Government
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How well do we understand the impacts of weather conditions on the UK's renewable wind and solar energy supplies?
Meeting note from roundtable chaired by Stephen Belcher, Chief Scientific Adviser, Met Office
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Any term marked with an asterisk is explained in the glossary at the bottom of this document.

Key points

- Weather conditions can determine both energy supply and demand. For example, a summer wind drought* due to persistent high pressure will both reduce energy supply and drive-up energy demand for cooling public and private spaces.
- Extreme weather conditions can affect renewable energy operations as well as production.
- The future resilience of the UK's renewable energy sector to compound low wind and low solar events needs further consideration, especially if compound events persist over consecutive years.
- Traditional forecasting is more effective for predicting electricity generation from wind, as similar wind conditions are often geographically widespread. However, conditions impacting solar power generation, such as cloud cover or aerosols, can be much more localised. Localised modelling may be more effective for predicting solar power generation than traditional forecasting.
- As renewable generation capacity increases through expanding renewable infrastructure, the need for storage decreases. However, there is always the need to maintain some storage capacity.
- Predictions of future weather conditions can be improved by using historical data spanning multiple years as input for models, but it is necessary to also consider decadal variability and longer-term climate change.
- Additional mechanisms for meteorological and energy generation collaborations among experts would be beneficial, as would more broadly publicising existing mechanisms.
- Data producers and data receivers need to communicate effectively to make sure datasets are homogenised for easy exchange and use.

1. Vulnerabilities in the current energy sector

1.1 Weather conditions which can limit the supply of wind and solar

- The large scale of wind droughts (which often coincide with heat in summer and cold weather in winter) means power deficits in Europe and the UK are likely to coincide, preventing the use of interconnectors to balance the demand to the UK grid.
- Renewable infrastructure is often concentrated in smaller areas, increasing the risk of localised disruption to infrastructure, such as from storm damage to cables bringing energy ashore, which could potentially reduce generation capacity.
- Many risks to renewable infrastructure are projected to grow, including coastal storm damage from rising sea levels, overheating from rising temperatures and flooding from intense rainfall.
- There is a risk to maintenance provision posed by extreme weather conditions, given the need to ensure human safety.

1.2 Wind

- A Met Office/National Infrastructure Commission study of Europe has found that grid vulnerability from wind droughts are projected to decrease due to milder winter temperatures – resulting in reduced demand for heating (for a future low-carbon energy system and compared to the same system in the present climate).
- However, grid vulnerability and power demand are projected to increase in summer due to both a greater probability of wind droughts and increased use of air conditioning.
- Individual weather events such as a high-pressure blocking event*, which can disrupt wind generation, will often last between one to two weeks.
- Inter-annual seasonal variations are a cause for concern and uncertainty. A Poisson distribution* works well for counting low wind days in a season but is much less effective for counting low wind days in extreme seasons, such as during strong El Niño years (ENSO).
- Models are confident of an extension of the storm track* and jet stream* into Europe in winter, which would reduce the likelihood of wind droughts during the winter months.
- Summer months are likely to become less windy as the jet stream is expected to shift poleward, making wind droughts during summer more of a concern.
- Recent summers have been stormier than usual due to a southward migration of the jet stream. This is a product of decadal variability termed the North Atlantic Oscillation* (NAO) and summers are predicted to become less stormy and therefore less windy in the near future. However, exactly how this decadal variability will impact future weather patterns is not fully understood.

1.3 Solar

- As the UK begins to experience seasonal variation and warmer summers, there is an increased need to develop durability in the solar power system.
- Hot summers can overheat solar panels, affecting their performance. The efficiency of silicon solar panels drops when an air temperature of 23°C is exceeded. There is potentially a need to look for alternatives to silicon constructed solar panels.
- Clouds and air quality both impact solar panel performance. Solar cells operate best in the 400 to 800 nanometre wavelength range.
- As well as increased cloudiness, the presence of aerosols (water vapour, dust, air pollution) in the atmosphere can reduce how much solar radiation reaches the Earth's surface.
- Synoptic storms* produce both cloud and wind. There could be a trade-off, in which regions with lower solar potential may have higher wind potential.
- Forecasting errors are often related to high solar PV* production and cloud, and the rate in which clouds appear and burn off.
- There is a lack of climate projection and research around radiation, and how radiation may affect PV solar panels.
- In winter, solar power generation drops to an eighth of what the generation on a typical June day would be.
- Spreading solar plants, rather than having a single point of connection, can help to minimise impacts of weather, increasing grid resilience to extreme conditions.

1.4 Compound events

- Compound events occur when there is concurrent low wind and low solar generational capacity.
- For combined solar and wind power output there can be as much as 2-3 GW of error over the UK on a given day.
- So far, there has not been an incidence of both high solar and high wind generation forecasting errors on the same day in the UK.
- In June 2023, a stable anticyclone caused low wind speeds over much of the UK, but there were also cloudy conditions across the South-east due to moisture from North Sea – illustrating the potential for a moderate compound event.
- During compound events, low power generation from wind is easier to predict, but forecasting uncertainty around localised cloudiness makes impacts on solar generation capacity less certain.

