THE ROLE FOR POWER-TO-GAS IN FUTURE ENERGY SYSTEMS: A MODEL-BASED ASSESSMENT FOR THE NETHERLANDS

Dr. J. de Joode, Policy Studies Unit, Energy research Centre of the Netherlands (ECN),
Amsterdam, the Netherlands, +31885158250, dejoode@ecn.nl

Overview

P2G - the conversion of (renewable) electricity into a gas (hydrogen, methane) - is considered an attractive option to both accommodate intermittent electricity supply from wind and solar resources and to decarbonise fossil fuel dependent end-use sectors (e.g. transport, built environment) (Le Duigou *et al.*, 2013). But what is the actual role that could be played by this technology? What are the drivers and bottlenecks for the P2G business case from an energy system perspective? This paper presents the results of a model-based, integral energy system analysis and a case study-based analysis for the case of the Netherlands (de Joode *et al.*, 2014).

Methods

An analysis of the potential for P2G in achieving long-term energy system targets requires an integral analysis on the overall system level because the P2G route potentially affects different energy value chains. P2G may be a viable flexibility option to efficiently deal with the intermittently challenge posed by the increasing penetration of wind and solar energy, but may also be a viable low carbon option for industry and mobility. These drivers are assessed using (a) an integral energy system modelling approach, and (b) a case study-based approach. The former approach takes into account relevant alternative technologies that may either provide flexibility to the system or can decarbonise energy end use and evaluates impact of different policy and social factors on the role for P2G (e.g. climate and renewable energy policy, social acceptance issues). The implemented energy system covers about 280+ energy production, conversion, transport and demand technologies, with a full representation of the electricity, gas and heating system value chain. Given any set of data input assumptions (on for example energy technology characteristics (Grond *et al.*, 2013), low-carbon technology potentials, CO2 emission reduction targets and renewable energy targets), the model finds the mix of energy technologies that serves final energy demand at least cost from a public perspective. In order to take into account hourly profiles for energy supply (e.g. wind and solar) and energy demand (heating demand, electricity demand) a new 'time slice' approach is developed and implemented. This involves the 'clever' grouping of hours throughout the year that are similar in their energy profile. In this way all 'extreme' energy system situations are captured, without putting to high demand on computational power. In the case studies the focus is on exploring the potential viability of P2G in (i) the Rotterdam industrial harbour cluster, (ii) in the North of the Netherlands, and (iii) in a distributed energy systems located near the three cities of Apeldoorn, Deventer and Zutphen. The time horizon adopted in the model-analysis is 2050, whereas the case study analyses use a 2030 time frame.

Results

Results from the model analysis are depicted using 'P2G factsheets' and using graphs that are showing the supply and demand balance for each 'time slice' of the year for the electricity, gas, hydrogen en heat balance. The P2G factsheet for each model run (scenario) report on aspects such as the amount of share of wind and solar energy in the system, the amount of energy curtailed, the amount of P2G capacity (electrolysers), the amount hydrogen produced, and the demand segments in which hydrogen is used (industry, mobility, gas system, etc.). The factsheet results indicate a role for P2G in particular the scenario's in which ambitious CO2 emission reduction targets are imposed. The amount of P2G varies if assumptions on the potential and availability of low-carbon options such as biomass, CCS and nuclear energy are changed. For illustration purposes, Figure 1 presents the supply and demand balance for the electricity system in the reference scenario. These type of figures provide information on the mix of energy technologies that is used in situations of for example low electricity demand with high intermittent electricity supply, and high electricity demand with low intermittent electricity supply. Based on comparisons across the assessed scenarios we find that P2G is one of the options that deliver electricity system flexibility. Others are dispatchable generation (gas-based, with CCS), energy storage, and flexible electricity demand technologies (such as electric vehicles).

