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Climate Services for Clean Energy

Converting climate forecast data to energy variables and understanding weather drivers

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4th December 2020

with thanks to: David Brayshaw, Paula Gonzalez, Andrew Charlton-Perez, David Livings, Phil Coker, Dan Drew, Dirk Cannon, Len Shaffrey, Hazel Thornton.

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Presentation Outline

- Motivation
- Conversion from weather to energy
- Examples of available datasets
- Some common modelling challenges
- Example uses of these datasets

Motivation

Why do I need all this weather data?

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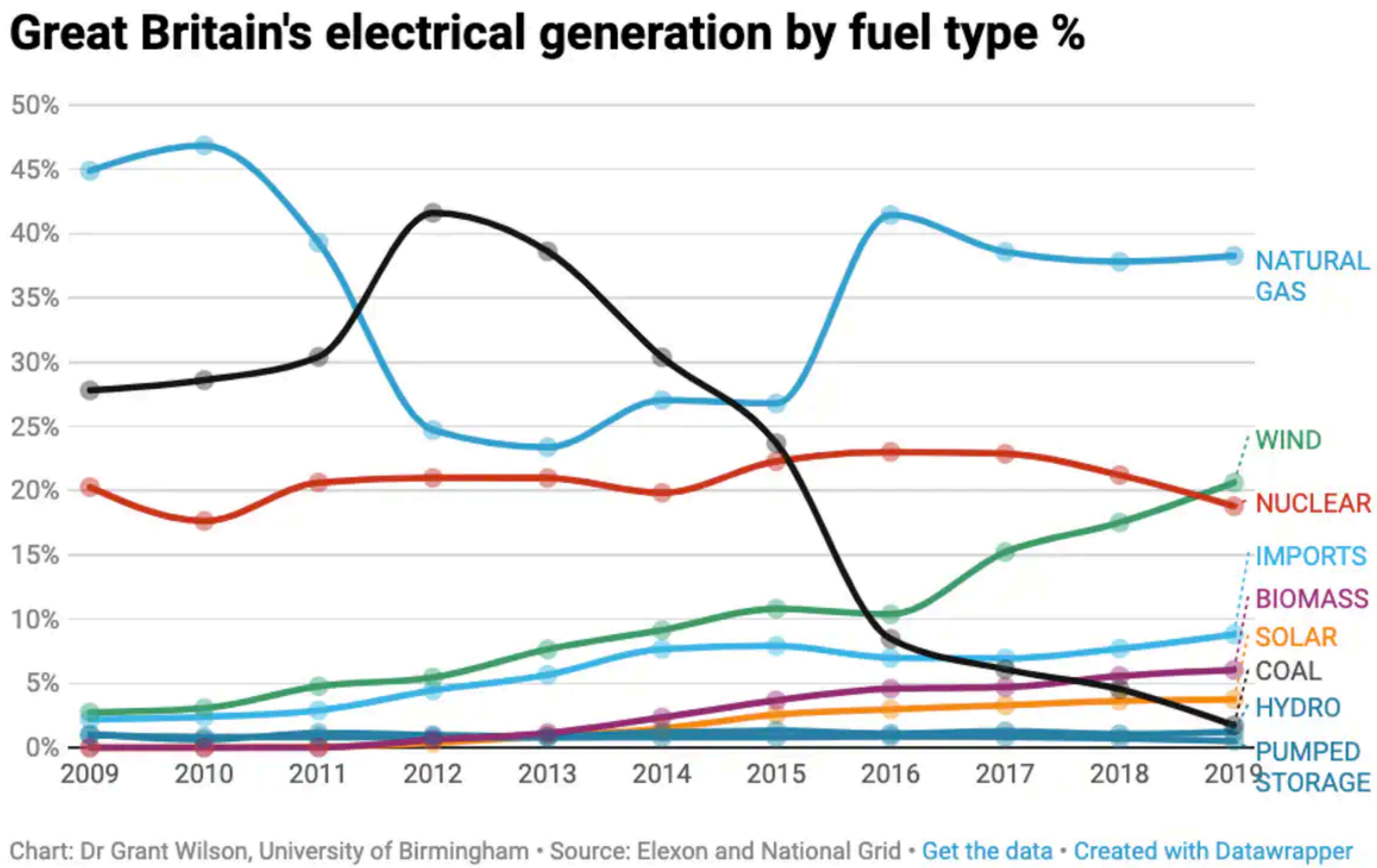
Why do we need weather and climate data?

- In order to meet government targets power systems are becoming increasingly weather-dependent
- This weather-dependence results in increases power system variability on numerous timescales from seconds-decades
- Energy systems are rapidly changing to meet climate mitigation targets, so metered data contains large trends, and past years data are less useful.
- Year to year variations in weather can cause large differences in power system modelling results.



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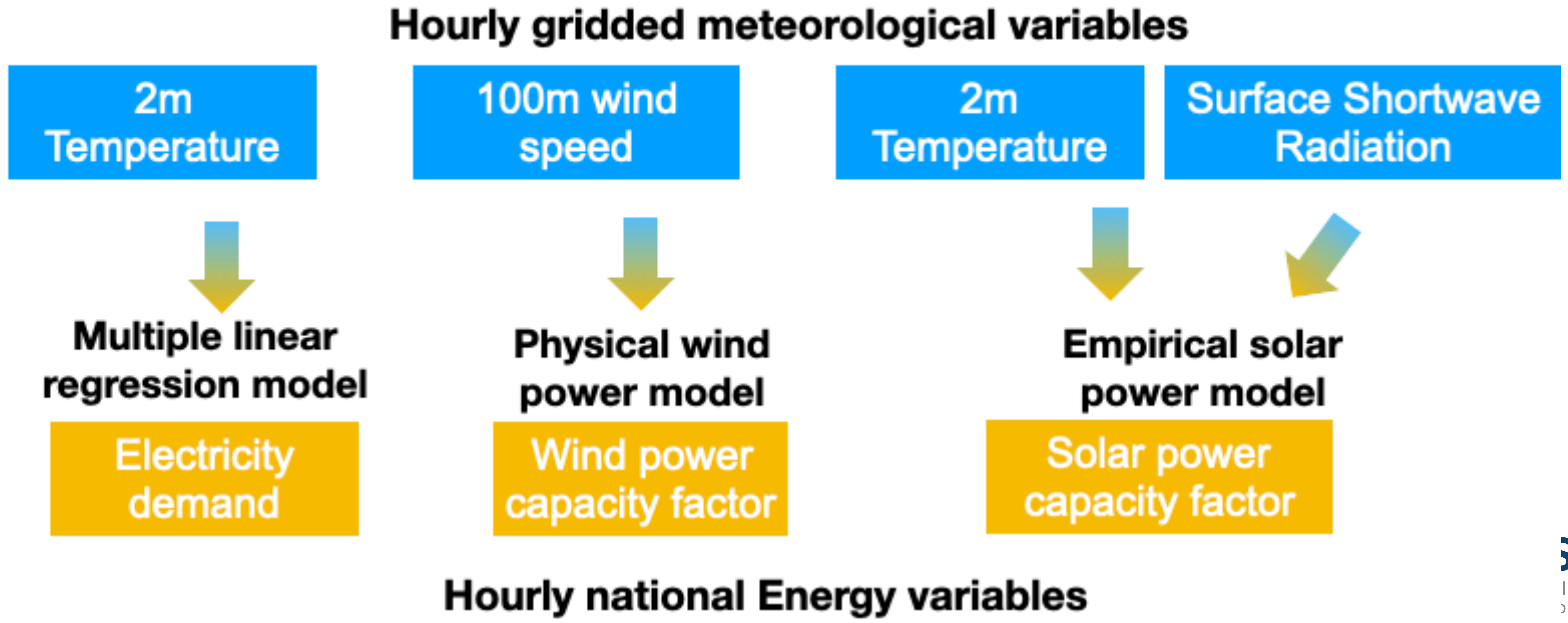
Conversion to energy models

- Gridded weather and climate data can be converted into energy variables using statistical or physical models.
- Generally the power system setup is fixed (e.g. 2020/2050 levels of demand/wind/solar) and many years of weather are passed through models.



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Conversions to weather

How do we do this?

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Demand modelling

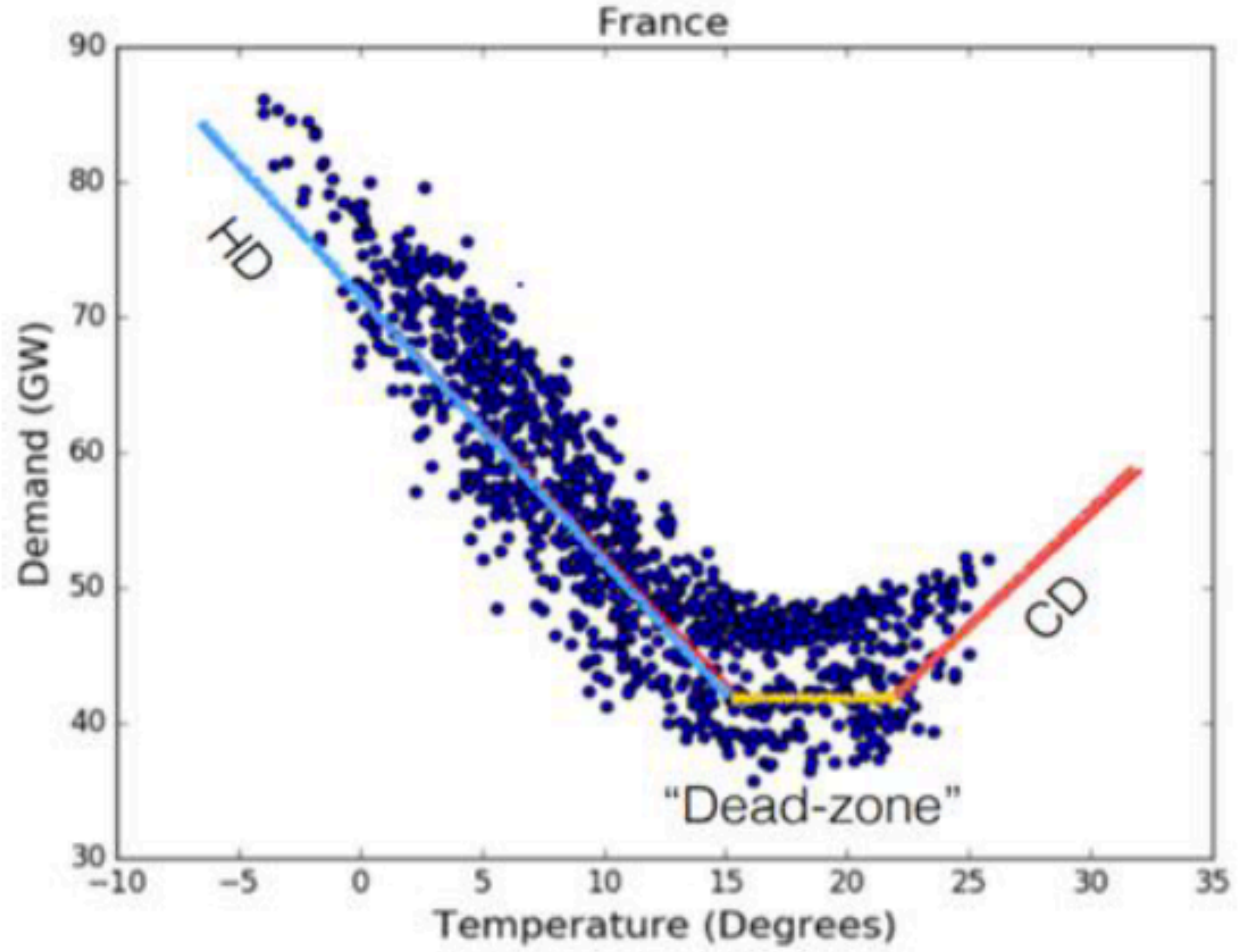
- Demand over Europe is predominantly dependent on near surface temperatures (other factors may include near-surface wind speeds, cloud cover etc).
- Heating Degree Days (HD) and Cooling Degree Days (CD) are a common metric for measuring temperature sensitivity
- There are both weather-dependent influences and human-induced factors (e.g. long-term trends, day of the week).
- Demand models include both of these factors and generally use a statistical technique (e.g. regression).

