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The role of hydrogen in the UK's greenhouse gas emissions reduction strategy – comprehensive value chain modelling and optimisation

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As the UK attempts to decarbonise and installs more intermittent renewable energy, matching energy supply to demand on a minute-by-minute basis will become increasingly difficult. Furthermore, the transport and heat sectors must be decarbonised in addition to the electricity sector. Hydrogen offers a potential solution to these issues. Through Power-to-Gas technology, excess renewable electricity can be used to produce H_2 through electrolysis, which can be stored and then reconverted to electricity, used as transport fuel or injected into the natural gas grid.

A comprehensive spatio-temporal MILP model for Great Britain (GB) was developed that can determine the best way to satisfy demands for electricity, heat and mobility, while also meeting the 2050 GHG emissions target. Issues such as the intermittency of renewables and energy storage dynamics are captured through an hourly time resolution. Seasonal time steps allow for variations in supply and demand over a year, and decadal intervals account for longer term investment decisions. Spatial dependencies are modelled by representing GB using 16 zones based on the National Grid Seven Year Statement study zones. The model determines how to best use resources by optimising the combinations of technologies to use; their capacities; where to locate them; when to invest in them etc.; and their optimal operation, which could include hydrogen injection into the natural gas network.

Figure 1 shows some results from an optimal scenario for GB in 2050. The potential that hydrogen offers can be seen, as electrolysers are operated variably throughout the day, consuming excess renewable energy when it is available but ramping down at times of high electricity demand. Hydrogen storage is used on both an intra-day and inter-seasonal basis to minimise renewable curtailment and help to keep energy demands and supplies in balance at all times.

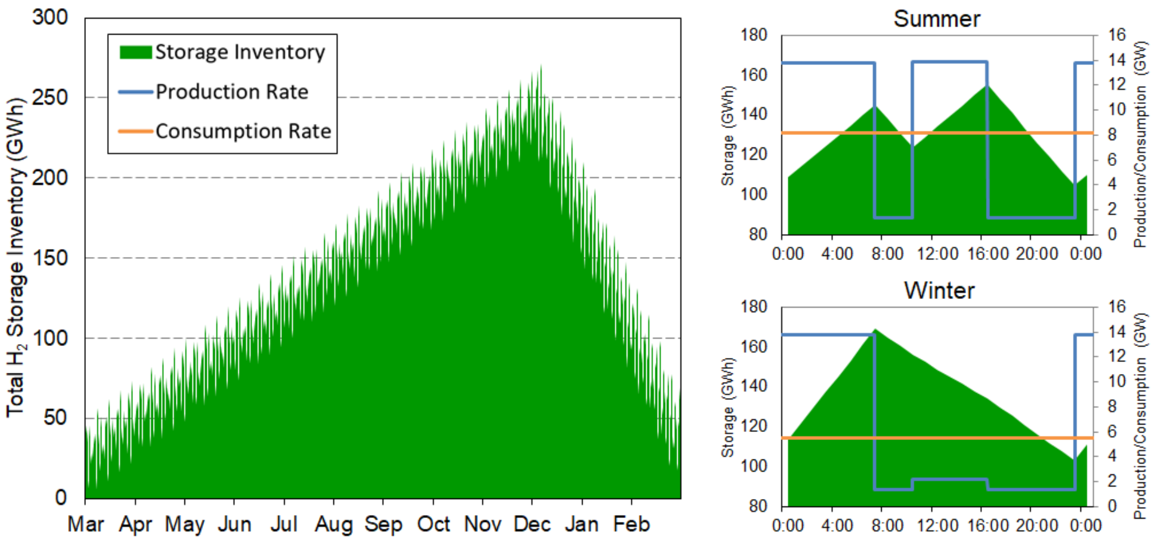

Figure 1: Hydrogen storage inventory over one year (left) and rates of hydrogen production and consumption along with hydrogen storage inventory for typical summer and winter days (right) for an optimal scenario for GB in 2050.