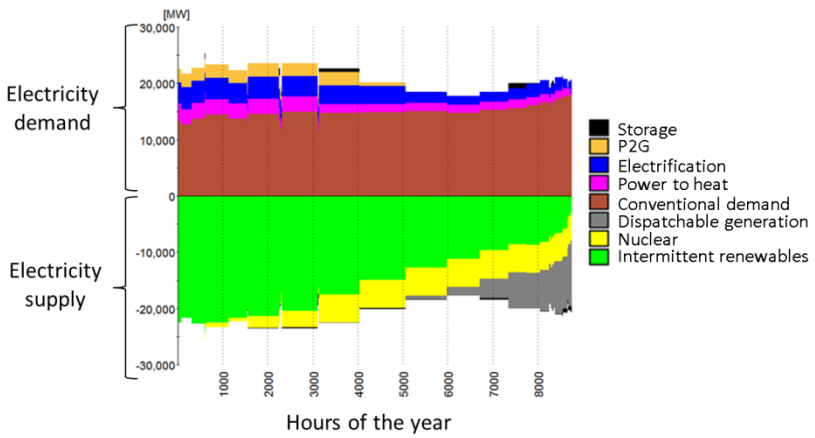

Figure 1: Electricity supply and demand balance in the reference scenario at an 80% CO2 emission reduction target (ECN)[1]

In three case study analyses the economic viability of P2G applications in 2030 were explored. The results thereof indicate that from a public perspective it is difficult to make a solid, positive business case for P2G. The high capital cost of electrolysers requires a relatively high amount of full-load hours. Based on expected future yearly electricity price profiles, we find that the prevailing electricity prices will be still too high, or will be low in terms of number of hours a year to justify such high capital investments. Furthermore, the price levels of the current markets for future hydrogen applications (industry, transport, built environment) are too low for P2G to become competitive in the short to medium term. In the longer term, higher level of CO2 prices would make a difference there.

Conclusions

Within the boundaries of our research (scope Netherlands, integral energy system analysis, time horizon 2050, and public perspective) the following conclusions may be drawn for our research:

- The need for flexibility in the electricity system (due to the increasing integration of wind and solar resources) is in itself insufficient for a positive business case for a P2G application from a public perspective;
- The key driver for a positive P2G business case is the degree of CO2 emission reductions required. Strong decarbonisation puts a high premium on hydrogen as a 'green' fuel that is capable of decarbonizing final energy demand in the built environment (heating demand), transport and industry;
- P2G is mostly about power-to-hydrogen, and less about power-to-methane. From a public, least system cost perspective, the methanation route (power-to-methane) is only a viable solution in strong decarbonisation scenarios when the energy system has already fully used its potential to capture and store CO2;
- P2G is a robust part of the future energy system – because of its role in decarbonizing traditional fossil fuel dominated end-user sectors – but its long-term role is contracts with the lack of positive business cases in the period to 2030. In order to have the relevant technology available it is important that demonstration projects are realised. The energy system and its actors thus need to prepare for a future where P2G is an important part of the energy system (Bleischwitz and Bader, 2010).

References

Bleschwitz, R. and N. Bader (2010). Policies for the transition towards a hydrogen economy: the EU case, Energy Policy, Vol. 38, Issue 10, pp. 5388-5398

de Joode J. *et al.* (2014). The role for power-to-gas in future energy systems: a model-based assessment for the Netherlands, final report of the TKI gas P2G system analysis study, *to be published*

Grond L. *et al.* (2013). System analysis power-to-gas: A technology review, DNV KEMA, June 2013.

Le Duigu, *et al.* (2014). Hydrogen pathways in France: Results of the HyFrance3 Project, Energy Policy, Vol. 62, pp. 1562-1569.

[1] This figure ranks the different time slices according to the amount of intermittent electricity supplied. The composition of the time slices (electricity supply categories below the X-axis, electricity demand categories above the X-axis) illustrate which type of technologies are implemented in an energy system with the lowest cost from public perspective.