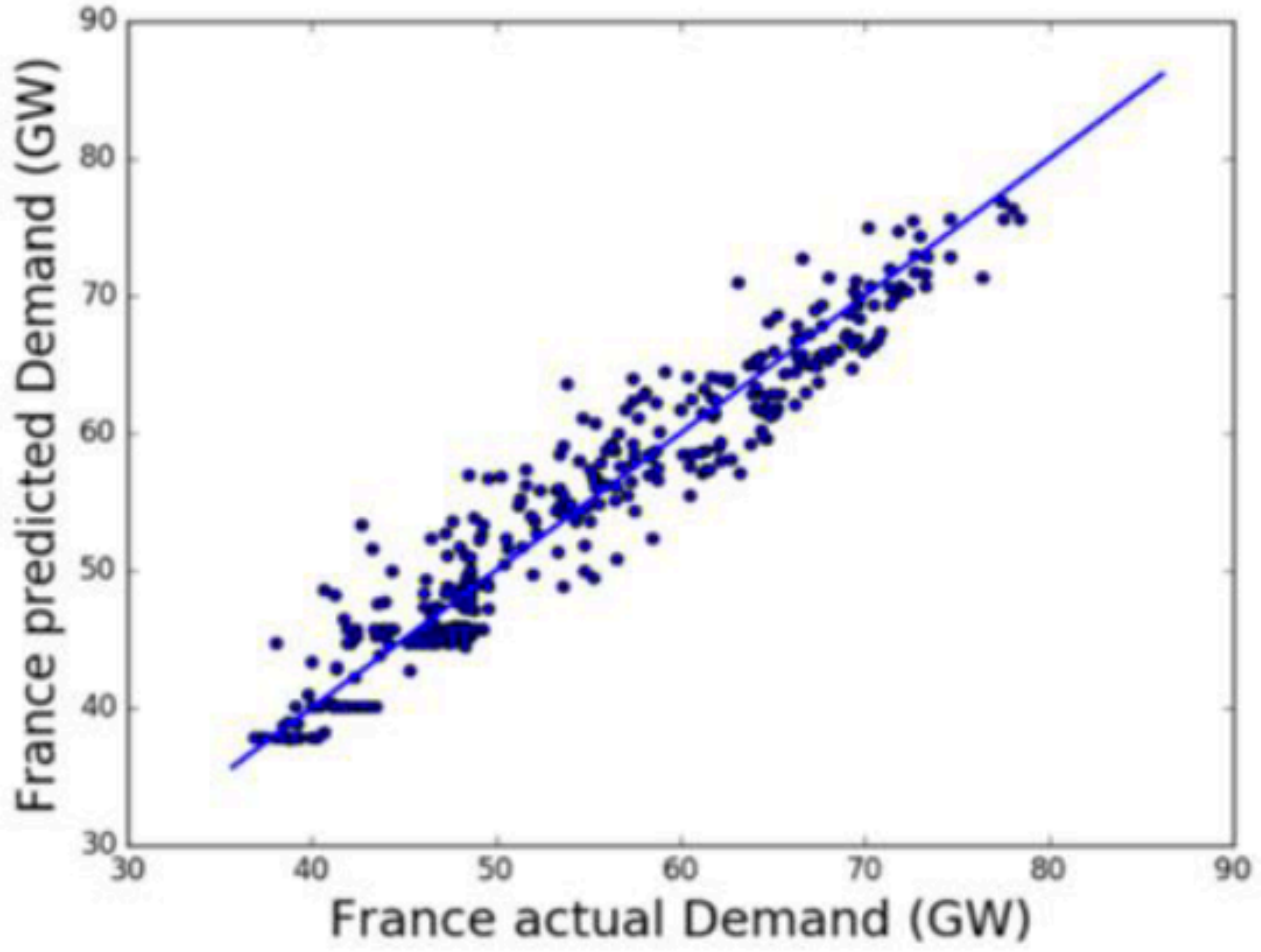
Weather dependent terms

$$Demand(t) = \alpha_1 LTT(t) + \sum_{i=2}^{7} \alpha_i Weekday(t) + \sum_{i=8}^{9} \alpha_i Weekend(t) + \boxed{HD(t) + CD(t)}$$

$$\text{If } T(t) \leq 15 : HD[t] = 15.5 - T(t)$$
$$\text{If } T > 15.5 : HD[t] = 0$$

$$\text{If } T(t) \geq 22 : CD[t] = T(t) - 22$$
$$\text{If } T < 22 : CD[t] = 0$$



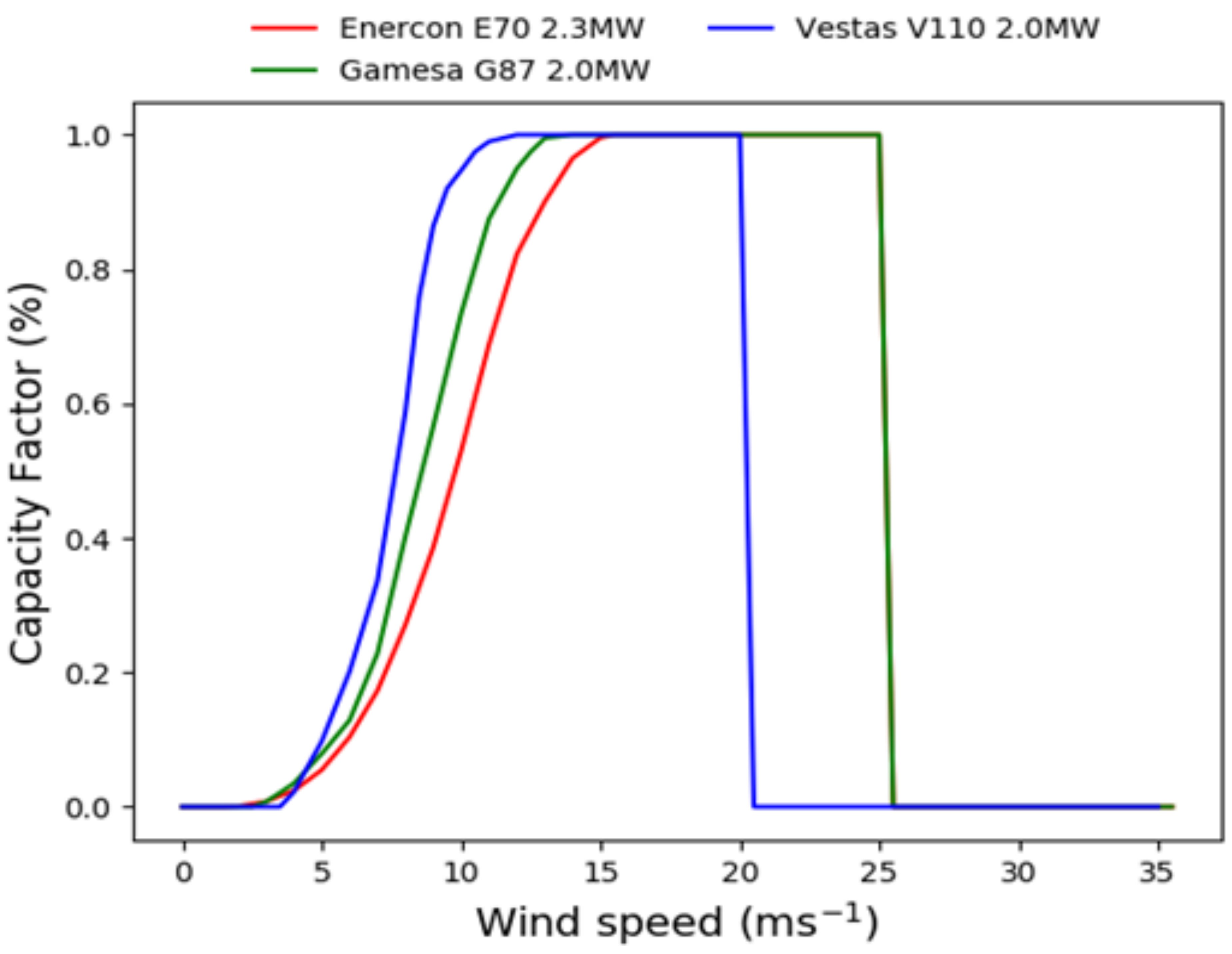


we can extract only the weather-dependent terms for some analysis of year-year variability

oomfield et al., (2020) for further details

Wind Power modelling

- Wind Power models are based on the non-linear relationship between wind speed and wind power.
- Gridded wind speeds are required at turbine hub-height (~100m)
- If the locations of wind turbines are known then the gridded wind power output can be calculated, or aggregated over larger regions (e.g. national level).



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See Bloomfield et al., (2020) for further details

Solar PV modeling

- Global Horizontal Irradiance is the main meteorological component required for a solar power model.
- Information about direct and diffuse components of solar radiation may be required, as well as local temperatures, solar zenith angles and operational characteristics of the chosen solar PV system
- Physical modelling techniques tend to need more information about local conditions than statistical or empirical solar modelling techniques.

relative efficiency factor

Irradiance

$$CF = \frac{Power}{Power_{STC}} = \eta_{rel}(G,T)\frac{G}{G_{STC}}$$

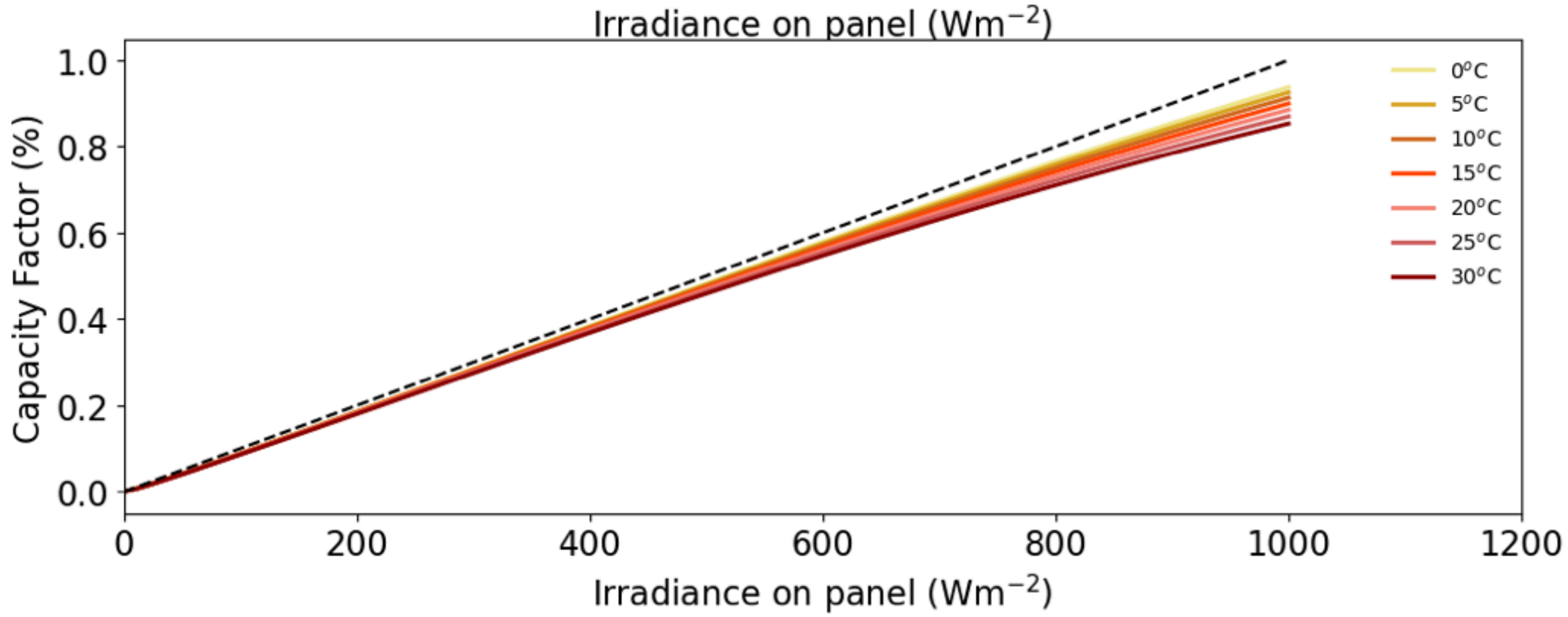
$$\eta_{rel}(G,T) = \eta_r[1 - \beta_r(T_c - T_r)]$$

efficiency at reference temp

decrease in efficiency per unit temp

cell temperature

reference temp



See Bloomfield et al., (2020) and Bett and Thornton (2016) for further details

Conversion to weather

Some common problems that are encountered

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Challenges in demand/wind/solar PV modelling

Demand

- Statistical models are dependent on the quality of the training data
- All countries have varying levels of weather-dependence, based on power system composition
- Contribution of human and weather factors means that unpacking the various components is complex

Wind Power

- Calibration of the underlying climate data is very important.
- Biases in the wind speed distribution can lead to large errors in wind power
- When looking at future climate simulations or S2S forecasts you are unlikely to have high resolution data
- Wind power generation can be impacted by factors “outside the physical model control” e.g. grid stability issues and the need for wind power curtailment

Solar Power

- There are only very poor records of where solar power generation is located
- A lot of solar/wind models based on the physics of individual panels not aggregated over areas

