Research Summary: A weather regime characterisation of Irish wind generation and electricity demand in winters 2009-11

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Unusually persistent cold spells were experienced in Ireland during the winters of 2009-10 and 2010-11, and electricity demand hit an as yet unsurpassed maximum during the coldest of these spells, over Christmas 2010. At the same time, wind speeds were lower than average, and thus wind generation output was relatively low. Considering the rapid increase in wind energy generation in Ireland, if this situation were to occur frequently and was not likely to be well predicted in advance, it could require large amounts of fossil fuel-based plant to be available.

In Ireland, the electricity demand specifically caused by weather factors is relatively small as most heating systems are oil or gas-based rather than electric. Weather does add a notable layer of variability over-and-above more regular and predictable components such as day of the week and time of year, however, and it is particularly critical to understand its variation during peak demand periods. Wind power is also, obviously, very weather-dependent and so it is useful to understand how weather-related demand and wind generation vary together with different weather patterns.

Weather on the surface of the earth is strongly influenced by conditions in the atmosphere far above. The daily pressure patterns at very high levels (upwards of 5km) can be categorised into distinct regimes, or patterns, using statistical techniques. Examining the types of regime occurring over an area stretching from Greenland to Greece and the Azores to Lapland can offer broad indications of what the typical weather in northern Europe will be like. Additional insight can be gained by looking in more detail at a phenomenon known as ‘blocking’. This situation occurs when an area of high pressure settles or moves only very slowly. The location of the ‘blocked’ areas affects the weather at the surface as the air

flows are diverted, moving warmer or colder air around the blocked area, and reducing the air flow immediately within it.

The study presented looks firstly at the relationship between concurrent winter wind generation and weather-related electricity demand (WRD) in Ireland from 1986-2015, and in particular, the wind power capacity factors at the highest levels of demand. A regression model has been developed to extract the weather component from the total daily electricity demand using temperature and cloudiness as the key weather parameters. A hypothetical 30-year wind power capacity factor time series has been derived using a model of local wind speeds, and for consistency, assumes that the current wind farms in Ireland have been in place since 1986.

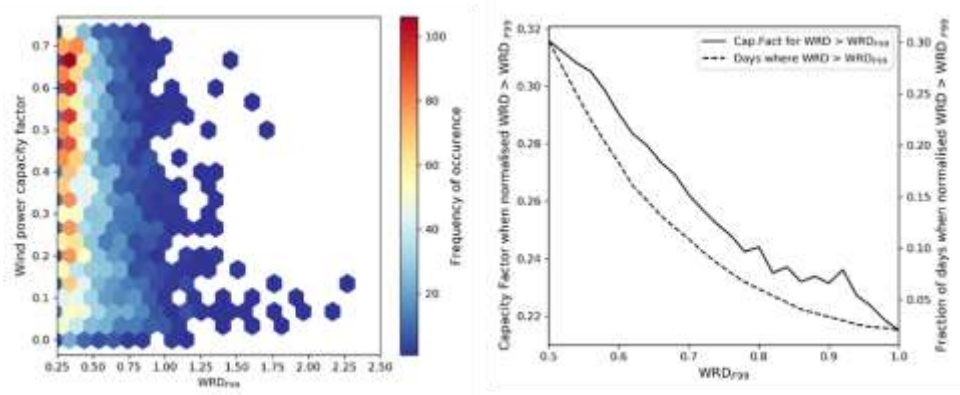

Figure 1. (Left) Bivariate histogram of winter weather-related demand and wind capacity factor 1986-2015. (Right) Mean capacity factor for increasing levels of weather-related demand: The x axis gives WRD_{F99}, the WRD as a fraction of the 99th percentile value. Solid line = mean capacity factor for all days with demand greater than WRD_{F99}. Dashed line = fraction of hours where demand is greater than WRD_{F99}.

It is shown that the winters of 2009-10 and 2010-11 had unusually low average wind capacity factors and high mean WRD – along with some particularly high daily outliers. There was some indication of a trend of decreasing wind capacity factors with increasing WRD, but this is strongly influenced by a small number of extreme results from the two aforementioned winters.

