to a resilient, carbon-neutral, and secure energy system. Together, EASE members have significant expertise across all major storage technologies and applications. This allows us to generate new ideas and policy recommendations that are essential to build a regulatory framework that is supportive of storage.

For more information please visit www.ease-storage.eu

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Disclaimer:

This content was elaborated by EASE and reflects a consolidated view of its members from an energy storage point of view. Individual EASE members may adopt different positions on certain topics from their corporate standpoint.

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