2. Building resilience and identifying evidence gaps

2.1 Maintaining grid stability in adverse weather conditions

- Solar has very fast ramp rates* compared to wind, but these rates can be offset by aggregating solar power generation and bringing them to one single point of connection.
- Storage of energy can help to manage grid stability, particularly in adverse weather, where wind and solar production may not be at their optimum.
- Building a third more wind and solar energy generation capacity than required for demand will help to reduce energy storage needs and optimise delivery costs of electricity.
- Analysing historic data sets over 37 years, there were several weeks with little to no sun or wind. To deliver our energy demand particularly through these conditions, tens of terawatts of storage would be needed to satisfy demand.
- Energy generated from solar, and wind can be stored as green hydrogen, and both are a cheaper alternative to using nuclear power to create green hydrogen. Electricity power generation from nuclear currently costs roughly the same as green hydrogen storage.
- Active consumers* can play an important role in managing grid demand during periods of low power generation through demand response or energy efficiency schemes.

2.2 Modelling and data

- Long-term historic datasets provide good temporal resolution, but do not factor in future climate change. Future analyses on UK wind and solar resilience including models should account for climate change-induced variability.
- There is a need for weather data collected over longer periods to be applied to modelling and forecasting to ensure accurate probability distribution of weather patterns.
- There is a risk that current climate projection models underestimate decadal variability in weather data.

2.3 Future wind and solar infrastructure developments

- Historical data sets are used when designing new windfarms, but they are now a less reliable indicator of future weather patterns due to climate change.
- The current lifetime of wind farms is 20-25 years, but there is a potential to extend it to 40 years. Therefore, government and industry should ensure wind turbines are resilient to more extreme weather conditions driven by climate change.
- The lifetime of a solar farm is generally 40 years, but existing operations could be extended by repowering existing sites.

- Solar farms need to consider exceptional weather events; a hailstorm in Australia damaged 20,000 panels. Currently, much of the interest in building solar farm resilience to extreme weather events is coming from the insurance sector. There is a need for research communities, industry and governments to contribute.
- Increasing frequency/severity of extreme wind conditions will impact a wind turbine's ability to generate power. Turbines have operational envelopes for wind conditions; (e.g. speed, turbulence, intensity) outside of these design conditions, power production will be reduced or stopped. Predicted increases in UK temperature are less likely to cause turbine shutdown but may reduce production.
- Modern megawatt scale turbines tend to feature high wind speed ride-through*mechanisms which prevent a sudden shut-down at higher wind speeds, instead reducing generation gradually. These mechanisms can be retrofitted to some existing wind farms but there are costs associated and not all turbines are suitable candidates.
- Modelling can be a more effective method to predict weather patterns compared to forecasting. There is more information on the operation and performance of plants, including performance in specific geographic locations, which can help to produce more reliable predictions.
- In future, there may be opportunities to use operational predictions rather than forecasting, which may improve accuracy of solar output models.

Participants

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Glossary

Active consumers: individuals or groups who consume, store or sell electricity generated on their premises.

Blocking events: areas of high pressure that remain almost stationary and distort the usual eastward progression of low-pressure systems.

Jet Stream: a narrow variable band of very strong, predominantly westerly air currents encircling the globe several miles above the Earth.

Low voltage ride-through: the capability of a wind turbine to stay connected to the grid, even when a severe fault occurs.

High wind speed ride-through: the capability of a wind turbine to provide power at higher winds rather than shutting down abruptly.

North Atlantic Oscillation (NAO): describes the relative changes in pressure between the Azores Islands (west of Portugal) and Iceland. Acting like a giant see-saw the NAO leads to changes in intensity and location of the North Atlantic jet stream. During positive NAO phases, the increased difference in pressure between the two regions results in a stronger Atlantic jet stream and a northward shift of the storm track. NAO can impact weather patterns in Europe over decadal timescales.

Poisson distribution: a statistical tool that helps to predict the probability of certain events happening when you know how often the event has occurred in the past. Provides a probability of a given number of events happening in a fixed interval of time.

Ramp rate: a measure of how quickly a power station can change its power output and supply to the grid as a portion of the power station's total power generation capacity.

Repowering: retrofitting and modernising existing power plants and installations.

Solar photovoltaics (solar PV): the process of converting light (photons) to electricity (voltage).

Storm track: a course followed by cyclones or storm systems as they move across land and sea.

Synoptic storms: a significant weather disturbance or storm system that affects a large area and is influenced by synoptic-scale atmospheric patterns.

Wind droughts: the lack of wind which often occurs at times of large-scale high pressure.