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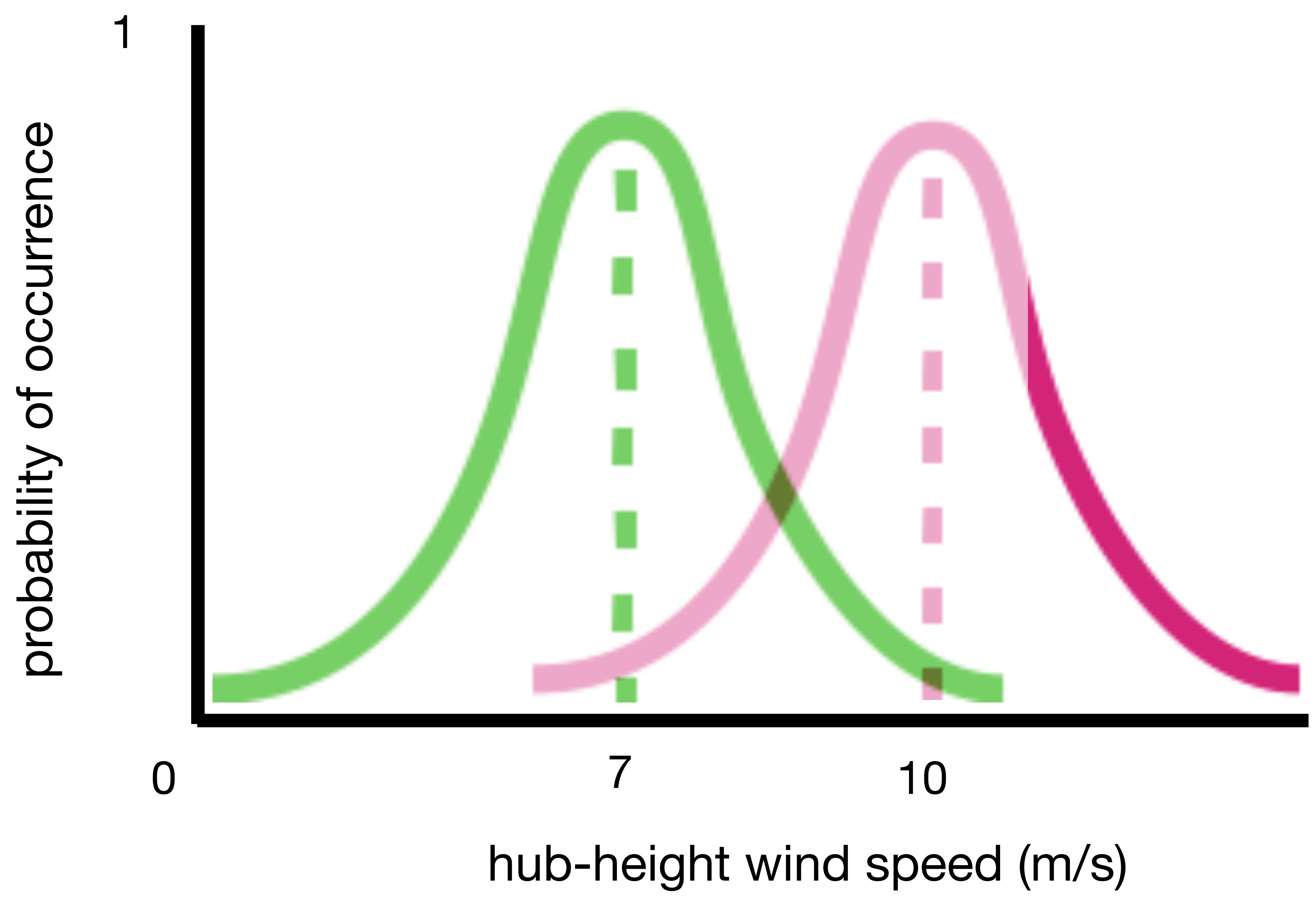
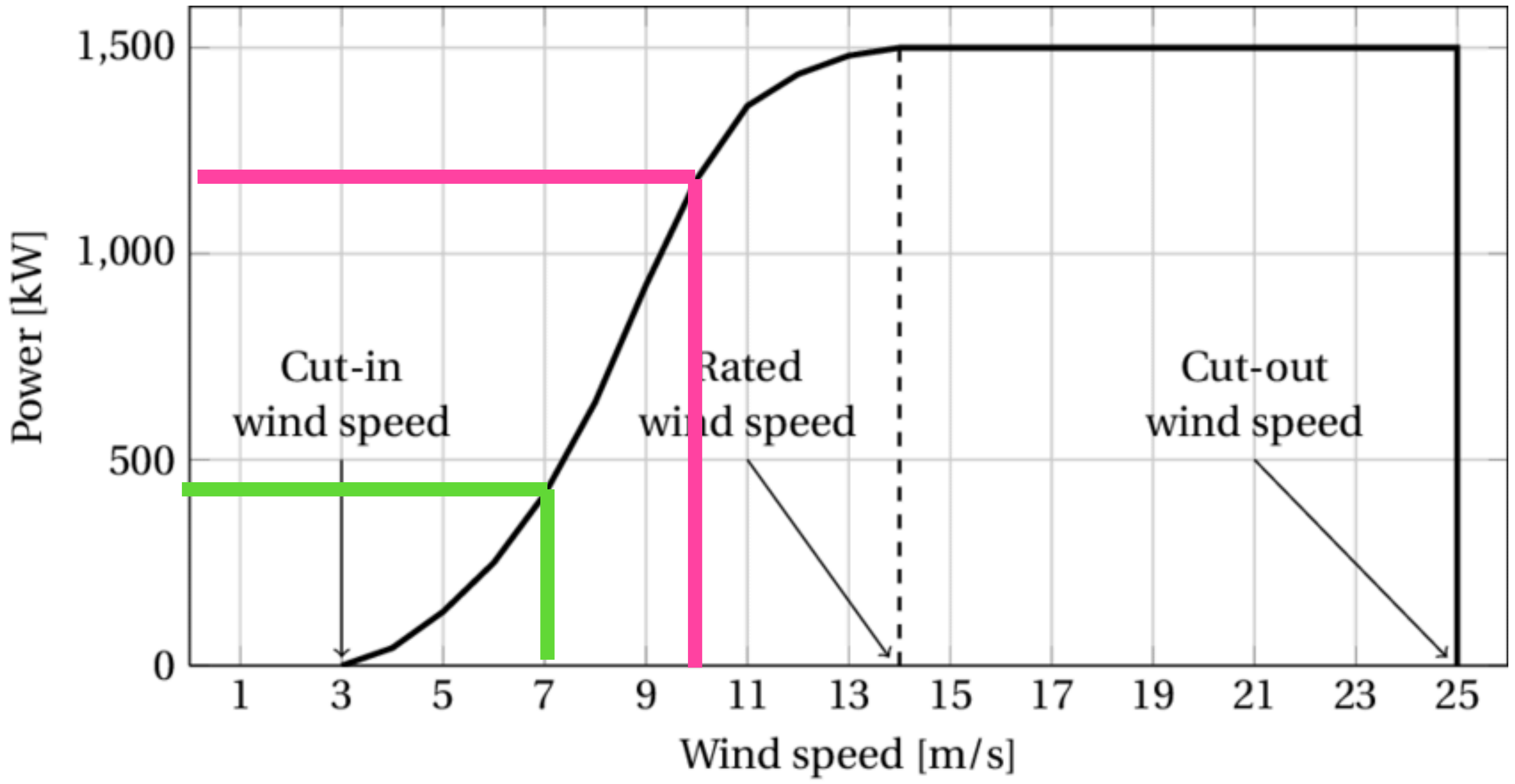
Wind Power modelling Challenges

- Calibration of the underlying climate data is very important.
- Biases in the wind speed distribution can lead to large errors in wind power output





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Wind Power modelling Challenges

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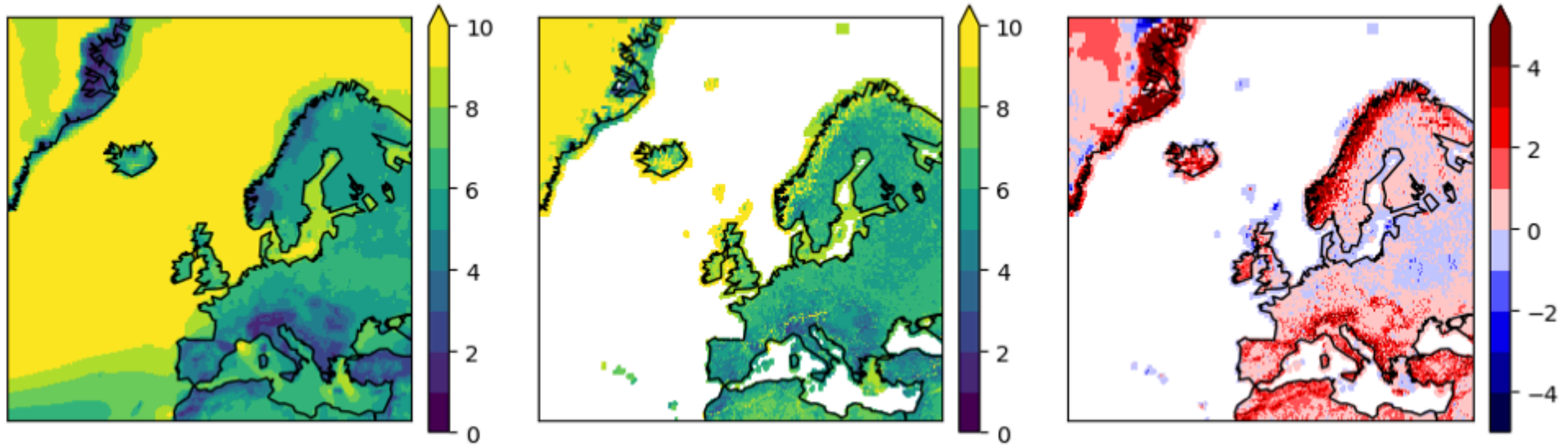

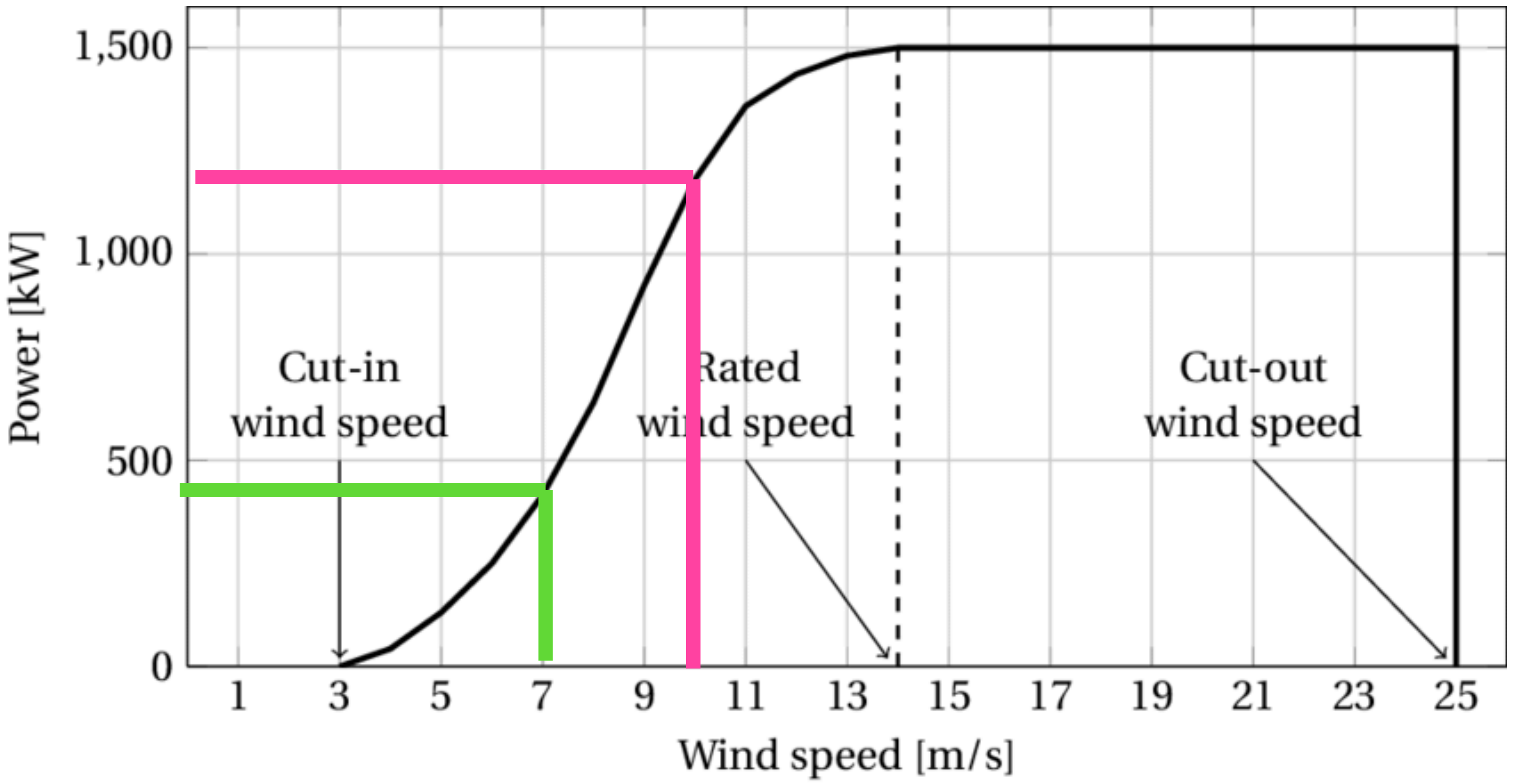

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See Bloomfield et al., (2020) for further details

Example datasets

current, future and S2S timescales

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Examples of available climate data

- A list of currently available datasets (all open access) is currently hosted on the opened forum.

openmod open energy modelling initiative

Freely available datasets of energy variables

Open data

matteodefelice 6 21d

Climate reanalysis datasets

(a version of this page is also available on github 1)
This page contains a list of all the **freely available** datasets of energy variables (electricity demand, wind/solar/hydro-power) reconstructions based on climate reanalysis or climate change projections.

