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THE ROLE OF POWER-TO-GAS IN THE ENERGY VALUE CHAIN

A true contender for the energy storage and deep decarbonisation challenge

Following the thought-provoking debate at the REKK Power-To-Gas Forum in February 2020 this brief explains how Power-To-Gas technology can be a viable solution for excess RES electricity and eventually allow natural gas infrastructure to have a second life in Europe's carbon neutral future. The main findings are the following:

- Remarkable advantage of the P2G technology is its capability to store low-carbon renewable electricity in the form of hydrogen (P2H) or synthetic methane (P2M).
- The Power-To-Hydrogen technology has widespread potential (transport, industry and even electricity production) but existing assets must be upgraded.
- The Power-To-Methane technology is equivalent to natural gas and could be injected into existing gas infrastructure without any conversion.
- Power-To-Gas processes are more expensive than producing hydrogen from fossil fuels or buying natural gas at TTF.

While Power-To-Hydrogen provides carbon-friendly energy solution in numerous sectors, the Power-To-Methane is well positioned to be a lifeline for future gas infrastructure in the European decarbonisation agenda.

ROLE OF POWER-TO-GAS IN THE ENERGY VALUE CHAIN

Climate ambitions of the EU dictate the long-term phase-out of fossil fuels including natural gas. This decarbonisation challenge has been largely met by technology gains in renewable energy production, which resulted in significant increase of renewable electricity capacity.

Exceptional growth occurred in photovoltaic and wind power plants, which are weather-dependent sources and difficult to predict. Therefore, a storage solution is needed for the quantity of electricity which could not be consumed at the time of the production.

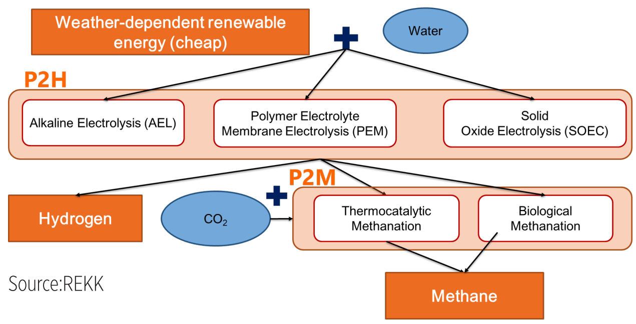
We argue that besides batteries, network connected electric cars and pumped hydro, one of the most viable energy storage solution is Power-To-Gas.

THE BASIC CONCEPT OF POWER-TO-GAS (P2G)

The main idea of Power-To-Gas technology is that the electricity is used to transform water into hydrogen and oxygen via electrolysis. After the electrolysis there are two options: 1) the process stops with hydrogen as output (Power-To-Hydrogen) or 2) CO_2 and hydrogen are converted into methane (called Power-To-Methane) (see Figure 1).

Hydrogen can be used directly as an alternative fuel in numerous sectors: it is feasible to use hydrogen as a fuel input in aviation, heavy duty railroad transport, railroad passenger vehicles (fuel-cell) and shipping. Moreover, it is technically also possible to use hydrogen in power plants or for heating, and it could be stored in gas or liquid form for future usage. These characteristics make hydrogen an alternative option for grid-balancing purposes, too. However, for traditional vehicles/plants to run on hydrogen as input fuel existing infrastructure must be upgraded. Furthermore, storing and transporting hydrogen in the current natural gas infrastructure is problematic, as the networks were built to accommodate methane-based natural gas. Network losses and other problems (e.g. hydrogen embrittlement, corrosion of steel pipes) limit the potential of non-site consumed hydrogen.

FIGURE 2: TECHNOLOGY OVERVIEW OF POWER-TO-GAS PROCESS TYPES



Source:REKK

A further (bio)chemical transformation of hydrogen will result another gas of high heat value: methane. This methanation process uses the hydrogen and CO_2 inputs to produce methane as an output. This can be injected into the existing gas networks as methane shares the same characteristics of natural gas.

