Power-to-gas

Short term and long term opportunities to leverage synergies between the electricity and transport sectors through power-to-hydrogen

Executive Summary

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EXECUTIVE SUMMARY

As part of its research program “The future of energy: leading the change”, Fondation Tuck sponsored a study performed jointly by Hinicio and LBST between September and December 2015 which evaluates the technical and economic potential of power-to-gas technologies.

Coupling the electricity sector to the gas, mobility and industry sectors; power-to-gas is viewed by many experts as key in a future energy system characterised by a large share of intermittent wind and solar energy generation.

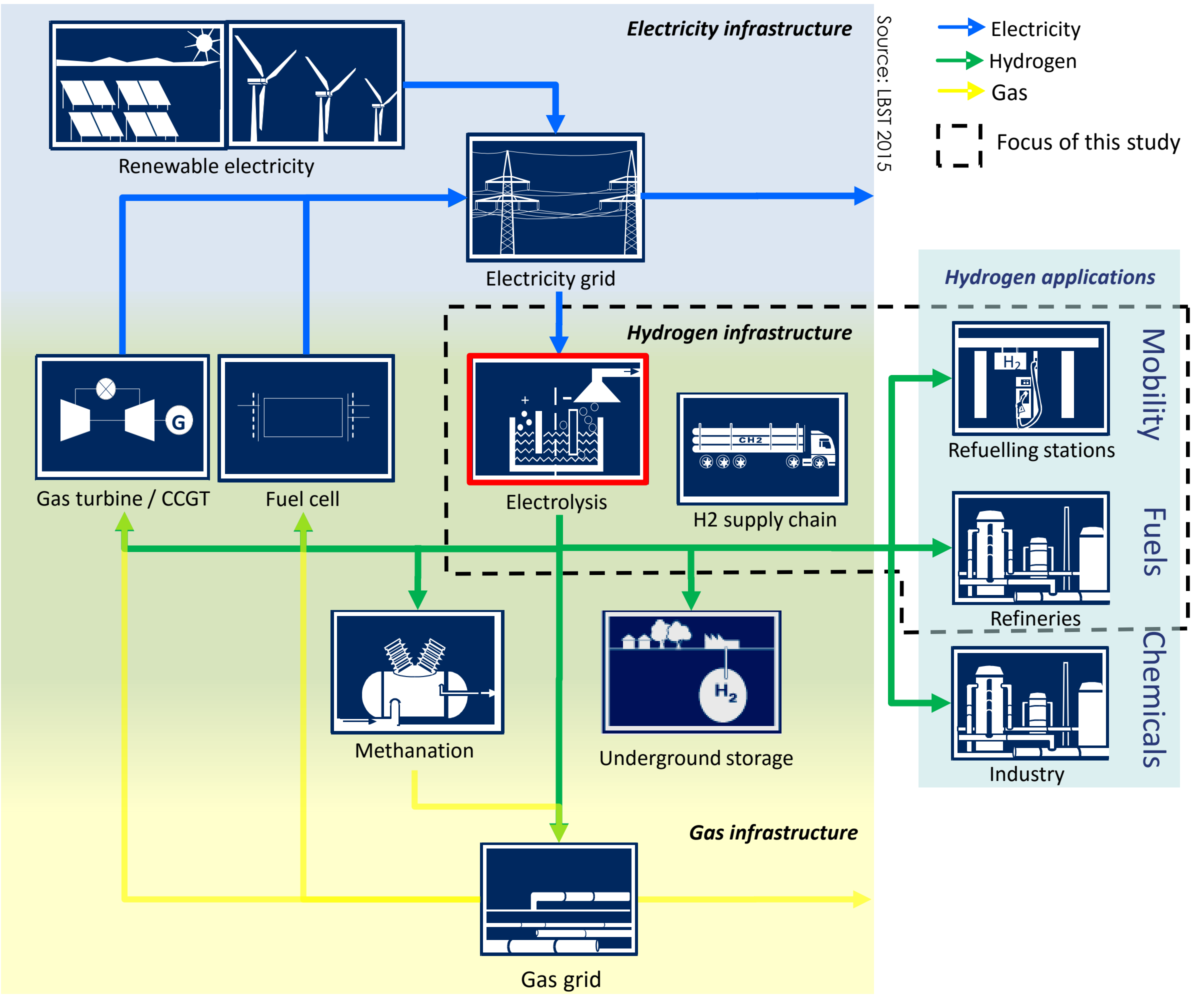

Figure 1: Overview on power-to-gas technologies and applications (source: LBST)