The list is a work-in-progress, please reply to this post if you want to add a dataset or suggest a correction.

Historical period

Datasets based on "observed climate" (weather stations, satellite, reanalyses, etc.).

Electricity demand

Name	Unit	Period	Domain	Spat. res.	Time res.	climate model(s)	data license	updates	URL
C3S Operational	Energy, Power	1979-present	Europe	Country	daily	ERA5	ECMWF Copernicus License 1.0	yes	C3S C
ECEM	Energy, Power	1979-2016	Europe	Country	daily	ERA-INTERIM	ECMWF Copernicus License 1.0	no	http://e
JRC 2020	Power	1990-2015	Europe	Country	hourly	ERA5	CC BY 4.0	no	https:/ 98c0-4
UREAD Energy Reanalysis	Power	1980-2018	Europe	Country	Hourly	MERRA2	CC Attributions 4.0	no	http://c

https://forum.openmod-initiative.org/t/freely-available-datasets-of-energy-variables/2291

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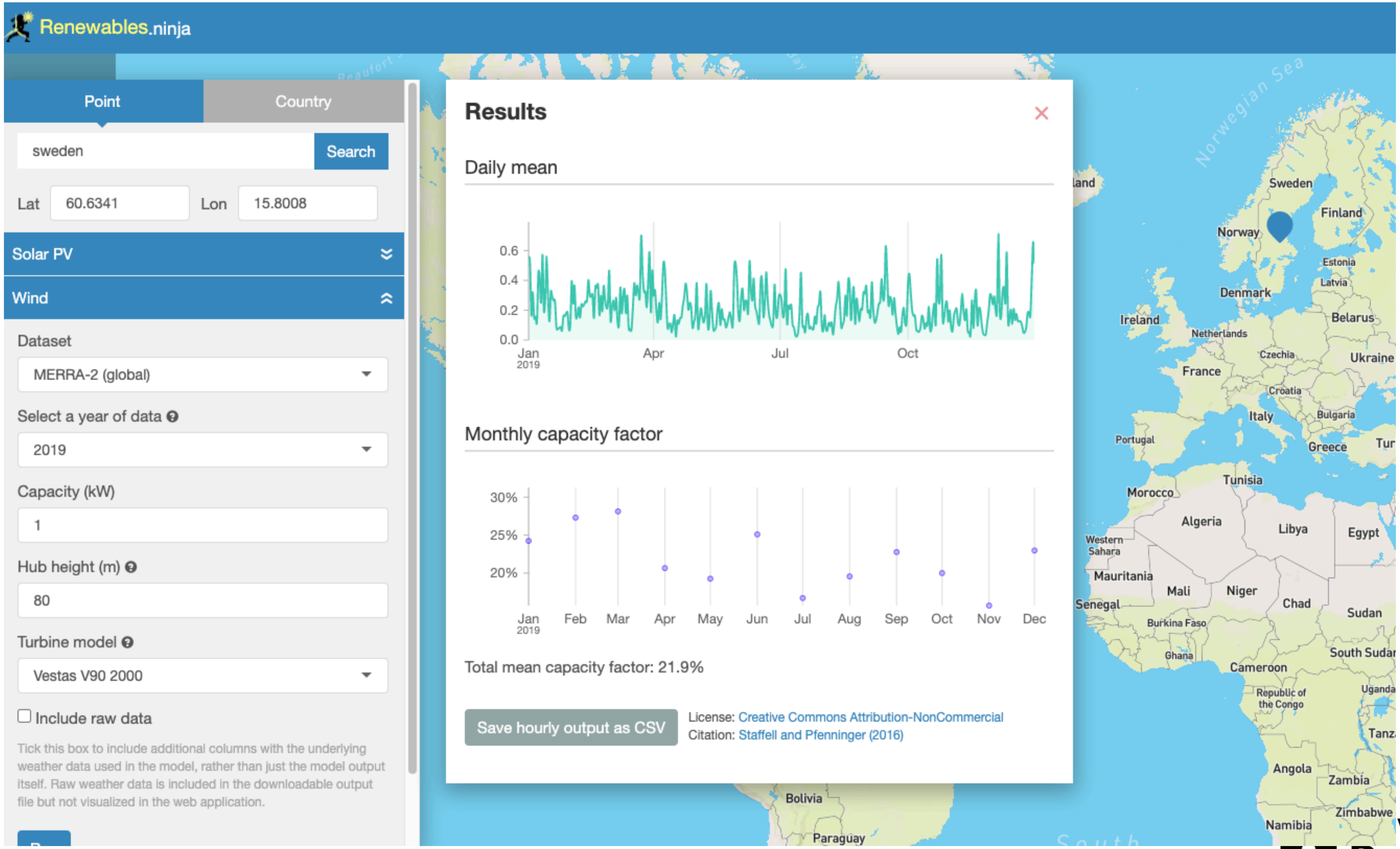
Renewables Ninja (wind and solar)

renewables.ninja



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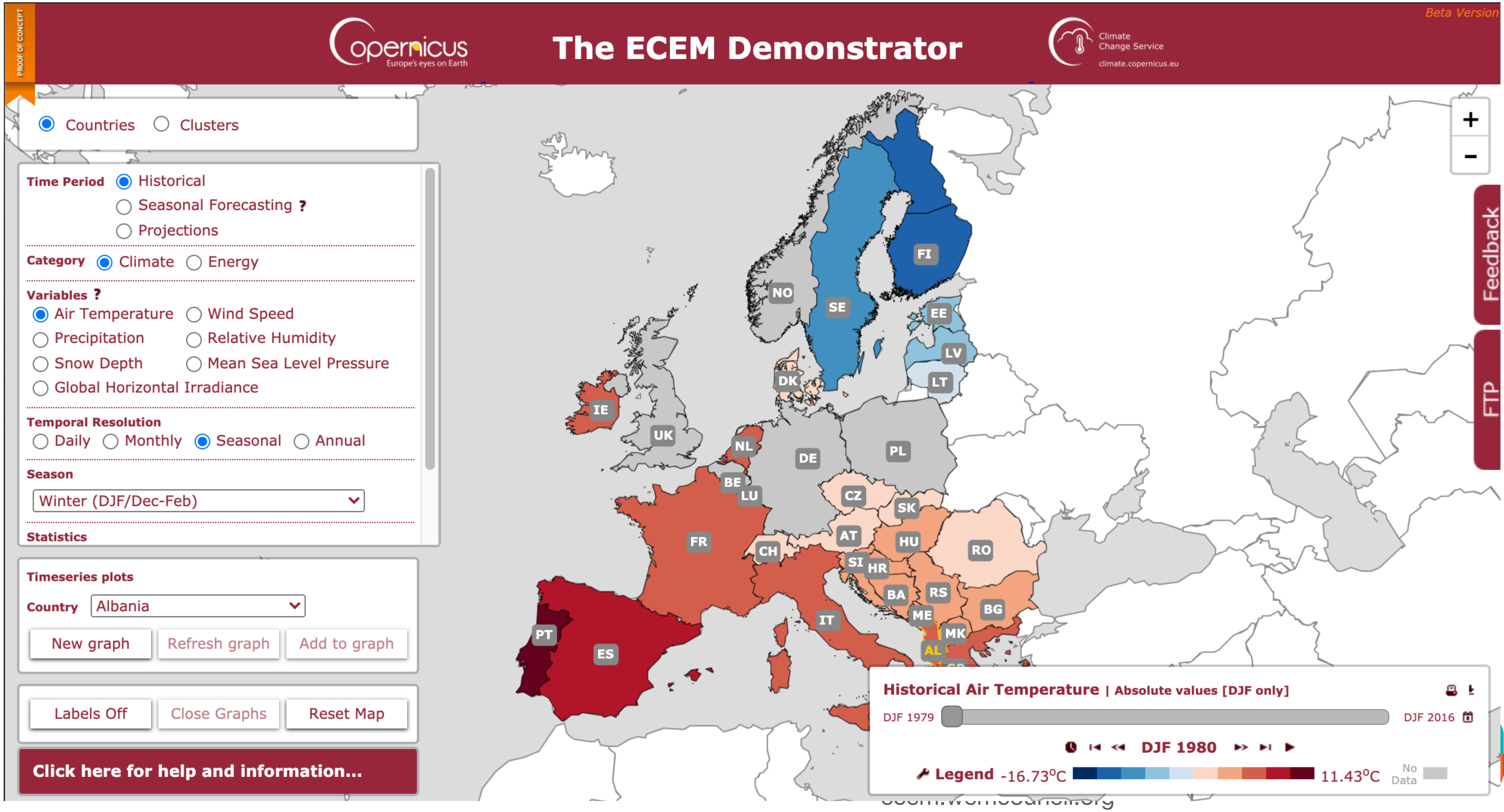
ecem.wemcouncil.org

ECEM: demand, wind solar

http://ecem.wemcouncil.org/



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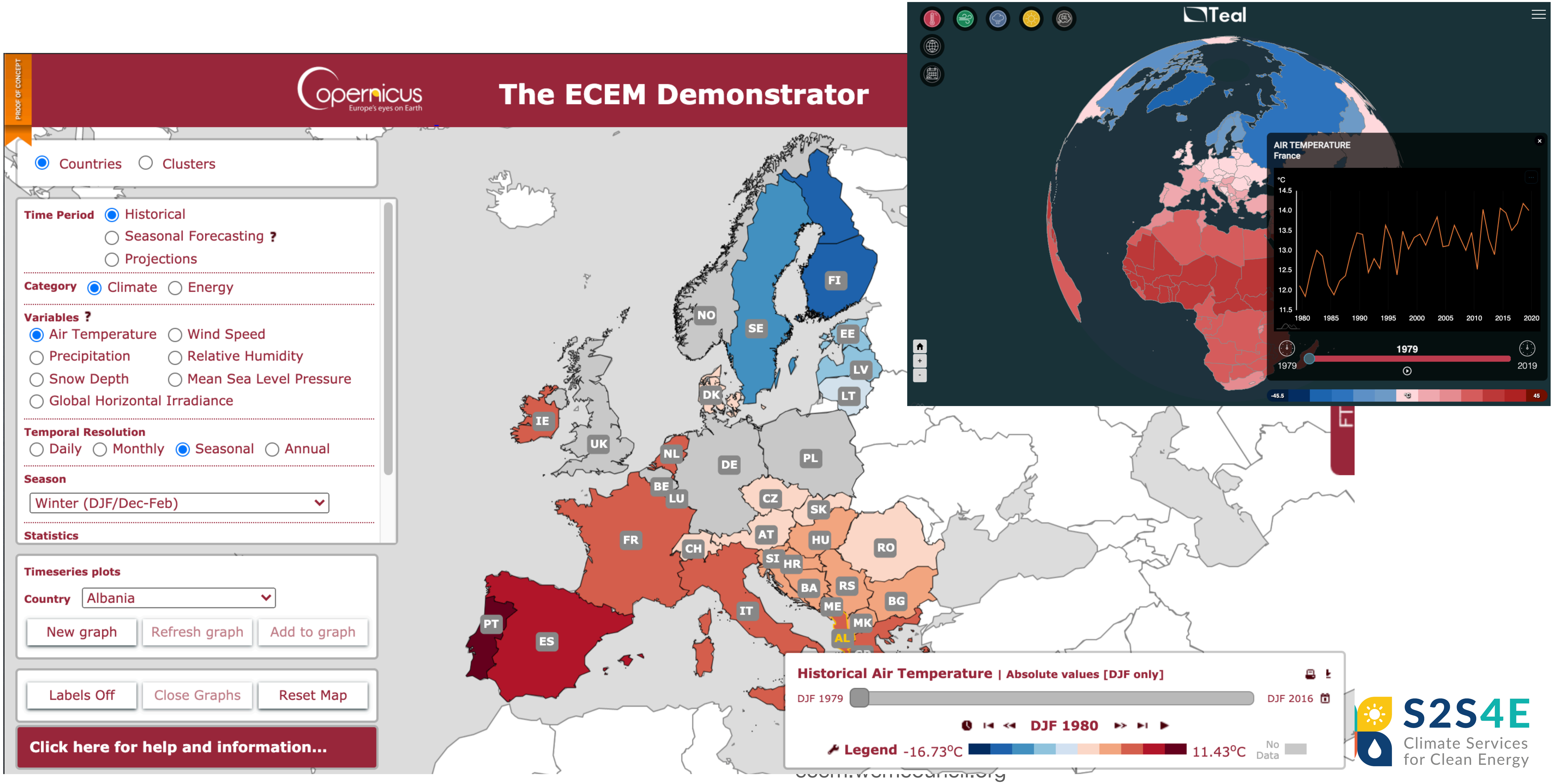
ECEM: demand, wind solar

tealtool.earth

ECEM education tool

http://ecem.wemcouncil.org/



UREAD: demand, wind, solar

https://research.reading.ac.uk/met-energy

University of Reading Research Data Archive

Home About Browse Statistics

Login

ERA5 derived time series of European country-aggregate electricity demand, wind power generation and solar power generation

Data Cite XML | Export

How to cite this Dataset

Copy

Bloomfield, Hannah, Brayshaw, David and Charlton-Perez, Andrew (2020): ERA5 derived time series of European country-aggregate electricity demand, wind power generation and solar power generation. University of Reading. Dataset. http://dx.doi.org/10.17864/1947.273

This is the latest version of this item.

