Spatiotemporal disaggregation of GB scenarios depicting increased wind capacity and electrified heat demand in dwellings

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Overview

The UK Future Energy Scenarios, developed by National Grid [1], the network operator in Great Britain, describe four future pathways for the energy system where wind capacity increases up to 20 GW onshore and 35 GW. Changes also occur to electricity demand, where the number of domestic heat pumps increases to 10 million by 2035 in one scenario. Like most other analyses of future energy systems, modelling and analysis is carried out at a highly aggregated spatial (national) and temporal (annual) resolution. In reality, wind speeds that drive generation vary across space and time at fine resolutions. This means that generation will vary temporally, and this variability will be influenced by the spatial configuration of the wind fleet. Concurrently increasing the number of heat pumps will mean that temperature, which also varies over space and time, will drive electricity demand to a greater extent than experienced in the past and potentially change the shape of the electricity demand curve, altering the residual demand after wind supply has been taken into consideration. Therefore, to begin to understand the implications of increased variability on the energy system, it is necessary to analyse both demand for electricity and wind supply at a disaggregated resolution in both space and time, for each of the scenarios. This study presents a method for disaggregating National Grid scenarios to a 0.5° spatial and hourly temporal resolution, linking the subsequent simulation of both demand and supply to accurate homogeneous weather data.

Methods

A gridded approach is adopted, as the primary data driving both supply and demand, weather data from the NCEP CFSR climate reanalysis is available in this format. It was also necessary to develop harmonisation methods to adapt non gridded spatial data and disaggregate non spatial data, these are described.

In order to model the scenarios the wind capacities described by National Grid are redistributed to the model grid following a multi criteria analysis of suitable land for development. The analysis takes into account the quality of the wind resource, planning restrictions and access to infrastructure. The resultant spatial configurations of wind capacity are shown in Figure 1. Hourly wind generation from the redistributed output is simulated in each grid square, for each scenario, using manufacturer wind turbine curves and spatially homogeneous hindcasted wind speed data from a climate reanalysis (NCEP CFSR). The simulations include over 200 onshore grid squares and approximately 50 offshore grid squares. The use of realistic locations means that the simulated generation reflects the geographically diverse winds that will be harnessed by potential future wind fleets.

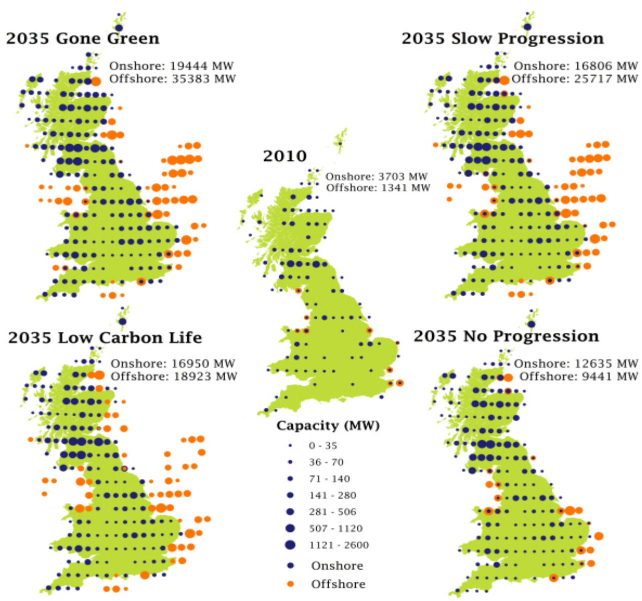

Figure 1: Spatial configuration of wind capacity in 2035 under each National Grid scenario

Demand for electricity is simulated using the Spatiotemporal Dynamic Energy Agents Model (SpDEAM, [2]). SpDEAM calculates electricity demand from all sectors. Non-heat demand is calculated top down; values from the National Grid scenarios are proportionally allocated to end uses, spatially disaggregated using census based population and building stock databases and temporally redistributed using activity profiles that vary diurnally, weekly, seasonally and annually. Heat demand in domestic buildings is calculated from the bottom up, based on a GB building and heat technology stock model which incorporates the effects of heat gain from other end uses, people and solar gains. Activity profiles are used in a similar manner to non heat demands. Population and building stock projections are used alongside National Grid's scenarios.

Results

Results are presented which demonstrate that high offshore capacity factors have a significant impact on the projected generation of different wind capacity scenarios. Analysis of extreme events under each scenario, facilitated by the disaggregated approach, demonstrate that there will be periods of up to 50 hours where supply exceeds demand for the most ambitious wind scenarios and all but one scenario will require solutions to store or transfer excess wind generation (Figure 2). High demand events are shown to occur at similar levels in all scenarios.

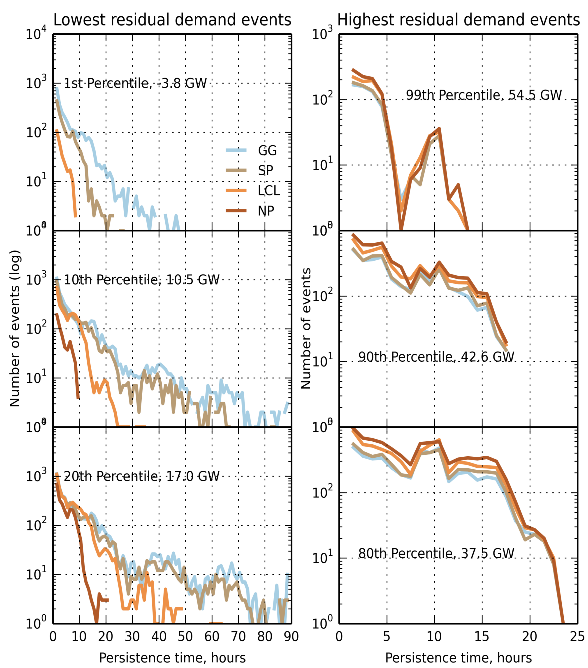

Figure 2: Extreme residual demand events for each scenario over 25 years.

Conclusions

The benefit of the disaggregated approach is shown in the ability to separate onshore and offshore capacity factors, demonstrating that they are much higher offshore, which should be taken into account in estimates of future wind generation. This analysis of extreme events demonstrates that there will be significant excess production under all but the lowest wind capacity scenario and indicated that this excess production will start from approximately 2020. Despite the addition of significant number of heat pumps the Gone Green scenario exhibits fewer high demand events towards the end of the scenarios than other scenarios which include very few heat pump

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References

[1] National Grid. UK future energy scenarios: UK gas and electricity transmission, 2014. *http://www2.nationalgrid.com/uk/industry-information/ future-of-energy/future-energy-scenarios*

[2] Sharp, E. Spataru, C. Barrett, M. and Dodds, P. Incorporating building specific heat loss and associated energy demand into electricity demand models for Great Britain. *Building Simulation and Optimisation* UCL, London, 2014.