A systematic analysis of some key uncertainties in the value of hydrogen storage investment

Introduction and Motivation

Many countries are considering investing in hydrogen technology as part of their electricity sector decarbonisation strategy, due to its many uses in facilitating a low carbon future. In a power system with a high share of renewable generation, hydrogen could be used as a storage medium to absorb excess supply on high renewable generation days, allowing for low carbon power supply at times of system stress. However, the usefulness of Hydrogen to a future energy system is determined by a set of unknown parameters. These include; the capital costs of hydrogen investment, carbon taxes, and the cost of hydrogen production relative to competing fuels and technologies.

In this project, I plan to systematically analyse this uncertainty. Using a complex capacity expansion model with high renewable penetration scenarios, I will run a series of models with different input parameters. This will allow me to identify areas of the joint parameter space over which hydrogen investment reduces total system cost. My proposed research question, therefore, is: "**under which combinations of future hydrogen cost parameters and carbon prices would investment in hydrogen storage bring about total energy system cost reductions?**".

Data and modelling

I propose using a detailed capacity expansion model, similar to that presented in Notebook 07. My model will include economic dispatch, with ramp and storage constraints. I propose to use the ERCOT 3-zone system as the study setting. I plan to model hydrogen storage technology investment as a binary capacity decision variable, that can be built at each of the three nodes. I plan to use a version of the model that includes 8 weeks' worth of data, rather than a full year, to reduce computational burden. The model will include brownfield generation, with renewables and storage, and linear unit commitment constraints.

My proposed methodology would entail:

- Determining a reasonable set of possible future carbon taxes, $c \in [0, C]$, future hydrogen fixed costs $f \in [0, F]$, and future hydrogen variable costs $v \in [0, V]$. I will need undertake a (necessarily brief) literature review in order to determine these sets. I will then discretise this three-dimensional parameter search space.
- Running the model for each permutation $p_i = \{c_{i_c}, f_{i_f}, v_{i_v}\}$, where i indexes the discrete values of each parameter. So, if $i_c \in \{1, 2, \dots, N_c\}$, $i_f \in \{1, 2, \dots, N_f\}$, and $i_v \in \{1, 2, \dots, N_v\}$, this would entail a total of $N_c * N_f * N_v$ model runs.
- For each p_i, record the build decision of hydrogen, and information about its utilization and the benefits it brings to the system (cost production/ capacity value). This will allow me to characterise which parts of the uncertainty space entail a positive system value of hydrogen investment.

Limitations, and expected results

This research proposal will necessarily be limited in its scope. For example, I will make pretty simplistic assumptions about the way hydrogen is deployed and used by the system. I will not be modelling Hydrogen's many other uses in the economy. I will also not explore sensitivities in the cost profiles of its competitors. Instead, I will fix their cost profiles at that provided by the input data. In my modelling I expect to find that high carbon prices, coupled with low Hydrogen costs, will make hydrogen capacity expansion more likely. My research project will aim to characterise the subset of p that implies positive system value (for the ERCOT 3-zone model input data setting) for hydrogen – and I will produce visualisations of these results.

Extensions

My motivation for proposing this research is twofold. Firstly, I am interested in developing future research on the viability of hydrogen investment in other settings. Secondly, I am interested developing the skills involved in this kind of policy analysis. In future research, I would like to extend this project to using data in the German power market, with more realistic hydrogen cost inputs, based on the location of salt caverns relative to demand, and potentially some sector coupling.