Description

The ERA5 reanalysis data (1979-2018) has been used to calculate the three-hourly country aggregated wind and solar power generation for 28 European countries based on a distribution of wind and solar farms which is considered to be representative of the current situation (2017). In addition a corresponding daily time series of nationally aggregated electricity demand is provided. The datasets have been produced to investigate the inter-annual variability of the three weather-dependent power system components.

** This is an update on the previous version of the data where there were issues with the timestamps in the 3-hourly wind and solar power data. **

Resource Type:	Dataset
Creators:	Bloomfield, Hannah, Brayshaw, David and Charlton-Perez, Andrew
Rights-holders:	University of Reading

Files

Full Archive

ERA5_energy_update.zip

Related CentAUR publications

Characterizing the winter meteorological drivers of theEuropean electricity system using targeted circulationtypes

Meteorological drivers of European power system stress

Statistics

Loading...

Dataset

Bloomfield, Hannah, Brayshaw, David and Charlton-Perez, Andrew (2020): ERA5 derived time series of European country-aggregate electricity demand, wind power generation and solar power generation. University of Reading. Dataset. http://dx.doi.org/10.17864/1947.273

Bloomfield, Hannah, Brayshaw, David and Charlton-Perez, Andrew (2020): ERA5 derived time series of European country-aggregate electricity demand, wind power generation and solar power generation: hourly data from 1979-2019. University of Reading. Dataset. https://researchdata.reading.ac.uk/id/eprint/272

Bloomfield, Hannah, Brayshaw, David and Charlton-Perez, Andrew (2020): MERRA2 derived time series of European country-aggregate electricity demand, wind power generation and solar power generation. University of Reading. Dataset. http://dx.doi.org/10.17864/1947.239

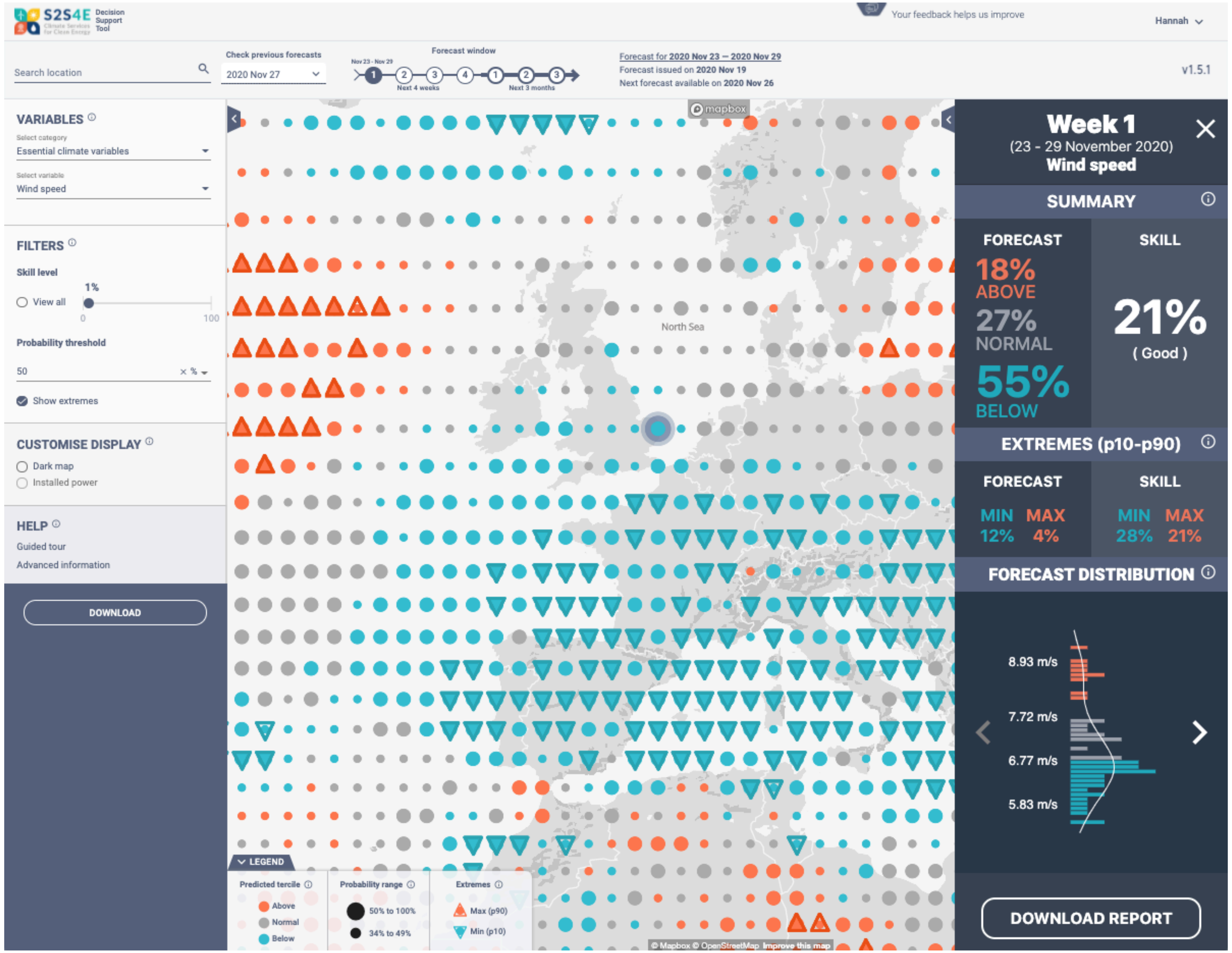
Gonzalez, Paula, Bloomfield, Hannah, Brayshaw, David and Charlton-Perez, Andrew (2020): Sub-seasonal forecasts of European electricity demand, wind power and solar power generation. University of Reading. Dataset. https://researchdata.reading.ac.uk/id/eprint/275

Drew, Daniel, Bloomfield, Hannah, Coker, Phil, Barlow, Janet and Brayshaw, David (2019): MERRA derived hourly time series of GB-aggregated wind power, solar power and demand. University of Reading. Dataset. http://dx.doi.org/10.17864/1947.191

- Reanalysis (MERRA2, ERA5)
- Forecasts (ECMWF, NCEP)

S2S4E: operational forecasts

https://s2s4e-dst.bsc.es/#/dashboard



https://research.reading.ac.uk/met-energy
for access to the hindcasts (~20 yrs)

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That’s a lot of data

What can I do with it all?

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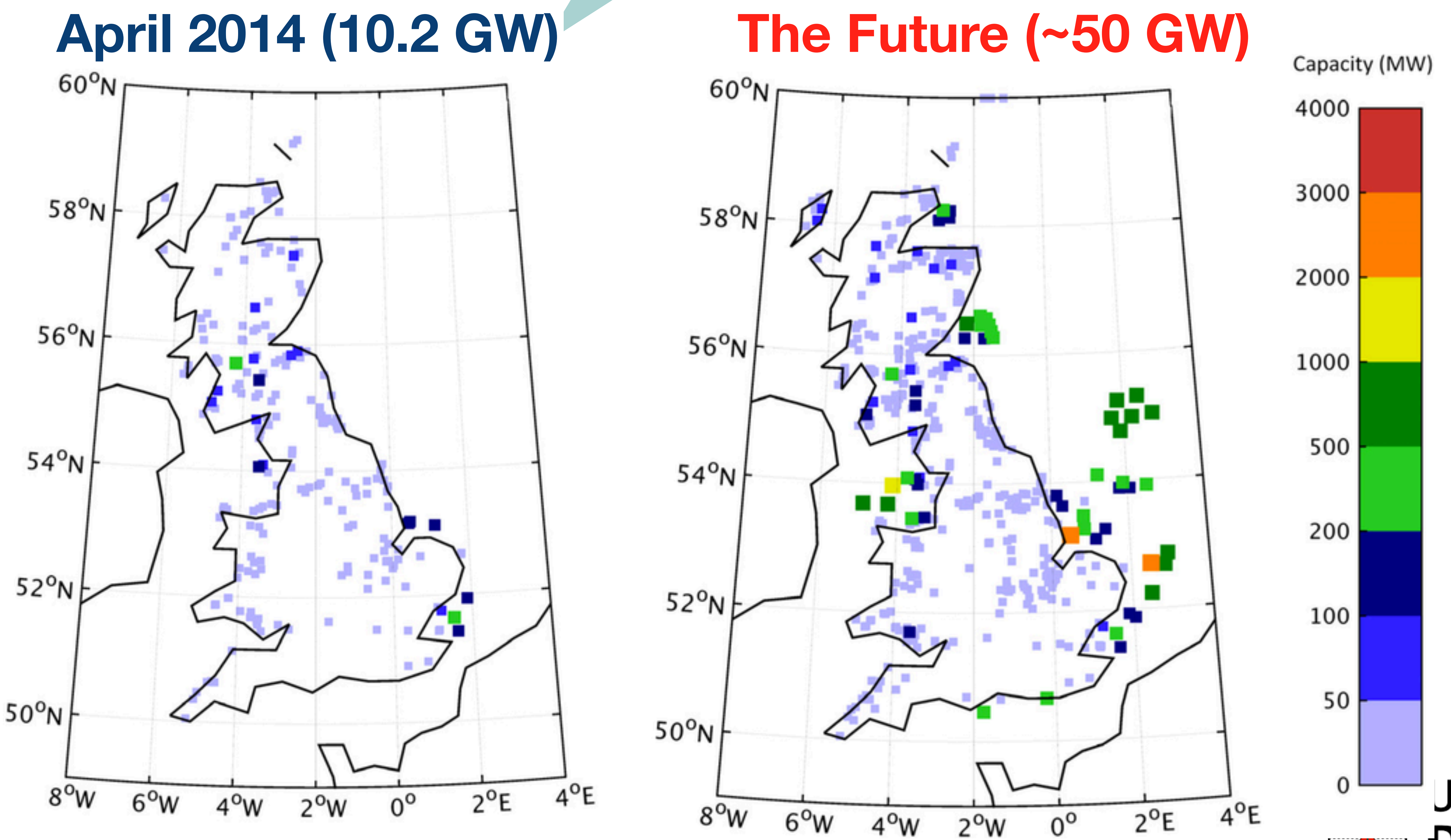
Understand Present/potential power system variability

How might GB baseload capacity reduce in a future power system with more wind power generation?

What weather conditions could cause the most power system stress?

What meteorological variables is my power system most sensitive to?



How might annual-mean CF change with increasing installed WP cap?

Are any of these characteristics predictable?

