Smart strategies for the transition in coal intensive regions

Project No: 836819

Fact Sheet: Power-to-X

September 2019

Description

The generation of electricity by renewable sources such as wind and sun is naturally subject to great fluctuations. While on windy, sunny days, surpluses are produced that can not be directly consumed or taken from the power grid, bottlenecks in the network can occur on windless, dark days. In order for the integration of renewable energy into the power system to succeed, long-term electricity storage systems are required, which store excess electricity cheaply and without loss for later use.

An alternative that has already been used is **Power-to-X technology**. This is the transformation of surplus electricity into forms of energy that, unlike electricity, can be saved or stored relatively easily. The term "power" stands for electrical energy and "X" for the form of energy into which the current is converted. In addition to balancing generation peaks in renewable electricity, Power-to-X technologies could also help boost the energy transition in the heating and transport sector. (Baunet_Wissen_, n.d.)

Power-to-X technologies include:

- Power-to-Gas (PtG / P2G - electricity to gas)
- Power-to-Heat (PtH / P2H – electricity to heat)
- Power-to-Liquid (PtL / P2L – electricity to fuel)
- Power-to-Hydrogen (PtH / P2H)

A short overview of the **benefits**:

- Long time stream storage possibly
- Storage in natural gas net and natural gas memories has big potential
- Decarbonization of the gas sector with PtG with renewable stream (Sophia Müller, 2018)

Power-to-gas (PtG / P2G - electricity to gas)

Power-to-Gas is a chemical process in which water is broken down into hydrogen and oxygen in an electrolyser by means of excess renewable electricity. In a further step, the hydrogen is converted with carbon dioxide to methane. It can therefore be easily fed into the natural gas networks and thus used for heating and as a heat supplier for industrial processes. (Baunet_Wissen_, n.d.)

A few **advantages**:

- Better storability
- Sustainability through CO_2 neutrality
- Reduced import dependency
- Promotion of connection technologies (Salcher, 2017)

Power-to-Heat (PtH / P2H – electricity to heat)

Power-to-heat technologies generate heat with excess renewable electricity. So far, these are predominantly large-scale applications. As part of their district heating supply, utilities operate, for example, **electrode boilers** (Figure 1) with outputs in the megawatt range to heat water, which is then fed into local and district heating grids. But it is also possible to use **heat pumps** that use renewable electricity as the driving energy to extract environmental heat from the air, soil or groundwater for heating purposes. (Baunet_Wissen_, n.d.)

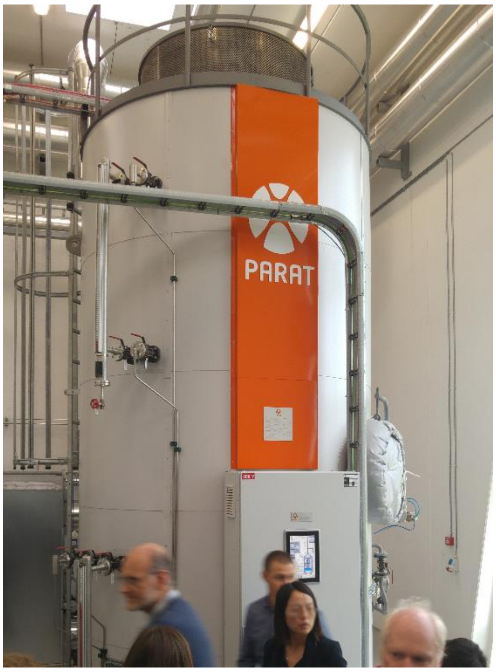

Figure 1: Electrode boiler (10 MW) at a district heating plant in Denmark (source: C. Doczekal)

- **Heat pumps** (Figure 2) use electricity to extract heat from the ground, compress it and then use it to run the heating system. What is great about capturing energy from the external environment is that for every kilowatt-hour of electricity required to run the heat pump, several kilowatt-hours of heat can be generated. Therefore, if you want to convert power into heat, heat pumps are definitely the way to go. However, they are only efficient **at lower temperatures**. (direkt, 2016)

Figure 2: A Heat pump at a district heating plant in Denmark (source: C. Doczekal)

- Whenever **very high temperatures** are needed – for example in industry – **electrode boilers** are used. Electrode boilers consist of huge tanks in which water is boiled directly. In contrast to immersion heaters, which use heating elements to generate energy, electrode boilers use electrodes and salt water. Electrode boilers directly convert renewable energy into heat. (direkt, 2016)

Power-to-Liquid (PtL / P2L – electricity to fuel)

Power-to-Liquid is a storage system in which hydrogen is first generated by means of electricity through water electrolysis (power-to-gas). The hydrogen can then be converted into hydrocarbons in a synthesis with carbon monoxide or carbon dioxide. Various syntheses such as methanol synthesis or Fischer-Tropsch synthesis (FTS) can be used. After separation of the water formed, the hydrocarbons can be further processed by refinery processes to commercial **fuels** and **chemicals**. (Santos, 2019)

Power-to-Hydrogen (PtH / P2H)

Power-to-hydrogen is the process of using electrolysis to split water into hydrogen and oxygen using electricity. Hydrogen is a versatile, clean and safe energy carrier that can be used as a fuel for power or as a feedstock in industry. It can be stored and transported as a liquid or a gas and can be combusted or used in fuel cells to generate heat and electricity. Therefore, hydrogen might play a key role in the seasonal storage of renewable electricity, while also having the potential to decarbonise other sectors when used for other applications, such as mobility applications, industrial uses or injection into the gas grid. (Irena, 2019, p. 1)

Achievements

Austria

In **Neusiedl am See** a new project of Energie Burgenland has been presented - a "power2heat" plant, which will be built in the coming months. This plant produces heat from wind power.

