INVESTMENT IN A GREEN-HYDROGEN SYSTEM UNDER ECONOMIC AND PHYSICAL UNCERTAINTIES

Luis María Abadie, Basque Centre for Climate Change, +34-944-014-690, lm.abadie@bc3research.org
José Manuel Chamorro, University of the Basque Country, +34-946-013-769, jm.chamorro@ehu.eus

Overview

The Paris Agreement 2015 aims to limit global warming this century to well below 2 degrees Celsius (preferably 1.5) compared to pre-industrial levels. This long-term goal puts pressure on countries to achieve climate neutrality by mid-century. In response, they plan a number of actions and take measures to reduce their greenhouse gas (GHG) emissions. For one, at the COP26 summit 2021 in Glasgow countries committed to reducing 6.3 billion tonnes of GHG by 2030. This challenge in turn calls for transforming current production and consumption patterns, and shifting toward a circular economy. Energy supply is a priority sector in this regard. The share of electricity in particular is forecasted to increase sharply in the future.

Power generation can be decarbonized by using energy sources with low or no GHG emissions attached. Variable renewable energy (VRE) resources such as solar and wind belong in this family. Unfortunately, however, they are intermittent and uncertain. They strongly depend on local weather conditions, which are rather different across space and time. These characteristics complicate the engineering and the economics of harnessing them for power generation.

Now, hydrogen shows considerable potential on both accounts. On one hand, unlike fossil fuels it is carbon free. Yet, as them, it lends itself to a range of applications, e.g. in transportation, manufacturing, heat and power generation… Nonetheless, hydrogen is not a source of primary energy. It is an energy vector: it requires a prior energy input to be produced; besides, it is able to store energy to be released gradually when required. Indeed, these special features render it a suitable complement to power supply from VRE resources like wind and solar. It is possible to exploit these synergies by combining an investment in a VRE facility with a power-to-gas (PtG) facility; in other words, by creating a hybrid system.

Methods

Potential investors in such a hybrid system have several 'real options' at their disposal, e.g. the option to delay investment, or to modify the scale of the project. The focus here falls on another option: at any time, the manager must choose between selling the power produced at the current market price or, alternatively, feeding it to the electrolyser for converting it into hydrogen.

Glenk and Reichelstein (2019) develop an analytical framework that applies to general hybrid energy systems and yields necessary and sufficient conditions for their economic viability. The model includes an adjustment factor that accounts for covariances between renewable power generation (via capacity factor) and power market prices.

Specifically, they derive the expression for the NPV of a hybrid system with a renewable energy capacity of $k_e = 1$ kW and a PtG capacity of k^*_h (also measured in kW) which is to be optimally chosen (efficiently sized); that is, they compute the NPV of an optimized hybrid system, NPV(1, k^*_h). This system will be economically viable if its NPV is positive and higher than that of the renewable power system without PtG, i.e. NPV(1, 0), provided the latter is cost-competitive on its own. The lowest hydrogen price for which the hybrid system makes economic sense (i.e. the above inequality applies) is the break-even price of hydrogen, p^*_h., which has a corresponding optimal PtG capacity k^*_h.