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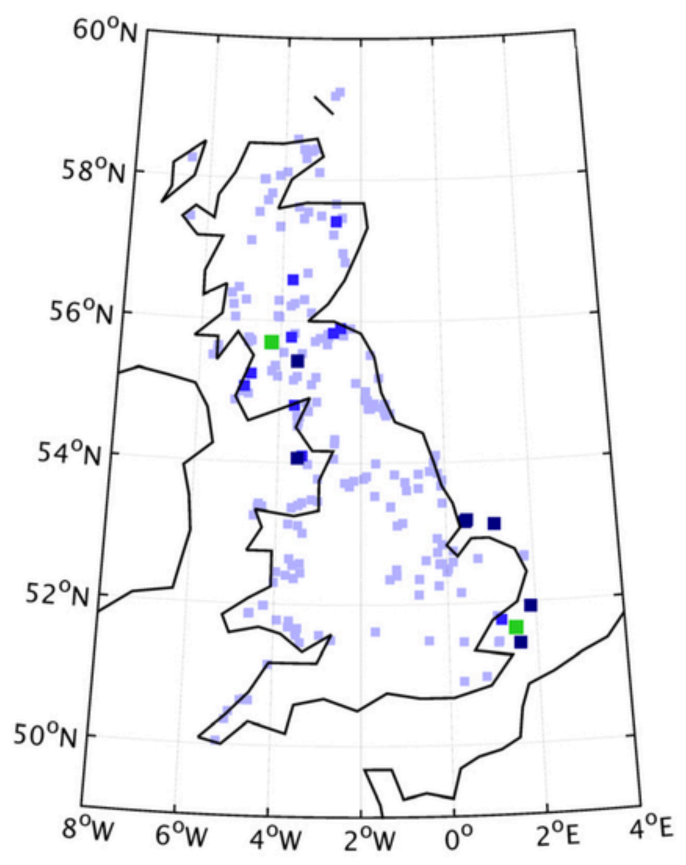
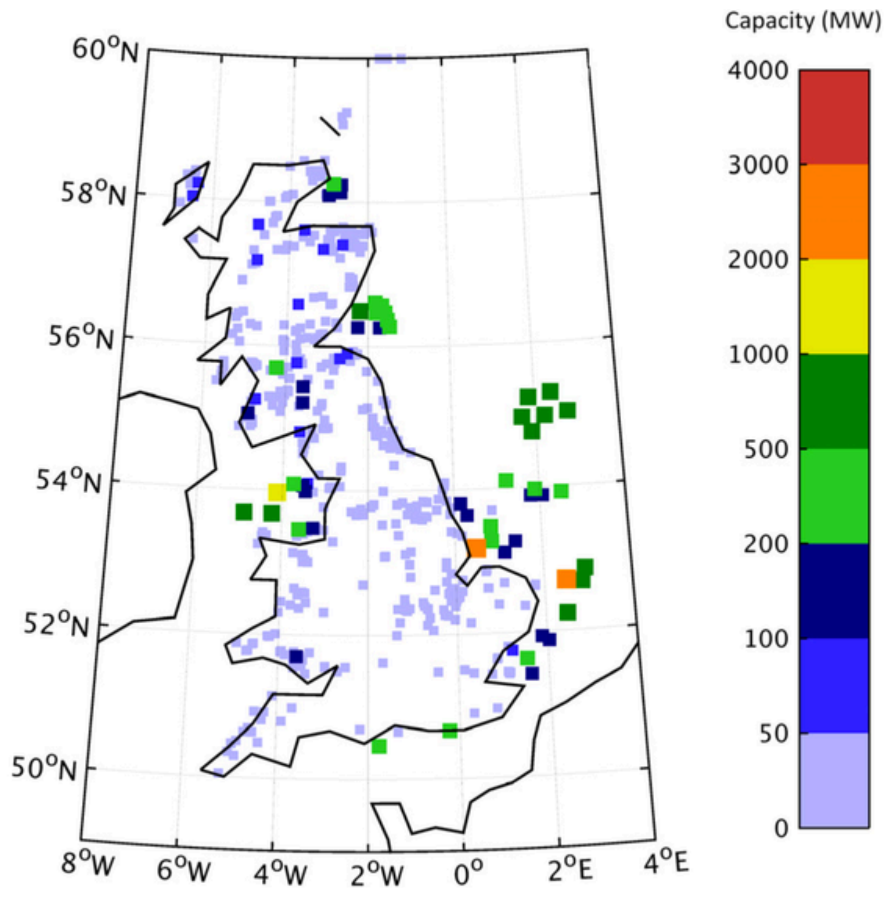
Understand Present/potential power system variability

How might annual-mean CF change with increasing installed WP cap?

April 2014 (10.2 GW)

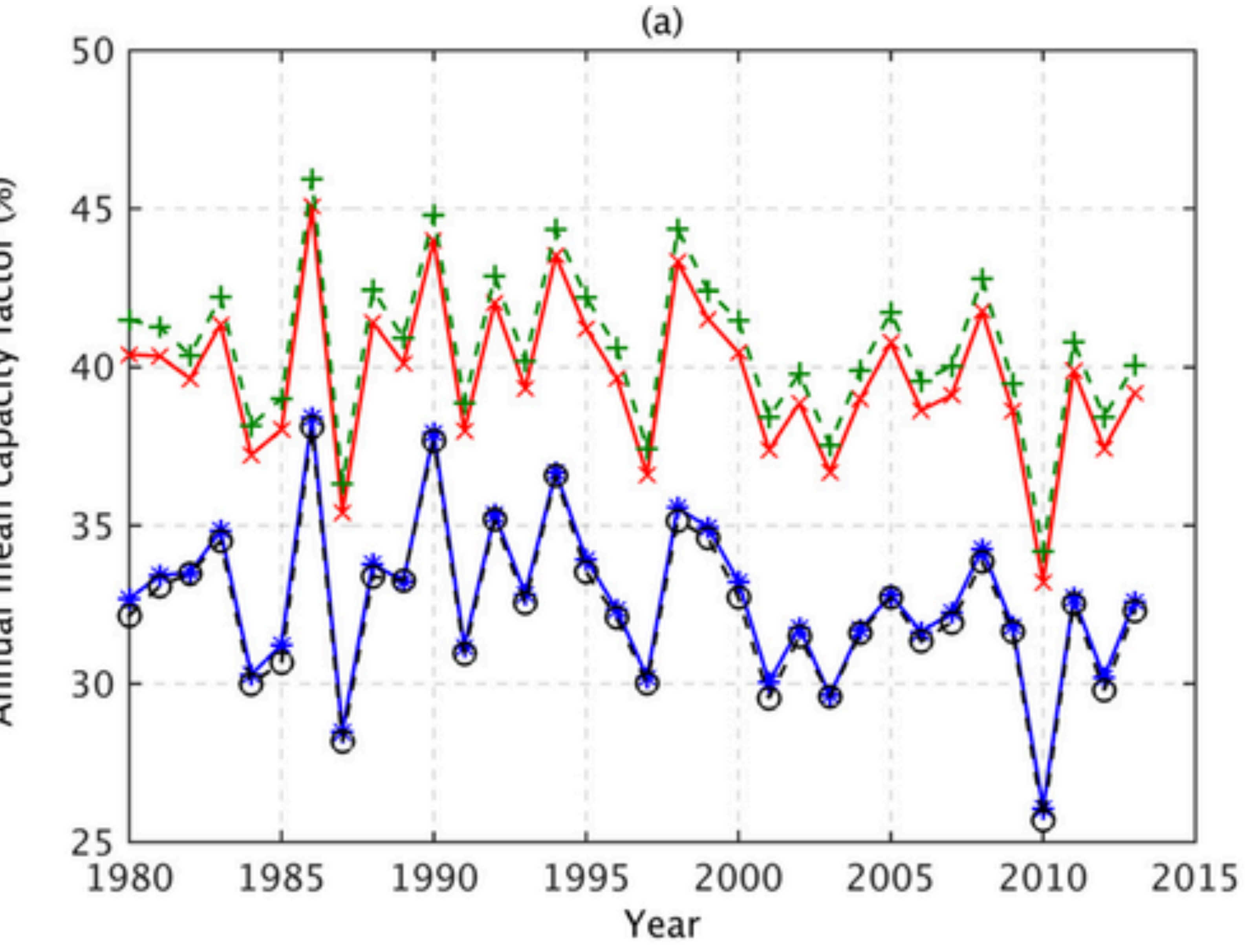


The Future (~50 GW)



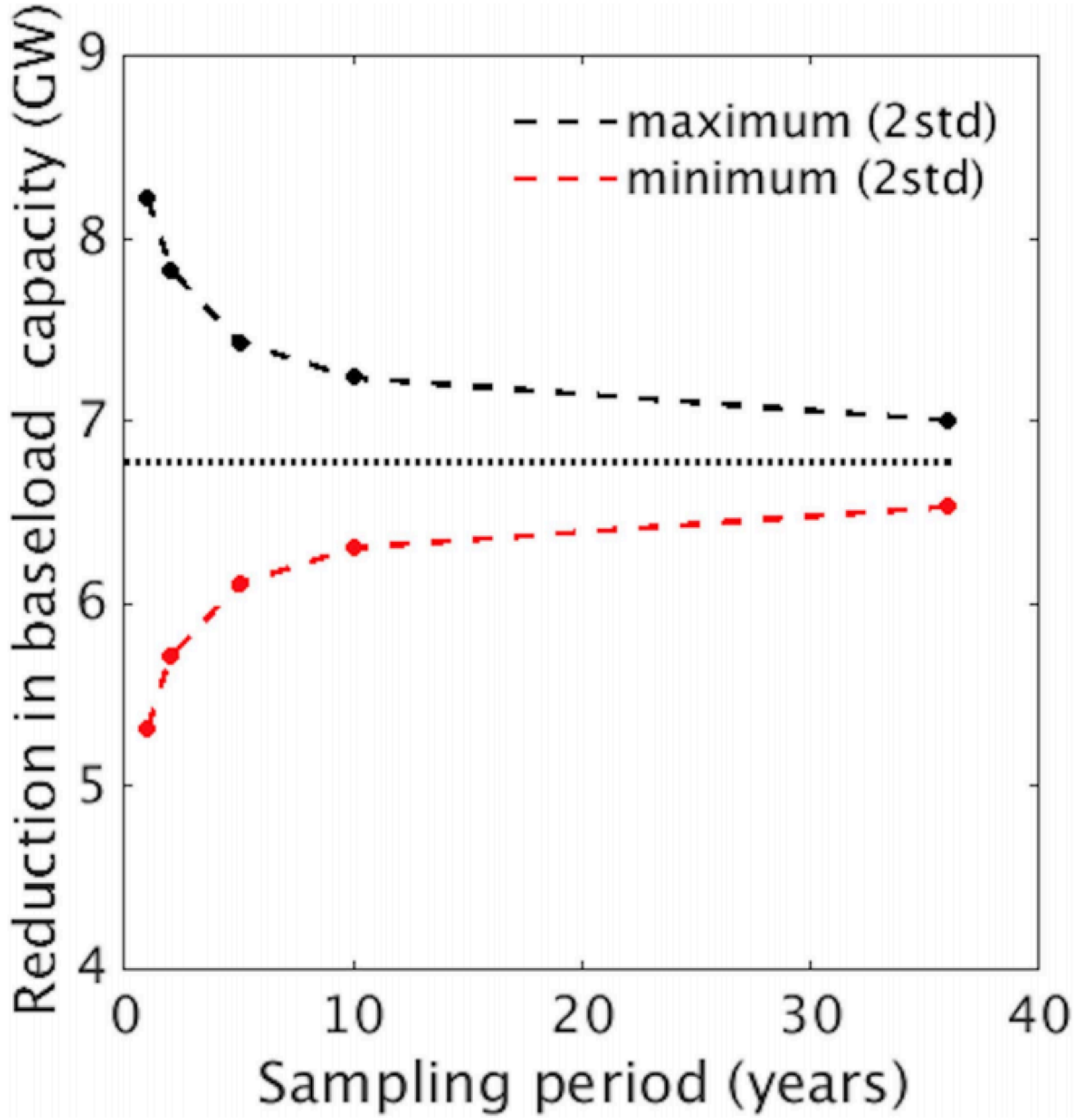
How might GB baseload capacity reduce in a future power system with more wind power generation?

current future current + future onshore current + future offshore



Increase in annual-mean CF, but. Still risks of poor generation years.

Reduction in BL operation. Much more certainty in the conclusions if you include 30-40 years of data rather than just 1 or 2.



for Clean Energy

Drew et al., (2015)

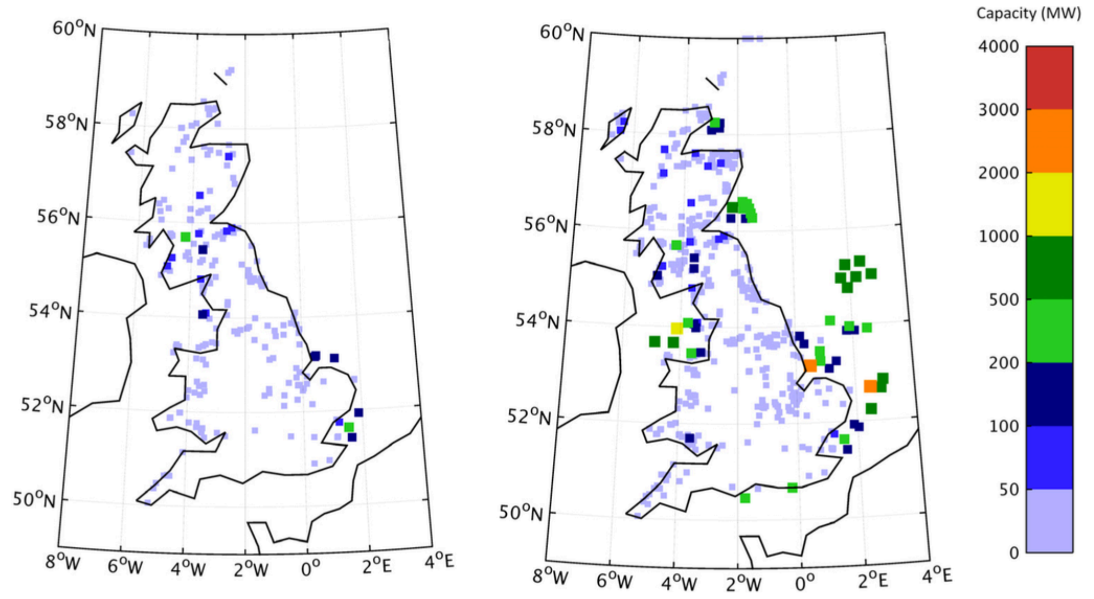
Bloomfield et al., (2018)

Understand Present/potential power system variability

What weather conditions could cause the most power system stress?

