Power-to-Gas technologies

Igor Dukeov and Tero Ahonen, Lappeenranta University of Technology, igor.dukeov@gmail.com

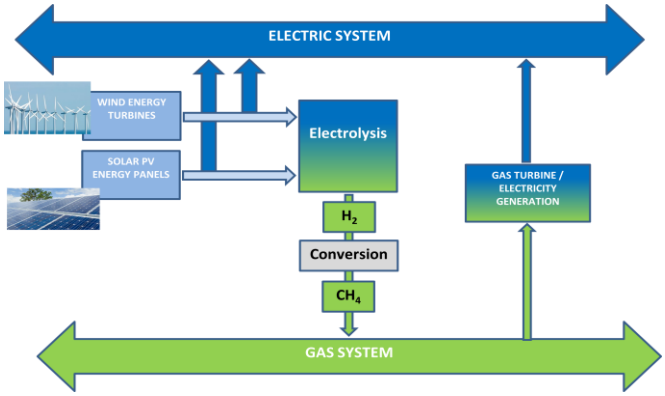
Power-to-X (a.k.a. **PtX** or **P2X**) refers to technologies dealing with conversion of electricity into some other power or substance. These technologies are under development as response to the necessity to find solutions for storing energy from variable renewable energy sources, as well as for carbon-neutral fuel production.

Hydrogen is the basic element in Power-to-Gas technologies

The term encompasses numerous technologies. The **X** in the terminology can mean, for instance, one of the following: gas, liquids, chemicals, heat, mobility or food. A traditional example of **PtX** is **Power-to-Heat** technology that is based on coupling of solar panels with a heat pump.

Power-to-Gas systems

One of the novel and market-ready **PtX** technologies is **Power-to-Gas** (**PtG**) technology that uses synthetic gas to store excess power produced by renewable energy sources. Thus, its application potential would be within regional electricity systems with a high share of variable energy sources and which have an access to a hydrogen (H_2) or natural gas (CH_4) infrastructure [1].



PtG systems can fulfill both the short and the long-term energy storage needs. In addition, PtG technologies facilitate the integration of renewables into chemical industry and mobility sectors thereby also accelerating their decarbonisation [2].

As PtG technologies are based on the use of hydrogen either as an energy storage or a chemical ingredient, they employ an electrolyser for hydrogen production. If allowed by the existing hydrogen level in natural gas network, hydrogen can be directly injected to the network, which is currently demonstrated in Central Europe [3].

The more common option is to convert hydrogen into methane, so it is fully equivalent with natural gas networks and the conversion systems can be a part of the existing biogas plant facilities [4].

Benefits and downsides of PtG

International targets to prevent global warming are positive towards fossil-free and renewable energy sources supporting the growing importance and expansion of PtG technology. Specific advantages for the further growth of the PtG technology are the following:

- PtG allows to convert volatile electricity obtained from renewable sources into synthetic gases (H_2 or another gas). The last can be used for various purposes, for instance, for the low carbon rate fuels or green chemistry.

- The gas obtained by PtG technology can potentially replace conventional fossil natural gas and by this contribute into decarbonization.
- PtG increases flexibility of energy systems by integrating electricity and gas grids.

On the negative side, the PtG technology demands high capital investment combined with regulatory and infrastructure challenges, why for instance direct feeding of hydrogen into natural gas network is still in piloting phase. Also the overall efficiency of PtG plants is usually below 50% without co-operation of biogas plant producing heat and CO_2 for PtG plant, meaning that higher efficiencies are achieved with pumped-hydro or battery storage systems.

Examples cases

Many countries invest in PtX technologies development. Currently the hydrogen related technologies have in general the industrial application. However, for example, Germany funded a €30 million first-phase research project into power-to-X options in 2016 [5] as well as has introduced the strategy for development hydrogen-powered vehicles and buildings. Various PtG projects are in pilot phase or even reaching an industrial scale.

The example of modeling the PtG technologies usage in the UK is given in [6]. The results showed that producing hydrogen from electricity is capable of reducing wind curtailment in a high wind case and decreasing the overall cost of operating the UK gas and electricity network. The northern part of UK was identified as a suitable region to develop hydrogen electrolysis and injection facilities due to its vicinity to a significant capacity of wind generation, as well as the existence of gas network headroom capacity.

There are not many positive cases of using PtG technology in Finland: Joutseno methane plant was under study in 2017. That methane plant would have been the largest producer of hydrogen and methane in renewable methane in the world targeting at the overall power of 18-28 megawatts. The plant is not yet profitable though its development continues [7].

References

1. *Akademienunion, eds. (2016). "Flexibility concepts for the German power supply in 2050: ensuring stability in the age of renewable energies" (PDF). Berlin, Germany. National Academy of Science and Engineering.*

2. *Lund, Peter D; Lindgren, Juuso; Mikkola, Jani; Salpakari, Jyri (2015).* "Review of energy system flexibility measures to enable high levels of variable renewable electricity"*. Renewable and Sustainable Energy Reviews.*

3. *FCH (2017). "Development of Business Cases for Fuel Cells and Hydrogen Applications for Regions and Cities - Hydrogen injection into the natural gas grid".*

4. *ETOGAS (2015). "Power-to-Gas: New Solutions for Power, Bio-Energy and Mobility".*

5. *RWTH Aachen (2016).* "Power-to-X: entering the energy transition with Kopernikus"*.*

6. *Qadrdan, Meysam; Abeysekera, Muditha; Chaudry, Modassar; Wu, Jianzhong; Jenkins, Nick (2015).* "Role of power-to-gas in an integrated gas and electricity system in Great Britain"*. International Journal of Hydrogen.*

7. *YLE (2017). "Joutsenoon kaavailtu uusiutuvan kaasun tuotantolaitos ei toteudu – teknologia liian kallista".*