TECHNOLOGY OVERVIEW USED FOR THE MODELLING

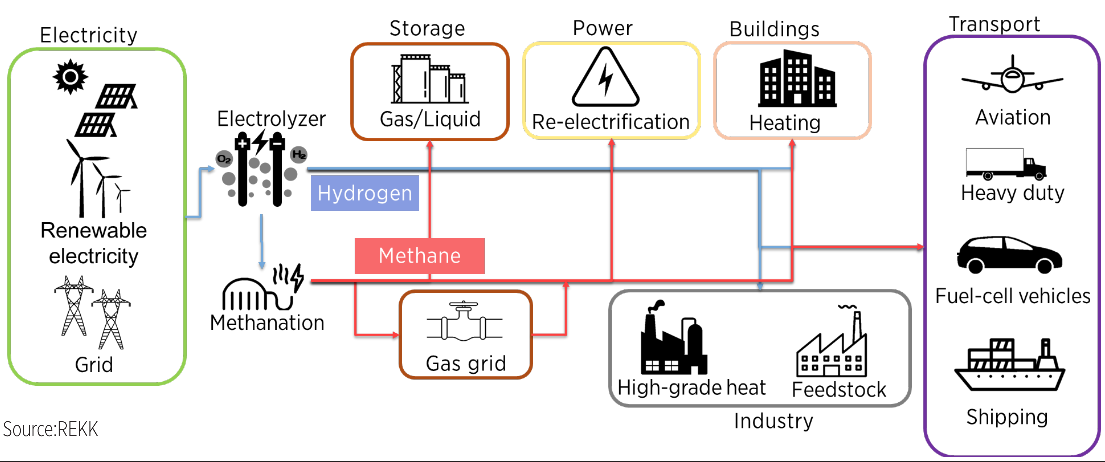
The calculations used to estimate the cost level of the process are summarized in Figure 2. Three prevailing alternatives for electrolysis which differ in their maturity and costs are described (AEL, PEM, SOEC). The methanation step considers two processes (thermocatalytic and biological) that also differ in maturity and costs.

POWER-TO-GAS USING METHANATION AS AN ENABLER OF SECTOR COUPLING

One of the key cost drivers is the wholesale electricity price and the availability of renewable electricity at low marginal cost. Thema et al. (2016) projects surplus electricity produced by weather dependent renewables in Germany to reach 60 to 100 TWh/annum by 2050 based on literature review while their modelling estimates 150 TWh/annum.

The concept of surplus electricity or excess RES electricity refers to electricity produced by weather dependent power plants that cannot be consumed at the source in real time– i.e. the price of electricity is zero or negative.

FIGURE 1: BASIC CONCEPT OF POWER-TO-HYDROGEN AND POWER-TO-METHANE (P2M)



Source:REKK

P2G solutions use the surplus RES-electricity and Power-To-Methane technology integrates renewable sources into the energy system with great potential for deep decarbonization goals.

European support for pilot P2G projects has increased in the recent years along with the share of the Power-To-Methane projects, reaching 70 MW by the end of 2018.

LEVELIZED COST OF ENERGY (LCOE) CALCULATION FOR POWER-TO-GAS SOLUTIONS

The current P2G projects rely heavily on public funds from green R&D programs because they are not yet mature and competitive. This section assesses the LCOE values that will ensure the technological competitiveness without public support.

Methodology

We used the LCOE calculation to compare the unit cost of energy production for P2G solutions using the following formula:

$$LCOX = \frac{\sum_{i=0}^{n} \frac{Costs\ in\ year\ i}{(1+WACC)^i}}{\sum_{i=0}^{n} \frac{Number\ of\ X\ units\ produced\ in\ year\ i}{(1+WACC)^i}}$$

Based on the ENEA study *The potential of Power-To-Gas* (2016), the three electrolysis and two methanation processes were compared (see Figure 2).