Indeed, power-to-gas provides a route for channelling substantial amounts of renewable energy to sectors that have been, until now, dependent on fossil energy sources - as required for meeting adopted climate goals (Fig.1). Power-to-gas also introduces a systemic flexibility resource which can, once implemented at large scale, significantly improves the operating conditions of needed dispatchable power generation by reducing the magnitude of load variations related to changing weather, while also decreasing curtailment of wind or solar power generation.

Furthermore, Power-to-gas can help maintain local balance between power generation and consumption where distributed power generation is added to the distribution grid, hence allowing to avoid power grid expansion for absorbing excess production.

The main condition for realising this potential is deployment ramp-up and continued scale-up. It is therefore essential to identify particular applications and associated conditions of implementation where this deployment could be market-driven already in the short term, considering also the policy environment.

Two particular applications have been identified and studied in order to evaluate their potential for supporting this power-to-gas technology ramp-up, considering in particular the framework conditions in France and in Germany respectively.

Green hydrogen in refineries is a promising means to reduce the greenhouse gas emission intensity of established transportation fuels in the short term, and a potential option to meet the requirements of the EU Fuel Quality Directive. In a scenario for France and Germany, it was assumed that the refineries' net hydrogen demand – today typically provided via steam methane reforming of natural gas – is to be supplied from green hydrogen from renewable electricity via water electrolysis by 2025 (Fig.2).

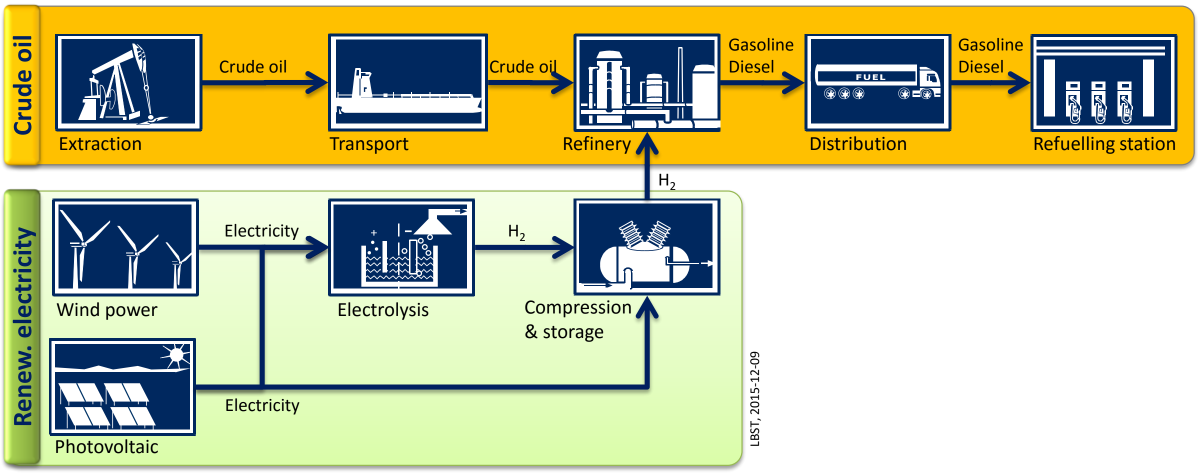

Figure 2: Schematic of the pathways for the supply of gasoline and diesel including hydrogen supply from renewable electricity (source: LBST)

With this process, a typical French and German refinery can reduce its greenhouse gas emissions 'gate-to-gate' by 14.1% and 7.2% respectively compared to today. In absolute terms, this is equivalent to the reduction of 1.33 and 1.50 million tons of CO_{2eq} per year with just 20 refineries, making this option highly effective. Indeed, this is a significant contribution to the ~10 Mt/yr CO_{2eq} emissions reduction that needs to be achieved in 2020 versus today to comply with the EU Fuel Quality Directive both in France and in Germany.