April 2014 (10.2 GW)

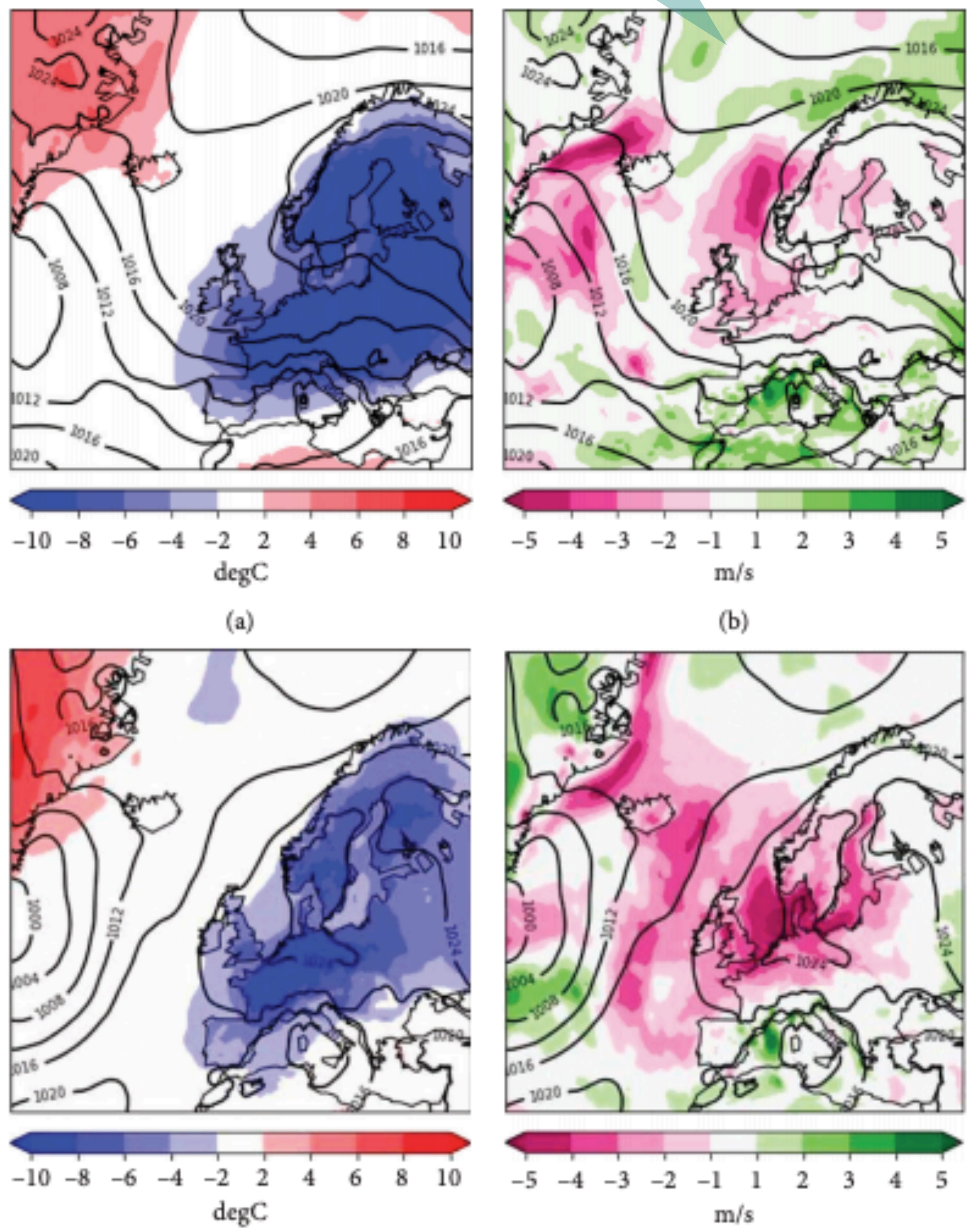
The Future (~50 GW)



What meteorological variables is my power system most sensitive to?

Demand

Demand-Net-Wind



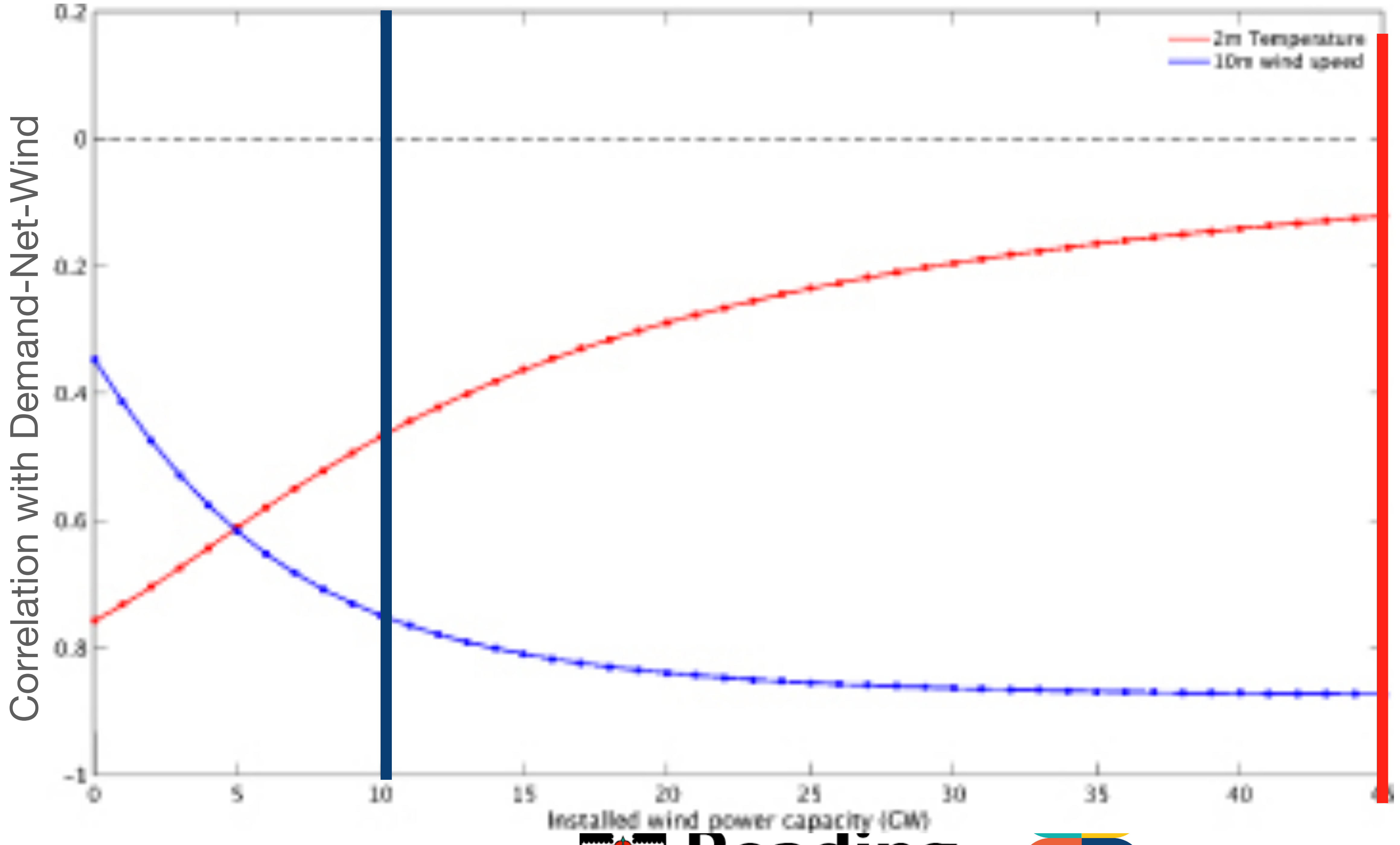
Weather conditions of highest stress change when you include more wind power generation

with more wind power generation systems temperature sensitivity rapidly decreases.

Bloomfield et al., (2020)

current (2014)

future (2050)



Bloomfield et al., (2018)

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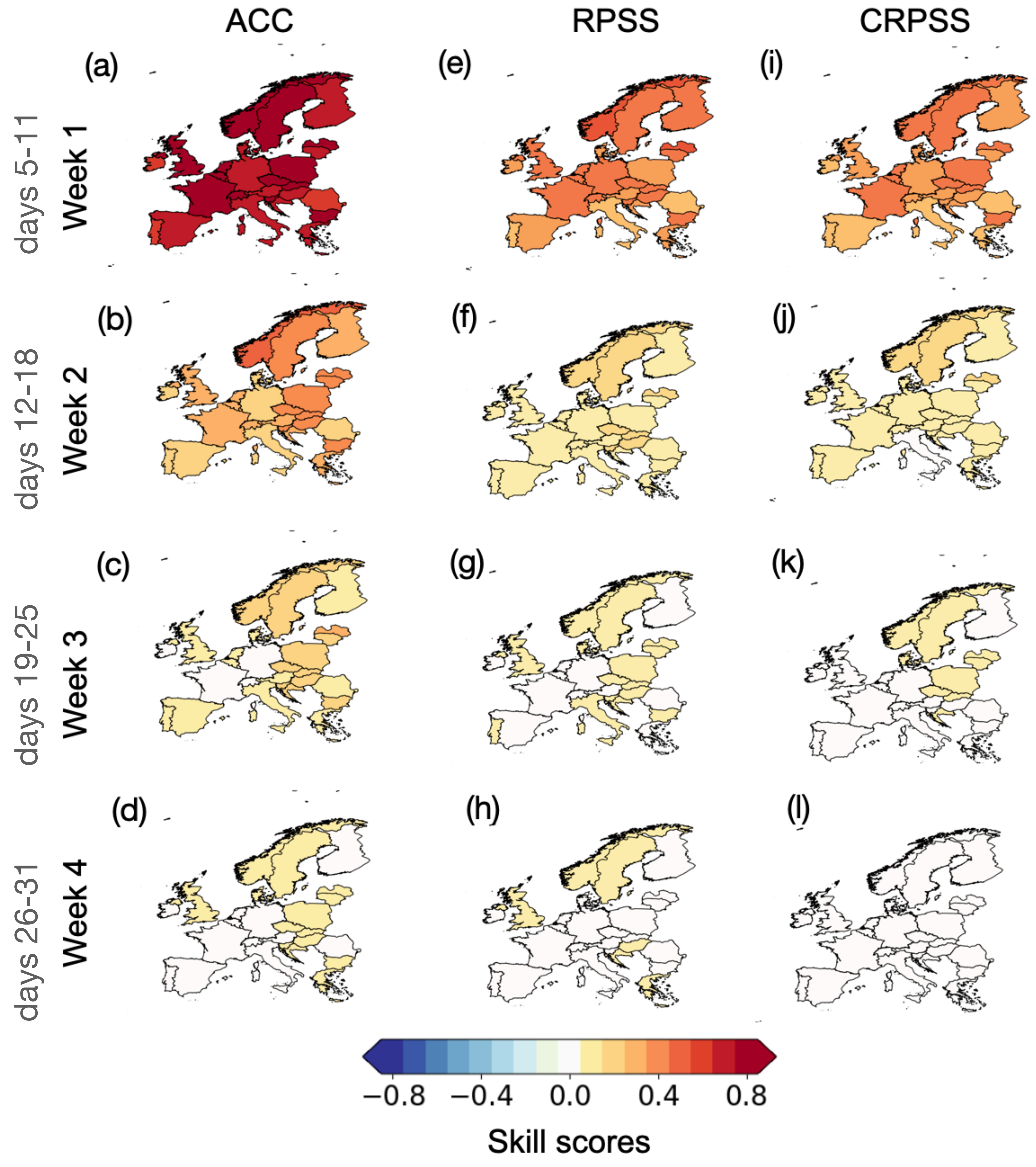
Predict future power system behaviour

Are any of these characteristics predictable?