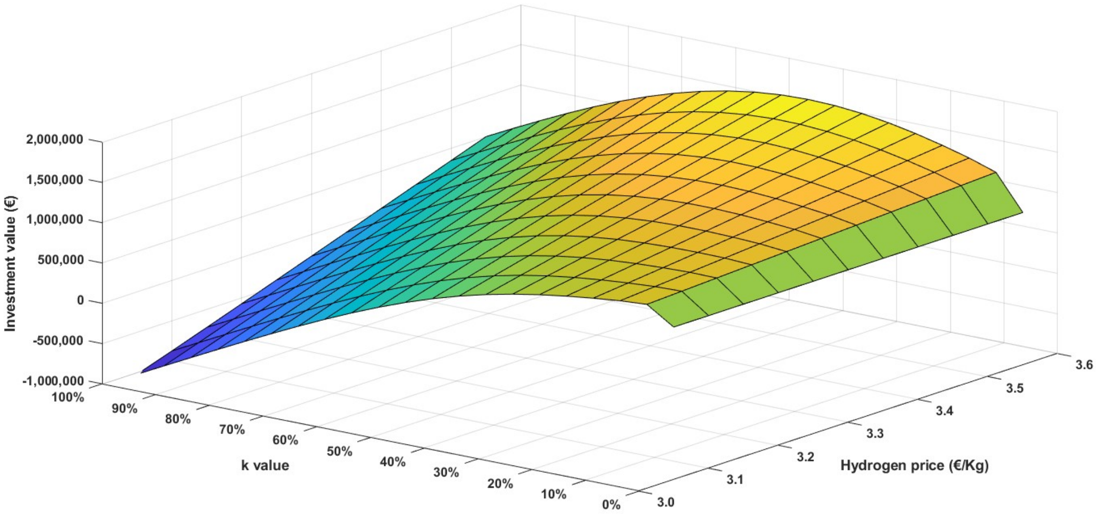
We draw on the above model to some extent, yet our model involves a few main contributions. Thus, we aim to develop a stochastic model where both the market price of power and the wind capacity factor evolve randomly over time; see for example Abadie & Chamorro (2021). This in turn leads us to estimate the underlying parameters of two stochastic processes from official or publicly available data sources. The model can then be simulated a number of times. Monte Carlo simulation allows derive the risk profile (or probability distribution) of the investment's net present value (NPV).

Results

Glenk and Reichelstein (2019) apply their model to wind parks in Germany and Texas. They find hydrogen break-even prices of 3.23 €/kg H_2 in Germany and 3.53 $/kg H_2 in Texas. In both cases the power price used is time invariant (0.0318 €/kWh in Germany and 0.0255 $/kWh in Texas). As they point out, each assumed hydrogen price (p_h) triggers a unique maximizing PtG capacity choice, k^*_h. Their Figure 1 shows the optimal size of the PtG facility in relation to a wind facility with a normalized capacity k_e = 1.0 kW under the assumption of a constant electricity price.

In this regard, we derive a surface that displays the hybrid project's NPV attached to pairs of hydrogen prices and optimal PtG capacities under the assumption that both the power market price and the wind capacity factor evolve stochastically over time. We run 1,600 simulations with hourly time steps that stretch over 30 years. Each simulation involves (correlated) time paths for the electricity price and the capacity factor.

Hybrid system's NPV (in €) as a function of hydrogen price and PtG capacity.



Above p_h = 3 €/kg moving from a wind facility alone (k_h =0) to a hybrid system increases the project's NPV (green edge furthest to the right). Henceforth, with p_h = 3.0 €/kg and 3.1 €/kg the NPV decreases monotonically, turning to negative for k_h above 0.7 kW. Nonetheless, starting from p_h = 3.2 €/kg and upward there is some scope for higher NPVs accompanied by bigger PtG capacities, but only up to a point (yellow area at the top); in the hydrogen price range considered here, k^*_h never surpasses 0.31 kW. Above this threshold the NPV declines. On the other hand, the NPV remains positive even with k_h = 1.0 kW provided the hydrogen price is p_h = 3.7 €/kg at least.

Conclusions

Electrolytic production of green hydrogen has sizeable potential to reduce GHG emissions. However, when evaluated from the viewpoint of a potential corporate investor, right now it seems unable to compete with large-scale fossil-based hydrogen production. At present it can be cost competitive with small- and medium-scale hydrogen supply at best. Nonetheless, several factors are improving its prospects and pushing it beyond these niche applications. On one hand there are market drivers, such as the continued decline in the purchase cost of electrolysers and wind turbines, and the forecast increase in the wind capacity factor; the future path of power price is more open to debate. On the other hand there are policy makers in charge of the energy and environmental regulation. Expanded carbon markets and sustained support mechanisms can further enhance the economic prospects for green hydrogen.

References

Glenk G., Reichelstein S.: "Economics of converting renewable power to hydrogen". *Nature Energy* **2019**, Vol. 4, 216-222, https://doi.org/10.1038/s41560-019-0326-1.

Abadie L.M[a], Chamorro J.M.: "Evaluation of a cross-border electricity interconnection: The case of Spain-France". *Energy* **2021**, 233, 121177, https://doi.org/10.1016/j.energy.2021.121177.