The work then examines the frequencies of weather regimes occurring in winters since the 1940s, and the associated wind generation and WRD during each of the winters. The days are categorised into one of four regimes, and the average wind capacity factor and WRD for the occurrence of each type of pattern is calculated. The regime representing a normal westerly flow of air from the Atlantic over the British Isles with no blocking ('zonal') is associated with the highest wind capacity factor and the lowest WRD. A regime with blocking over the mid-Atlantic gives the lowest wind capacity factors but average WRD, whilst a block over Greenland is related to high WRD and the second lowest average wind capacity factor.

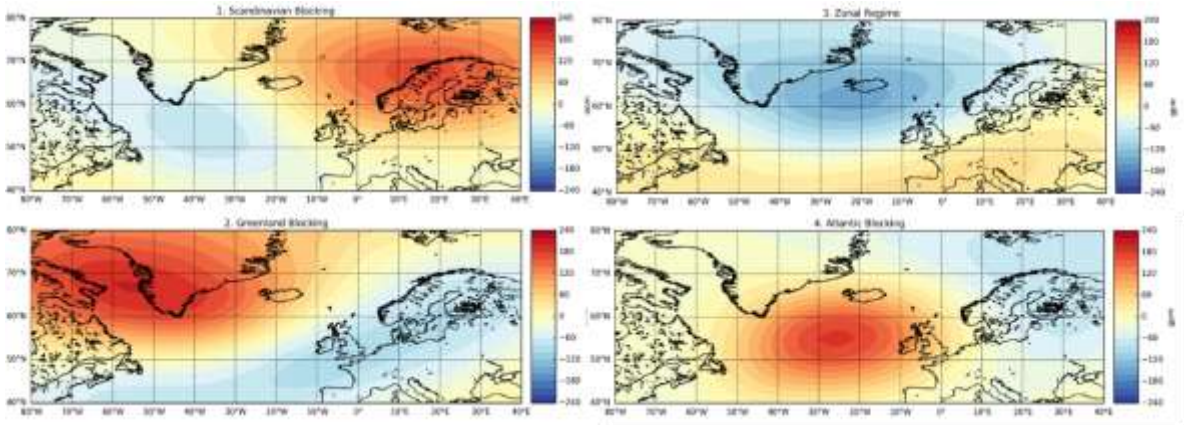

Figure 2 Weather regimes identified on the basis of mean geopotential height anomalies for each pattern (cluster 'centroids'). Occurrence frequencies: 1. 26.7%, 2. 18.7%, 3. 32.0%, 4. 22.6%.

Table 1. Winter wind capacity factors and weather-related demands for each identified weather regime 1986-2014

Weather regime	Mean wind capacity factor	Standard deviation of wind capacity factor as % of mean[1]	Mean WRD as % of long-term mean	Standard deviation of WRD as % of mean**Error! Bookmark not defined.**
1. Scandinavian Blocking (ScB)	0.35	57%	98%	40%
2. Greenland Blocking (GrB)	0.31	61%	127%	50%
3. Zonal (Zo)	0.47	38%	89%	30%
4. Atlantic Blocking (AtlB)	0.28	71%	100%	37%

Finally, a detailed analysis of blocking locations for the two extreme winters compared with other cold, calm winters shows that there was an unusually high prevalence of blocking in the mid-Atlantic and to the west of Greenland in the 2010-11 winter, not evident in other cold, calm years. This emphasises that the particular conditions of the 2010-11 winter might not recur very often, assuming climate change does not alter the frequency of such events.

Key findings

- The research found that the relationship between wind generation and the weather-related component of demand in Ireland shows some evidence of wind capacity factors decreasing as demand increases.
- The association between wind generation/demand and atmospheric patterns was found to be strongest when looking at monthly average conditions, and certain patterns are strongly associated with higher or lower average capacity factors and weather-related demand levels.
- The particular atmospheric conditions experienced during the winter of 2010-11 were found to be particularly unusual compared to other years since the 1940s.
- Examining monthly atmospheric patterns – for example, as part of a seasonal forecast - could help to identify the potential for more extreme conditions to occur in that season, which could allow the system operators to plan ahead with other types of generation.

(1) A weather regime characterisation of Irish wind generation and electricity demand in winters 2009-11. Available from: *https://www.researchgate.net/publication/324453172_A_weather_regime_characterisation_of_Irish_wind_generation_and_electricity_demand_in_winters_2009-11* [accessed Aug 09 2018].

[1] In effect, this is coefficient of variation