Results

The LCOE is driven mainly by the technology (electrolysis, methanation) and input costs, e.g wholesale electricity price. The cheapest processes are Polymer Electrolyte Membrane Electrolysis (PEM) and Biological Methanation process.

Based on Hungarian wholesale market in 2019, the wholesale electricity market modelling resulted in an average price of 39 EUR/MW available for 6490 hours. A price of 50 EUR/ton was applied to the CO_2 input and water was not priced because the unit cost is very low in most EU countries. However, it could be relevant in the future with large-scale P2G uptake.

The results show (Figure 3) that the LCOE value of the P2H process is around 100 EUR/MWh. The methanation increases LCOE for P2M technologies but makes it compatible with the existing infrastructure (gas pipelines, gas storages etc). Based on the Hungarian wholesale electricity market characteristics, the cheapest LCOE value of the P2M process is 110 EUR/MWh.

The LCOE of the methane produced by the P2M process is around 10 times higher than the TTF price (13,6 EUR/MWh on average in 2019), meaning it is not competitive.

Role of fuel costs on the LCOE

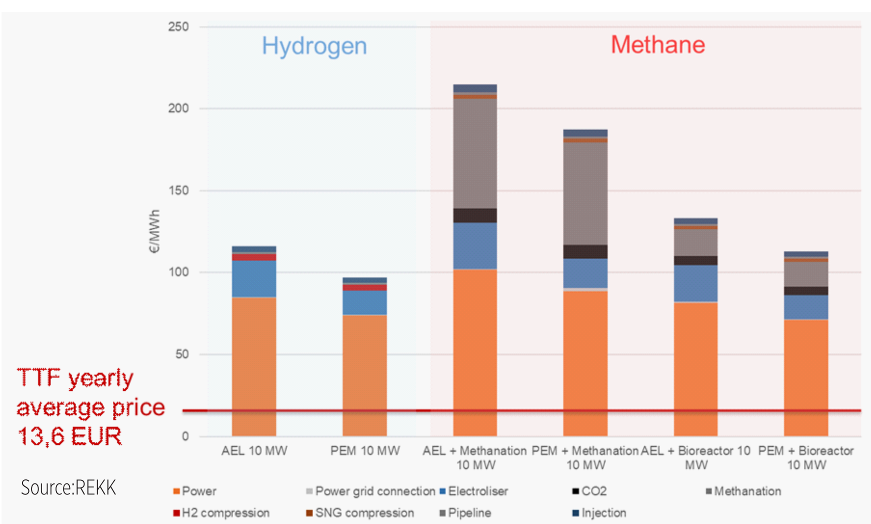
The same calculations applied to the 2019 German market resulted in P2G LCOE 10-15 EUR lower due to cheaper wholesale electricity (31 EUR/MW) and more available hours (7354). The P2M process is still much more expensive than natural gas at the TTF.

Role of technology cost on the LCOE

The potential technology cost reduction should also be carefully considered. The learning curve of the solar panel has demonstrated that R&D and economies of scale can result in a rapid fall in CAPEX. The Store & Go project report (2018) estimated that P2M technology costs are mainly driven by the CAPEX of methanation, with CAPEX expected to decrease 50% by 2050.

Thus, further support will be needed during the upcoming period to keep P2M in the game as a promising element of the green transition.

FIGURE 3:LCOE VALUES OF THE P2H AND P2M PROCESSES USING HUNGARIAN MARKET (HUPX) CHARACTERISTICS, 2019

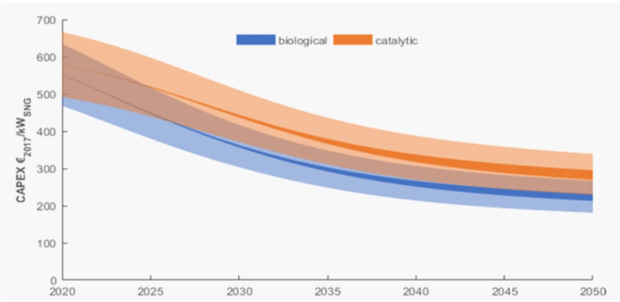


ROLE OF P2M IN THE EUROPEAN UNION'S DECARBONIZATION TARGETS

P2G technologies can become competitive in the longer term with technological improvements and demand driven economies of scale but in the near term support is required to keep them on track for deep decarbonization of difficult to abate sectors.