To enable the "power2heat" - plant in Neusiedl am See to produce heat from wind power, a direct line from the transformer station to the heating station is being built. (ORF, 2019) So the wind turbines produce directly electricity for the heat pump at the heating plant to supply the district heating grid.

H2Future consists of a 6 MW electrolyser, proposed to be installed at the **Voestalpine Linz** steel production site in Austria, and is expected to study the use of the electrolyser to provide grid balancing services such as primary, secondary and tertiary reserves, while also providing hydrogen to the steel plant. (Irena, 2019, p. 5)

The Winddiesel R&D project shows how all Diesel driven private cars in the county **Burgenland** could be supplied with 100% renewable Diesel. 4 biomass plants (total 211 MW) in combination with wind parks (total 141 MW) in Burgenland could generate this Diesel amount. The demonstration plant (50 MW) could achieve a Diesel price of EUR 1.10 per litre at the filling station. (Winddiesel, 2019)

Germany

Rheinland-Pfalz Mainz: Hydrogen is already being successfully produced from wind power on an industrial scale at the municipal energy park there. It is used in industry, for heating or in fuel cell buses in public transport. (Wischniewski, 2019)

Denmark

A project in Denmark demonstrated that a 47% to 61% reduction in peak load could be achieved using EVs and heat pumps.

The project assessed the potential peak load reduction by using heat pumps attached to smart devices that can control its functioning, exposed to price-based demand-response programmes. (Irena, 2019, p. 5)

Scotland

A wind power-to-heat scheme is being implemented as part of the Heat Smart Orkney project.

Households will be provided with energy-efficient heating devices that will draw the excess power generated from the community-owned wind turbine, otherwise meant to be curtailed. (Irena, 2019, p. 6)

Netherlands

HyStock is a project developed by EnergyStock, a subsidiary of the Dutch gas transmission system operator Gasunie, and is the first power-to-gas facility in the Netherlands. The project consists of a 1 MW proton exchange membrane (PEM) electrolyser together with a 1 MW solar field that will supply part of the electricity required to generate hydrogen from water. (Irena, 2019, p. 5)

Link to the **demonstration projects** (Austria, Denmark, Scotland, Netherlands and more)

https://irena.org/-/media/Files/IRENA/Agency/Topics/Innovation-and-Technology/IRENA_Landscape_Solution_11.pdf?la=en&hash=2BE79AC597ED18A96E5415942E0B93232F82FD85

Challenges

At present, it is hardly possible to operate such a plant **economically**, and not only because Power-to-X processes inevitably lose energy in the course of conversion. There is also still a lot in the way of regulation. (Wischniewski, 2019)

The relatively low efficiency of power-to-X methods producing synthetic fuels limits their employment to areas in which the direct use of renewable sources of energy is either barely possible or simply not possible at all.

Another hurdle for the market high run is the classification of the stream relation of Power-to-Gas plants as a last consumption. This regulation entails that the plant operators for the used stream must pay to deliveries like the EEG reallocation and under circumstances net remunerations – an essential reason for the fact that green hydrogen and with it produced fuels are very expensive even today. (Diermann, 2019)

For example, the high energy density required in the maritime and aviation industries makes electrification difficult to achieve, whereas chemical plants use hydrogen as a base component to manufacture several kinds of goods, such as adhesives and fertilizers. (Hydrogeit, 2019)

A short overview of the **challenges** of Power-to-X:

- not yet economically presentably
- not yet suitable amounts in profit stream available
- low efficiency
- high cost (Sophia Müller, 2018)

Enabling conditions

Important enabling conditions would be:

- Modification of the network charge system
- Approximation of CO_2-pricing of electricity and chemical fuels
- Promotion of facilities and storage capacities that can not compete economically with conventional energy production (Sophia Müller, 2018)

The Power-to-X technologies are intended to solve **two major problems**.

Firstly, they are intended to make use of surplus green electricity, which will be generated more and more frequently on windy and sunny days as solar and wind energy continue to be expanded. **Secondly,** they should make it possible to use green electricity in other sectors as well - for heating buildings, in internal combustion engines in transport and as raw materials in chemical production. The technical word for it: sector-coupling (Wille, 2019)

In fact, it would be wrong to blindly switch to the new energy sources. They are not per se climate-friendly and sustainable.

If normal electricity, as it flows in the grid today, is used, 700 to 1100 grams of CO_2 are produced per kilowatt hour of the new energy sources. By way of comparison, if natural gas is burned directly, it is only 240 grams, and 300 grams for Diesel. Switching to heating or refuelling would therefore be highly counterproductive. The situation is different when green electricity from additionally built solar or wind power plants is used. Then Power-to-X can be considered almost **climate-neutral.** (Wille, 2019)

But it is not only the power source that is important for the climate balance. The origin of the second component needed for the new energy sources also has a great influence: **Carbon dioxide.** It is needed to convert hydrogen, which is produced by electrolysis in the Power-to-X processes, into easily manageable energy carriers, such as synthetic methane, which can be fed into the natural gas grid, or synthetic fuel.

According to the analysis, Power-to-X only makes sense if the CO_2 is obtained directly from the air or during biomass combustion: "This is the only way to create a CO_2 cycle with the ambient air". Using carbon dioxide, which is produced in conventional industrial processes, is counterproductive. (Wille, 2019)

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 836819. The sole responsibility for the content of this report lies with the authors.