Power-to-gas and power-to-liquids for managing renewable electricity intermittency in the Alpine Region

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Background

Large scale deployment of renewable energy sources (RES) can play central role in reducing CO_2 emissions from energy supply systems, but intermittency from solar and wind technologies present grid integration challenges. High-temperature co-electrolysis of steam and CO_2, in the so-called power-to-gas (PtG) and power-to-liquids (PtL) configuration, could provide a path for utilizing the excess intermittent electricity from a power system by converting it into chemical fuels that can be directly utilized in other sectors, such as transportation and heating.

Aim of the study

The main focus of this work is to emphasize on the impacts of temporal and spatial intermittency of RES in power dispatch systems as well as on the utilization of excess intermittent electricity via PtG and PtL processes into other energy sectors (such as transportation, heating or power, in the context of long-term storage).

Power-to-gas/liquids

Recent development and performance improvements have demonstrated efficient co-electrolysis of $H_2O(g)$ and CO_2 in Solid Oxide Electrolysis Cell (SOEC). The ohmic resistance as well as the cell degradation rates and mechanisms are rather similar as in the electrolysis of steam alone . In the light of such developments of SOECs, an overall conversion efficiency of 70% are to be expected. This efficiency refers to the calorific value of the final product (liquid methanol in the case of PtL and methane gas in the case of PtG) and the power input to the process.

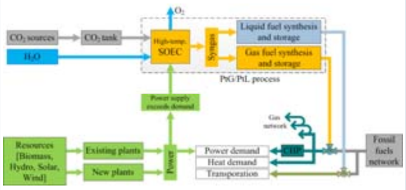

Fig. 1. *Schematics of the power balancing and long-term storage concept PtG/PtL*

Methodology

The study is carried out using BeWhere model [1]. BeWhere is a geographic explicit cost optimization model, based on mixed integer linear programming (MILP), written in GAMS and uses CPLEX as solver.

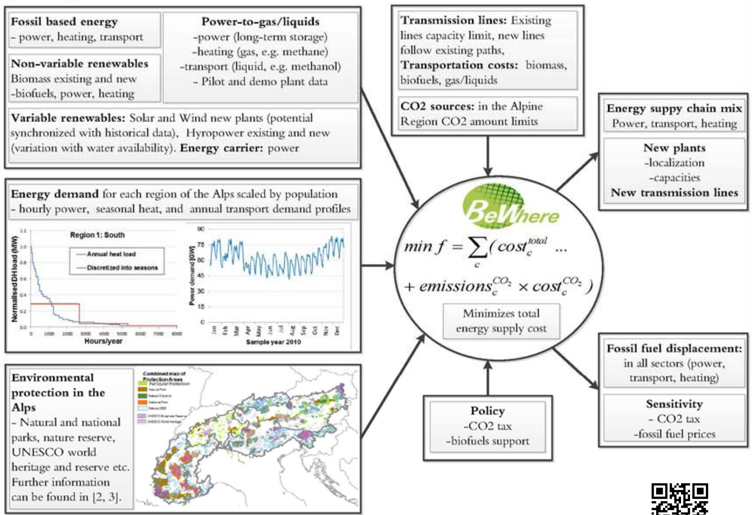

Fig. 2. *BeWhere Alps optimization model structure*

Preliminary results

Power generation mix

Figures 3 through 5 present the power generation mix and the resulting over-generation potential for the sample year at carbon price €150/tCO_2.

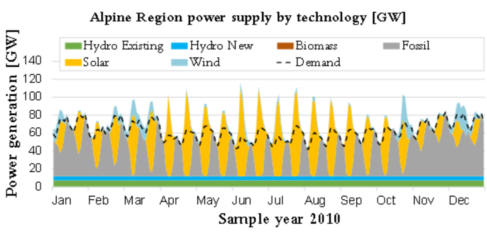

Fig. 3. *Aggregated hourly power dispatch system at the sampled hours. Over-generation, available for PtG/PtL production, is represented by the area above the demand curve.*

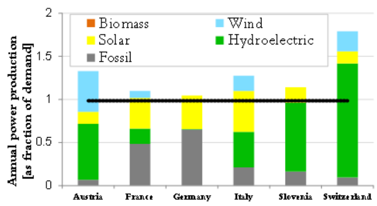

Fig. 4. *Power supply as fraction of demand by sector in each country and the corresponding over-generation capacities. Hydropower accounts for both existing and new plants capacities.*

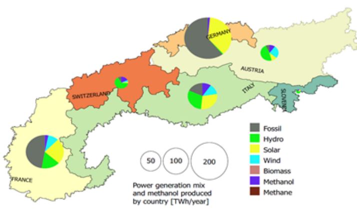

Fig. 5. *Power generation mix by sector in each country, and the corresponding liquid or gas produced, in TWh/year. Hydropower accounts for both existing and new plants capacities.*

Sensitivity Analysis

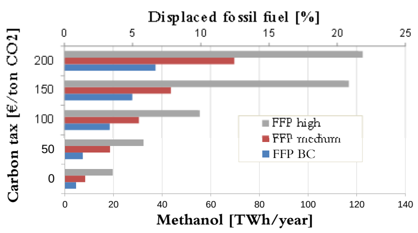

Fig. 6. *Sensitivity of methanol production to carbon tax at different levels of fossil fuel prices (FFP) (represented by the bottom x-axis scale) and the corresponding displaced fossil fuels from the transportation sector, represented by the top x-axis scale. The total transportation energy demand of the region is about 570 TWh/year.*

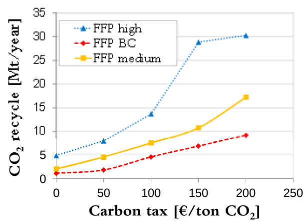

Fig. 7. *CO2 recycle, in Million tons per year [Mt/year], over the range of variation of carbon tax and at different levels of fossil fuel prices.*

Summary

The results of the model at this stage can be summarized in the following contextual remarks:

- The PtG and PtL concepts add flexibility to the energy system by linking power to gas/liquid fuels that can be used in other sectors.
- PtG and PtL provide the opportunity to recycle large volumes of CO_2 into the fuel supply system.
- Under the assumed economy and operating conditions of the SOECs, results indicate these technologies can enable greater integration of renewables into the energy system.
- The sensitivity analysis shows even without carbon tax and at base case FFPs the model builds PtL plants.

Ongoing and future work

There is ongoing work to enhance transmission lines (both existing and new) and fossil power plants representation in the model.

Further into the future we plan to enhance the model by considering only bioenergy based CO_2 sources and use it to investigate net reductions in atmospheric carbon in the context of negative emissions.

Further reading

[1] *http://www.iiasa.ac.at/bewhere*

[2] *Kraxner F, Leduc S, Serrano León H, et al. Modeling and visualization of optimal locations for renewable energy production in the Alpine Space with special focus on selected pilot areas. Alpine Space model. ISBN: 987-3-7045-0150-9, 2015.*

[3] *Kraxner F, Leduc S, Serrano León H, et al. Recommendations and lessons learned for a renewable energy strategy in the Alps. ISBN: 978-3-7045-0151-6, 2015.*

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