Power to Gas – A Sector Coupling Perspective

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Key Messages:

1. To date, the electricity transmission grid and currently available technologies efficiently integrated renewable sources of electricity into the power system. The ongoing energy transition will require additional developments.
2. Power to Gas – and other P2X (e.g. Power to Liquid, Power to Heat, …) - may have the potential to reduce the cost of the decarbonized energy system in particular when the end consumption is either gas or other high value energy forms.
3. Scaling up of P2G technologies for exploring their industrialisation potential needs to start as of now.
4. The ENTSOs are cooperating in an open way to study the impact of foreseen technologies including Power to Gas onto grid planning.

1. Context: challenges to integrate wind and photovoltaic production

The European energy system is undergoing a major transition in order to reduce carbon emissions. To achieve this, there are political RES integration and carbon reduction targets. For the electricity sector, one of the key elements in this transition is the increase of renewable energy production. Wind turbines and photovoltaic panels are among the production technologies having high potential / low cost across Europe. They generate electricity; hence, the electrical system will be a key element in the transition of the energy system.

Both wind and photovoltaic produce electricity in a volatile pattern, e.g. the production follows the sun and the wind and may not match demand patterns. Thus, an energy system based on wind turbines and photovoltaic panels faces three major challenges:

- The difference between local generation and consumption leads to a clear need for **electricity transmission or storage** or **conversion to other energy forms or carriers.**
- Full load hours (assuming lack of wind/sun and/or cold winter nights) require a reliable backup leading to a clear need for a **backup system** with high level of **energy** covering low volatile RES availability for weeks/months periods and very high power for short periods of time (no wind and no sun at high demand).
- High volatile generation and possible low utilisation rates of renewable energy sources require **high system flexibility** in order to optimally utilise the installed RES capacities and to avoid potential overrated system development at the same time.

A cost-efficient energy transition requires a coordinated planning, design and implementation of all system elements involving generation, transmission, distribution and consumers/prosumers across all energy sectors. The energy conversion between different energy systems is being regarded as an instrument allowing for the optimisation of the overall system. On one side, each conversion leads to efficiency loss. On the other side, it creates value taking into account the existing end user technologies and improved RES integration.

2. Ways to perform this system Integration

There are several complementary ways of **integrating wind and photovoltaic** production into the overall energy system:

- Integration using the power grid. As local production usually differs from the local consumption, the energy has to be brought into the load centres. In addition, there are geographical differences across Europe in both consumption and production patterns. It is possible to obtain a higher utilisation of the renewables, by transporting the power to the area with needs for electricity. However, this requires reinforcement of the power grid.
- Integration converting power to gas. The output can be used directly as hydrogen or be blended into the gas flows or after a further conversion step as synthetic methane. This could be used as:
    - Raw material in the chemical industry.
    - Final energy for heating, road and maritime transport, industrial processes, …
    - Further conversion to other high value energy carriers (e.g. ammonia).
    - Electricity generation.

  In the case of electricity generation, the integration will use two step conversions, i.e. convert power to gas and then back again from gas to power. However, current technology generates considerable loss of energy due to the two conversion steps.

  P2G/P2X has the potential to become a seasonal storage system in addition to the hydro-power storage systems with large energy capacity. Seasonal storage is important as studies have shown that a high level of renewable generation based mainly on solar and wind generation can only be achieved together with seasonal storage systems.
- Electrical power storage (short term storage). Power storage is considered with limitations for large energy volumes but may be a feasible solution to obtain stability in the power system, for peaks (i.e. minutes and hour imbalances) up to daily imbalances.
- Power to thermal storage. Thermal storage can be very flexible in terms of power usage and may be efficient up to mid-term time frame.

3. Focus on Power to Gas

The concept of making renewable energy available to customers with a P2G technology looks very promising due to advantages stated below. In simple words the P2G electrolyser could be operated similar to a **transformer** between the electricity and the gas system which injects gas into the gas system. The advantages based of producing synthetic gases like Hydrogen and possibly synthetic Methane are:

- Some technologies to produce gases are extremely flexible and are therefore suitable for the variable electric infeed.
- The state-of-the-art efficiency for such conversion process is already high with a potential to increase further.
- This approach will provide seasonal flexibility and storage, building on existing gas network and underground storage. Already today the gas system offers over 1100 TWh of underground storage capacity. Existing gas Infrastructure – after technical adaption – can be used for long-term energy storage and transportation.
- Synthetic gases can be used for industrial processes and heating and thus help to decarbonise other sectors.