Full cost assessments show that green hydrogen in refineries is cost-efficient with greenhouse gas mitigation costs below German infringement costs and in the range of or even below other measures in transportation. Furthermore, it can be implemented in the short-term, because bulk quantities of hydrogen are already used in refineries, there is a track record in France and Germany with regard to the deployment of renewable power plants, and both countries have strong industry players in the electrolyser and hydrogen value chain.

From a wider perspective, bulk green hydrogen demand from refineries is of high strategic importance. Activating the electrolyser cost reduction potentials through capacity and learning-curve effects from the deployment of 1600 MW_e (France) and 1800 MW_e (Germany) cumulated electrolyser capacity entails long-term benefits for all power-to-gas and power-to-liquid applications that are needed for the energy transition. In line with the 'polluter pays principle', the cost burden to get the electrolysis technology through the economic 'valley of death' is shared among many fuel users with a knock-on effect on the fuel sales prices in the order of 0.8 and 0.5 cent per litre of diesel equivalent in France and Germany respectively.

To pave the way for green hydrogen use in refineries, it is **recommended** to:

- Adapt the EU Fuel Quality Directive and national regulatory frameworks to facilitate and encourage green hydrogen use in refineries;
- Improve the data basis on hydrogen use in refineries through further research activities; and
- Support business case analyses for individual refineries and regional roadmaps for renewable power and hydrogen infrastructure deployment.

Semi-centralised power-to-hydrogen systems (Fig.3) could become an effective and economically viable way of developing the supply of renewable or low-carbon hydrogen to emerging fuel cell electric vehicle (FCEV) fleets with co-benefits for the local energy system by facilitating the integration of renewables and enhancing local energy autonomy and strengthening the local economy.

These systems combine electrolysers at MW scale with means of distribution of compressed hydrogen to nearby points of utilisation, such as hydrogen refuelling stations or industrial facilities consuming hydrogen. Addressing the needs of multiple points of hydrogen consumption with a single hydrogen production plant provides economies of scale while facilitating the provision of grid services. Furthermore, the location of the unit can be chosen for maximization of operational management synergies with other industrial activities and for optimal interfacing with the power and natural gas grids. This set-up, which can be implemented with the current technology offer, allows the provision of multiple energy services resulting in the combination of complementary revenue streams. Combining multiple revenue streams is a key condition of economic balance and financial risk management, as the delay in local hydrogen demand ramp-up for mobility applications is typically a key hurdle to overcome.