- Pass (calibrated!) forecast data through the models described earlier
- UREAD have published datasets of European Demand, Wind Power, Solar Power hindcasts from 1996-2016 for 2 sub-seasonal models (ECMWF and NCEP, ~40 day forecasts)
- Good skill seen in week 1 (days 5-11) useful skill still present at longer lead times

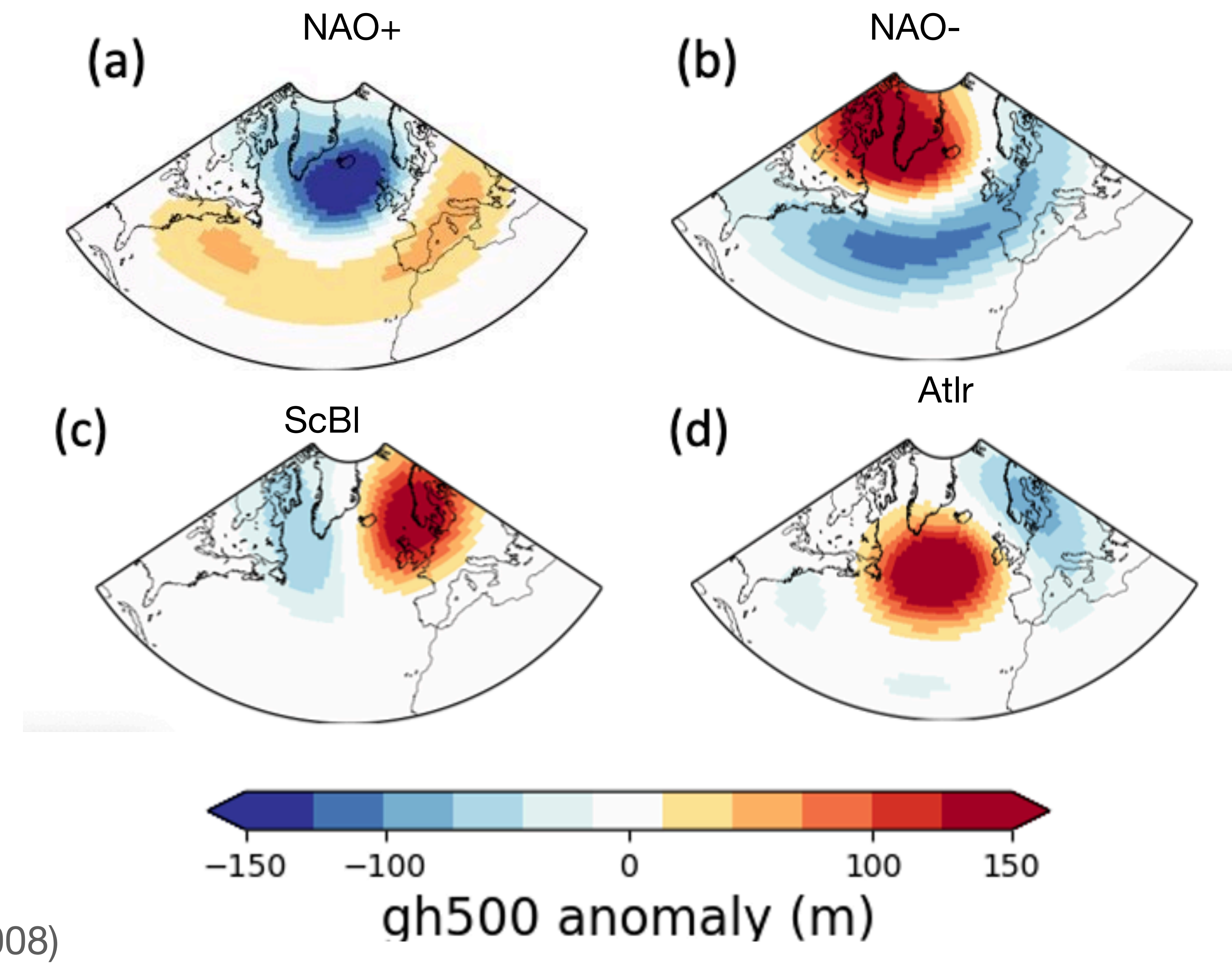


Data: Gonzalez et al., (2020)

Description: Bloomfield et al., (in review), contact for a copy

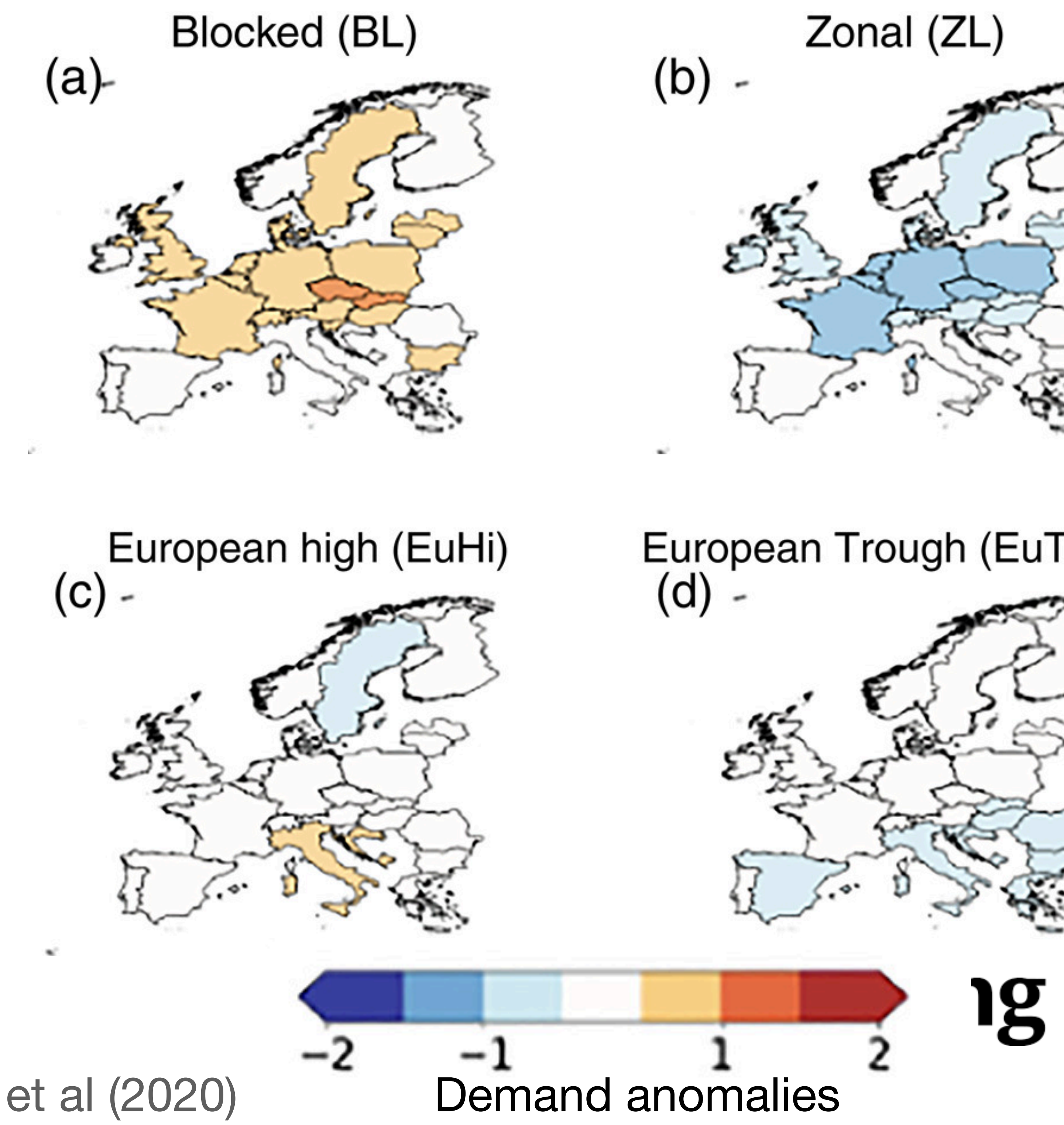
Using weather patterns to forecast energy variables

- Weather regimes.
- Patterns based on large scale, upper atmospheric meteorological data.
- Constructed using k-means clustering of principal components of the gridded data.



Cassou (2008)

- Targeted Circulation Types.
- Constructed using k-means clustering of principal components of European power system data.
- Better relationship to system of interest than 'traditional' weather regimes.



Bloomfield et al (2020)

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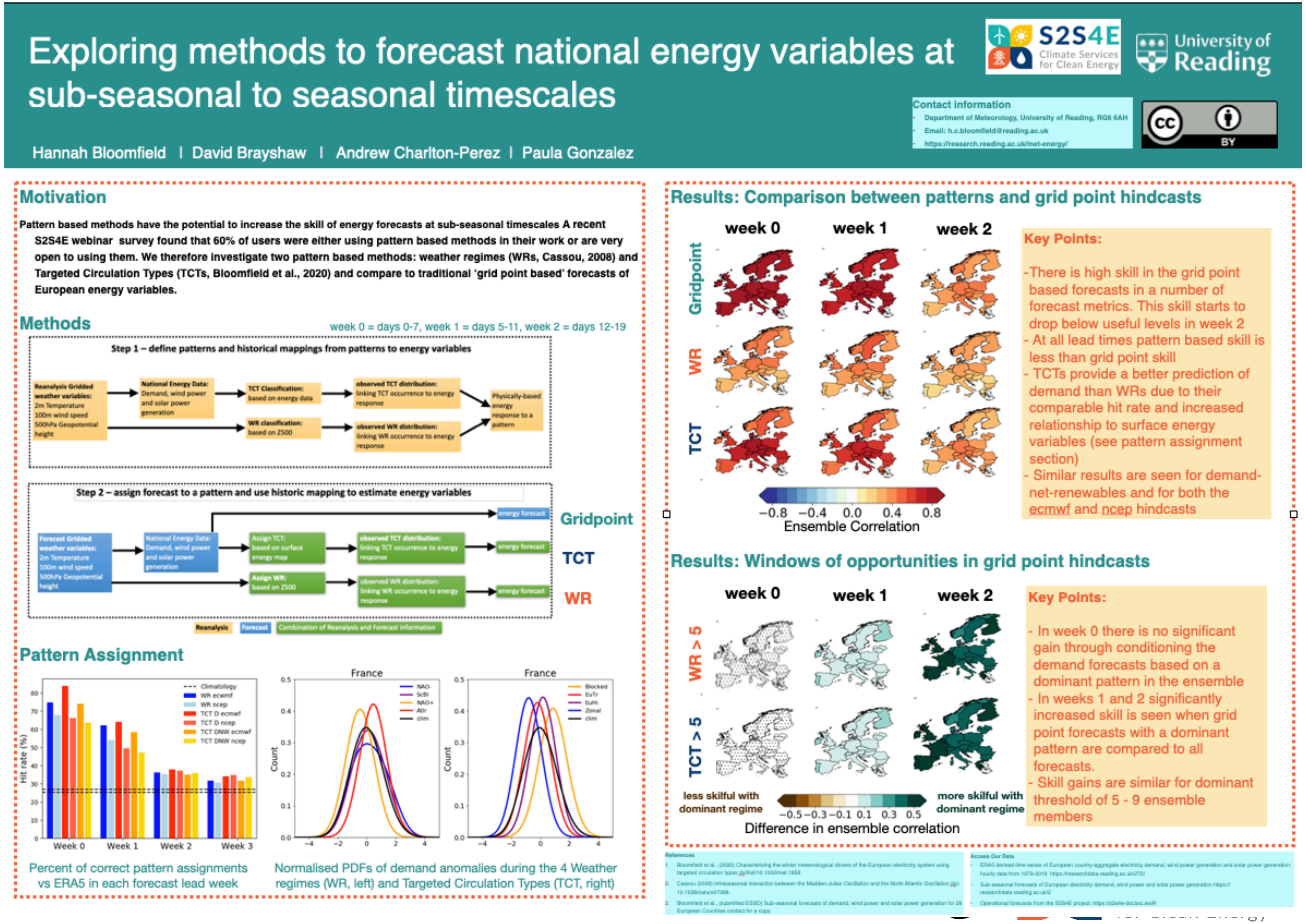
Using weather patterns to forecast energy variables

- A recent S2S4E webinar survey showed pattern methods are commonly used in the energy industry to forecast
- Patterns have the potential to provide enhanced skill compared to grid point based forecasts
- Current work at UREAD is investigating how well pattern based methods (like European weather regimes, or TCTs) compare to using the grid point forecast data.
- Visit the poster later for more details about this.



Summary

- Gridded meteorological datasets from weather forecast models, reanalysis and climate model simulations can all be converted into weather-dependent power system components.
- A number of datasets exist for open-access use which have completed this conversion and published methods.
- These datasets are useful to answer a number of research questions associated with the weather-dependent uncertainty in power system modelling.
- Increased collaboration between the energy and meteorology communities can help tackle future research questions about weather-dependent power system behaviour.

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References and datasets

- Bloomfield et al., (2020) Characterizing the winter meteorological drivers of the European electricity system using targeted circulation type https://doi.org/10.1002/met.1858
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- Bloomfield et al., (2016) Quantifying the increasing sensitivity of power systems to climate variability https://iopscience.iop.org/article/10.1088/1748-9326/11/12/124025
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- Reanalysis derived demand, wind and solar power data: ERA5, http://dx.doi.org/10.17864/1947.273 MERRA2: http://dx.doi.org/10.17864/1947.239
- S2S forecasts of demand, wind and solar power data: http://dx.doi.org/10.17864/1947.275
- Renewables Ninja renweables.ninja
- ECEM future climate/energy data: http://ecem.wemcouncil.org/

With thanks to the whole team energy-met@reading team

Any Questions?

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