However, some significant challenges have to be addressed and overcome:

- As of today, only small P2G plants are in operation (up to 10 MW) and accordingly, the production of synthetic gases is currently expensive. However, costs reductions could be expected when learning curve effects materialize. This is necessary in order to have much higher installed capacity in the GW region available by 2030.
- Electrolysis manufacturing capacity needs to develop for the upscaling challenges.
- The production costs of synthetic gases are mainly determined by capital costs and thus high utilisation rates reduce the costs per kWh; in addition, cost reductions are expected due to up-scaling and learning effects.
- Given that the current framework of regulations, market incentives, tariffs, etc. has not taken into account the opportunity of P2G, seasonal storage and other technologies, there is a need for further development and existing hurdles have to be addressed to make it possible.

4. First Assessment of Power to Gas

The electricity system and the gas system could be considered as complementary to each other:

- The electric system allows the production of large quantities of renewable energy, but it has limitations to provide long term electric storage.
- On the other hand, the gas system's ability to store large quantities of renewable energy is very high.
- The electric system is a fast, real time system and as such, it is featured with limited long-term flexibility, whereas the gas system is flexible also long-term and can provide its flexibility to the electric system.

The continuously growing penetration of the renewables increases the need for electricity ancillary services to cope with the large amount of volatile energy and thus has a significant impact on the technical and financial aspects of the electricity system operation. Thus, from a **system perspective** a coupling of electricity and gas will result in a more stable overall system as a whole. In addition, the societal costs of the combined sectors could eventually decrease because:

- the complementary characteristics of the two sectors support each other so that RES can be integrated more efficiently,
- existing infrastructure which will require some adaptations could potentially be used (e.g. gas grid and gas storage),

- continued utilisation of existing end user technology, when conversion is not cost efficient or fast enough,
- gas storage (in addition to a number of hydro power storage systems, which could also be expended) is the only known seasonal storage with sufficient capacity, and
- synthetic gases are valuable energy carriers for heating, transportation and the chemical industry, together with biomethane and decarbonised gas.

The EC and the European Council support the approach of implementing P2G facilities from the system perspective.

5. Modelling of sector coupling

Consistent gas and electricity scenarios are prerequisites for capturing the potential sector interdependencies in planning the grids. Proven "State of the Art" models exist for each sector separately for rigorous development studies on the basis of these scenarios. However, ENTSO-E and ENTSO-G advance their collaboration into exploring the areas where more detailed assessment of interlinkages could provide added value under real life conditions.

6. Conclusion and next steps

In order to decarbonise the energy system, it is necessary to consider all the available technologies.

Power to Gas appears to be a promising development in cases where the end consumption of energy is in the first step hydrogen, either pure or blended into the gas flows or synthetic methane and *not* electricity. This will already create opportunities for an increased decarbonisation of Europe's energy consumption and it will facilitate new applications in other sectors. P2G – or other P2X technologies - could be the second step of system development when the electric system could not fully integrate the variable RES and more seasonal storage, or other energy usage would be needed. In addition, P2G could be an option as (seasonal) storage when the remaining conventional (dispatchable) generation is not adequate to deliver the needed load during low solar/wind generation.

Studies show that seasonal storage systems will still be needed when decarbonisation levels are getting higher in the energy sector. Since more flexibility is needed in the short term as well, the highly controllable P2G plants could be a valuable contribution to maintain secure and efficient power system operation although learning curve effects still need to materialise. On this background, exploring the industrialisation opportunities of P2G needs to start now.

The system supportive usage of P2G can best be realised by cooperation of electricity and gas TSOs. Thus, for the system supportive functions the TSOs should be in the lead to develop the technical requirements for system integration of P2G plants while consulting policy makers, regulators and other market participants.

If such systems are to have a significant effect, the installed capacity has to be in the GW-range by the early 2030ies. That means the size of P2G facilities has to be technically up-scaled significantly. Therefore, it is important:

- to start the upscaling process of P2G plants at least by a factor of 10 and
- to study and demonstrate the grid supporting capabilities of P2G plants.

Starting these processes as soon as possible is a first and very important step to contribute large scale decarbonisation.