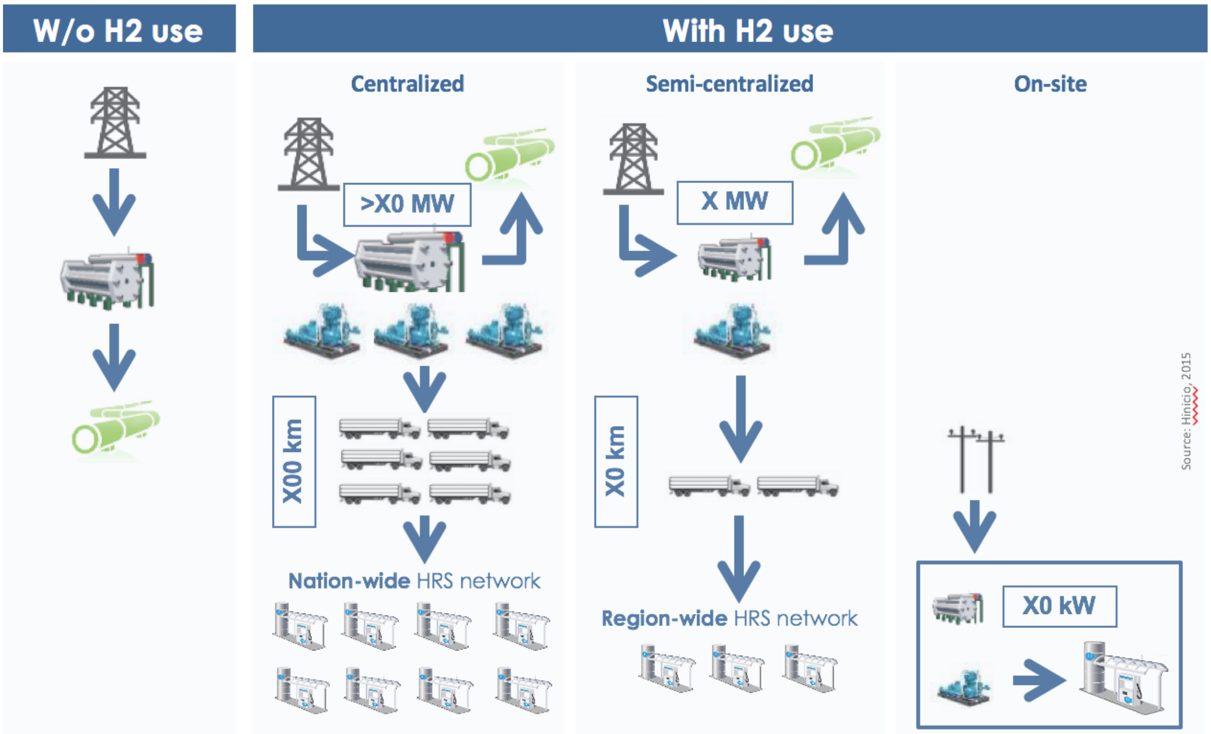

Figure 3: Illustration of various power-to-hydrogen configurations (source: Hinicio)

Starting from a reference set of hypotheses (on electricity prices, technology costs etc.), and examining different variations, the following **conclusions** can be drawn from the techno-economic analysis of the semi-centralised power-to-hydrogen system:

- Assuming the application of a certain number of favourable regulatory conditions which are considered defendable[1], achieving economic balance seems feasible for short-term deployments in France; therefore, with some further support -for instance in the form of investment subsidies- such deployments could attract private investment.
- The French fee regime (as applied in this study) would be particularly favourable for Power-to-gas. In contrast, the grid fee regime currently applied in Germany handicaps Power-to-gas. In the short-term, the study concludes that the economics of Power-to-gas are therefore more attractive in France rather than in Germany.
- Injection into the natural gas grid can generate two complementary revenue streams – from sales to the gas grid, and from services to the power grid performed when injection is taking place - which reduces exposure to uncertainty of revenues from the hydrogen market.
- A potentially attractive alternative to purchasing the needed electricity on the spot market is to contract its supply directly from a renewable power producer. Since consumption would take place only when this electricity has the lowest market value (i.e. during the hours for which the spot market prices are typically

[1] Exemption of grid fees and taxes for the electricity used to produce low-carbon hydrogen that is injected into the natural gas grid, a feed-in-tariff comparable to that applied to biomethane, and application of the conditions (exemption of grid fees) that are applicable to "electro-intensive" facilities.

extremely low), the producer could accept a high level of discount for supply under such conditions, in return of visibility on the sales price. In the short term, a power-to-hydrogen system could afford to pay 30% of the full cost of renewable electricity under such a scheme. Taking into account technological improvements[2] and cost reduction of power-to-hydrogen and power generation from renewables expected by 2030, a power-to-hydrogen system could afford to pay the full average cost of renewable electricity (although it would only be consuming it in absence of strain on demand).

- The study shows that an economic balance could potentially be achieved without public financial support by 2030 in both the French and German market environments thanks to technological improvements.

For the development of power-to-gas as a key component in energy transition, the study authors **recommend** to:

- Create a feed-in tariff for the injection of green or low-carbon hydrogen into the natural gas grid of a level comparable to that of biomethane in France;
- In France, grant the hyperélectro-intensif status to hydrogen power-to-gas production;
- In Germany, provide similar tax, EEG appropriation, and grid fee benefits to hydrogen production by electrolysis as the hyperélectro-intensif status;
- In Europe, further develop sustainability criteria, certification procedures and accountability of green or low-carbon hydrogen towards EU targets, especially with regard to the EU Renewable Energies Directive (RED) and the EU Fuel Quality Directive (FQD);
- Exempt electricity used to produce green or low-carbon hydrogen injected into the natural gas grid from grid fees and energy taxes;
- Financially support the implementation of supplying hydrogen to fuel cell electric vehicles.

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[2] These technological improvements are an increase in electrolyser efficiency, the extension of stack lifetime and the reduction of electrolyser capital costs.