Renewable generation and green hydrogen: infrastructural requirements for a resilient, independent, net-zero energy system

Gianni Goretti[2, 1], Colm Lowery[1], Aidan Duffy[2]

1. ESB Generation and Trading, Dublin, Ireland

2. Technological University Dublin, Dublin, IRELAND, Ireland

1. Objective & Background

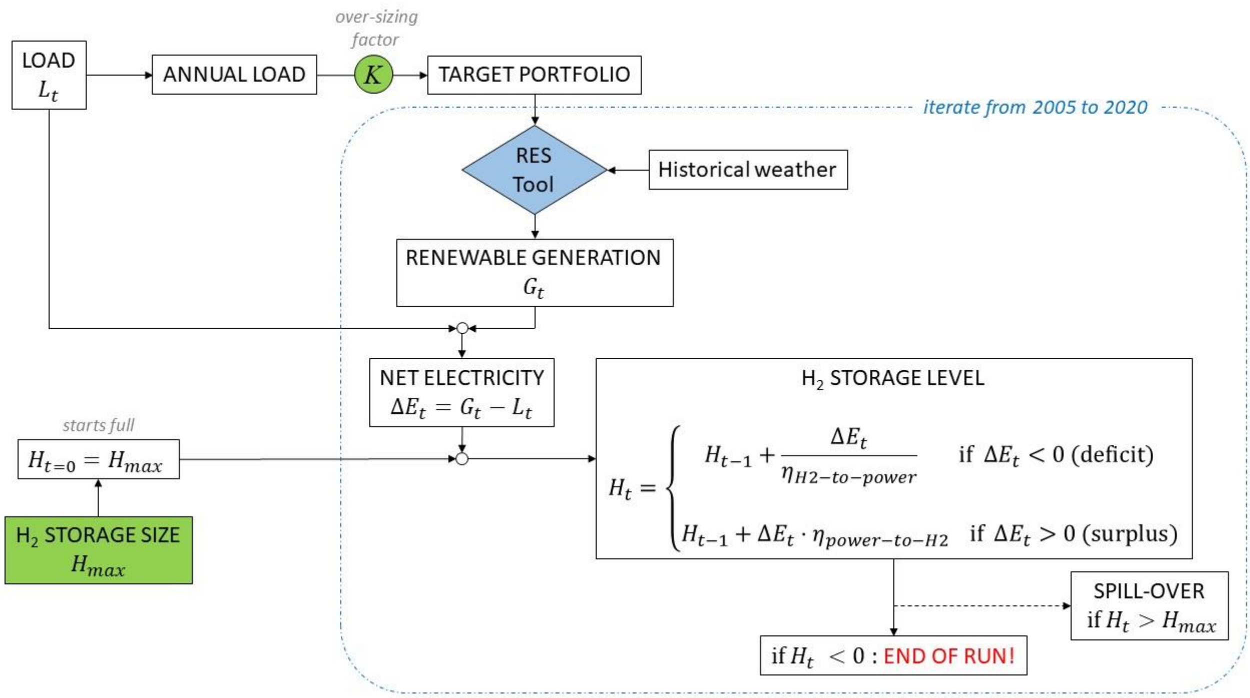
The objective of our work is to model a resilient, independent, net-zero energy system in order to identify the infrastructure requirements needed to operate such system.

Ireland is used as the case study, where generation is assumed to be fully renewable and based on wind and solar power and green hydrogen (H2) storage. The study is carried out from a strategy perspective, with the main priorities being security of supply and self-sufficiency of the system as an island. Resilience is tested by simulating system operations for 16 consecutive years and ensuring that demand is satisfied at any point in time.

2. Method

Based on a portfolio of onshore and offshore wind and solar PV plants, renewable generation is modelled at hourly resolution using historical weather data (from 2005 to 2020) from the ERA5 reanalysis dataset. Demand is modelled based on a forecast of electricity load for a future, highly-electrified energy system. The operation of the power system is then simulated by matching the renewable generation profile to the demand profile on an hourly basis; a surplus of electricity generation is stored as H2, while a deficit is drawn from the H2 storage (see flowchart below). The minimum size of H2 storage allowing demand to be always satisfied is then determined.

The infrastructural requirements necessary to run the system safely for the 16 consecutive years are identified, including the size of the renewable fleet, green H2 storage, electrolysers, dispatchable (thermal) fleet, and interconnectors. By adding capital costs to each system component, the optimal mix between these technologies is found.



3. Principal Findings

The results of the study show that a resilient, independent, net-zero system requires massive investments in infrastructures.

For a future annual demand that is three times the size of today's electricity load:

- the size of the renewable fleet has to increase 2.7 times,
- the capacity of green hydrogen storage needs to be one quarter of the annual load,
- the size of electrolysers (needed to convert electricity into H2) is comparable to the peak load, and
- the dispatchable fleet (necessary to convert H2 back to electricity) has to double in size.

Moreover, it was found that, in a wind-dominated system, autumn is the new "winter peak", and the stress period (*dunkelflaute*) for the system is closer to two years, rather than two weeks.

Finally, the negative correlation between wind and solar is found to be beneficial, with solar power complementing wind to significantly reduce storage requirements.

4. Discussion

Some of the assumptions made in this work will be relaxed in the future, and the model refined and extended to account for other factors (for example, connection with other systems to import/export electricity, weather conditions based on climate change scenarios). However, the results of this study already highlight the fact that substantial investments are necessary to achieve the net-zero goal in a resilient way.