It is worth to have a wider look on the effects on climate goals. In the baseline case, the P2M process is mainly based on renewable electricity. However, it is also possible to source from nuclear or coal power plants which would raise environmental issues.

FIGURE 4: LEARNING CURVE ESTIMATION FOR METHANATION SYSTEMS WITH AN UNCERTAINTY OF +/-15% ON INITIAL CAPEX



Source: Store&Go

Moreover, the P2M process depends on a large amount of CO_2 input which might accelerate the development of CO_2-capture technologies. REKK calculations assumed CO_2 was purchased on the market, but it is possible to capture CO_2 from the air or from the emission of fossil fuel plants:

- CO_2 from fossil power plants: Carbon capture is considered the technology that can significantly reduce CO_2 emissions from fossil fuel combustion. Cebrucean at al (2015) finds that this solution reduces the net efficiency of a plant by up to 14% points and increase the cost of electricity by 30-70%.
- CO_2 from biomass: Schiebahn et al (2015) concludes that the fermentation of biomass to biogas or bioethanol offers an opportunity to create CO_2 free of charge as a waste product. However, the volume of CO_2 is limited.
- CO_2 from industrial processes: CO_2 can also be captured from the emission of industrial processes; steel and cement have the greatest potential. Heela at al (2018) calculates the feasibility of capturing the 2,5 million tons of CO_2 from the cement industry in Switzerland to produce methane from renewable H_2 via P2M.
- CO_2 from air: Technically it is possible to capture CO_2 directly from the atmosphere. A Canadian start-up claims (Carbon Engineering 2020) this can be done at a cost of about $100/ton.

CONCLUSIONS

The Power-To-Gas technology is a strong candidate for storing energy with a logical application to intermittent renewable-sources. Meanwhile, Power-To-Methane can be injected into the existing natural gas infrastructure. REKK derived the LCOE between EUR 110-210/MWh (based on technology type), and finds that a fall in the main cost drivers (CAPEX and wholesale electricity price) does not create much overall savings.

The advantage of the P2M technology might not be ensured by its standalone competitiveness but its integration and value added to renewable energy sources and the traditional gas sector.

P2G can conceivably be a major piece in the deep decarbonisation challenge. It ensures the possibility for renewable H2 production and the rising P2M capacity might accelerate the development of CO_2-capture technologies.

Questions still to be answered:

- Future role of P2G: What is the future role of P2M in a decarbonized world? Is it the enabler of sector coupling? A solution for energy storage? Or the saviour of the gas companies' business model?
- Competitiveness of the technology: Shall we compare the LCOE value of the P2M to TTF gas price or to alternative storage options?
- Learning cost forecasts: What can we expect for the decrease of the P2G cost learning curve?
- CO_2 extraction from polluting sectors: Can the CO_2 from fossil fuel power plants or industrial plants or from the air be used in the methanation process?
- Decarbonization point of view: To what extent can we call P2M carbon-friendly? What is the carbon-footprint of the process along the whole value chain?

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REKK FOUNDATION

The goal of the REKK Foundation is to contribute to the formation of sustainable energy systems in Central Europe, both from a business and environmental perspective. Its mission statement is to provide a platform for open-ended, European-wide dialogue between government and business actors, infrastructure operators, energy producers and traders, regulators and consumers, professional journalists and other interested private entities. The Foundation will develop policy briefs and issue papers with forward-looking proposals concerning challenges posed by energy and infrastructure systems and organize regional forums allowing stakeholders to become familiar with the latest technological and regulatory developments within the industry.

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