The effects of weather and climate change

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Renewable Energy System Weather Effects & Energy Storage

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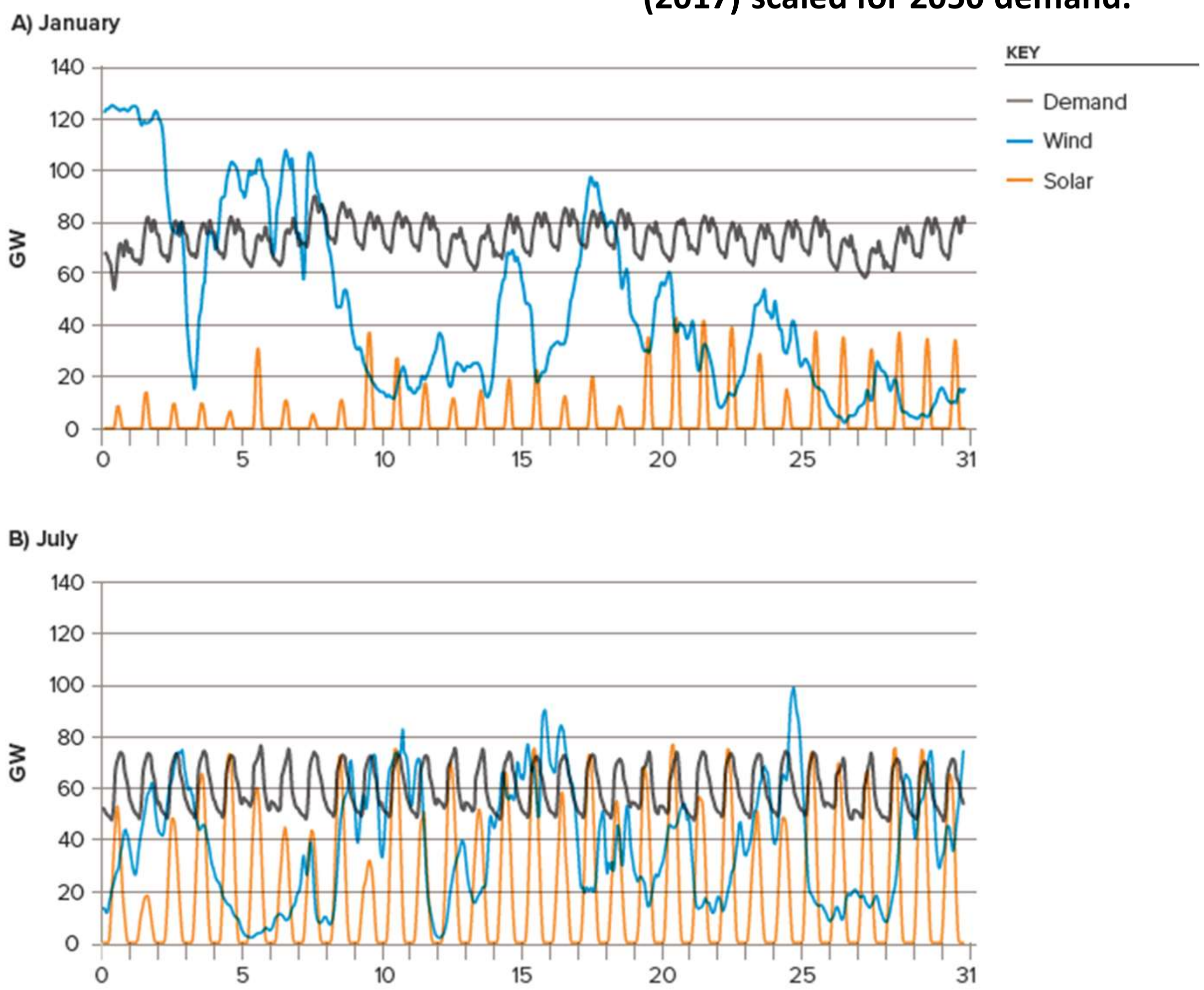
Renewable energy studies

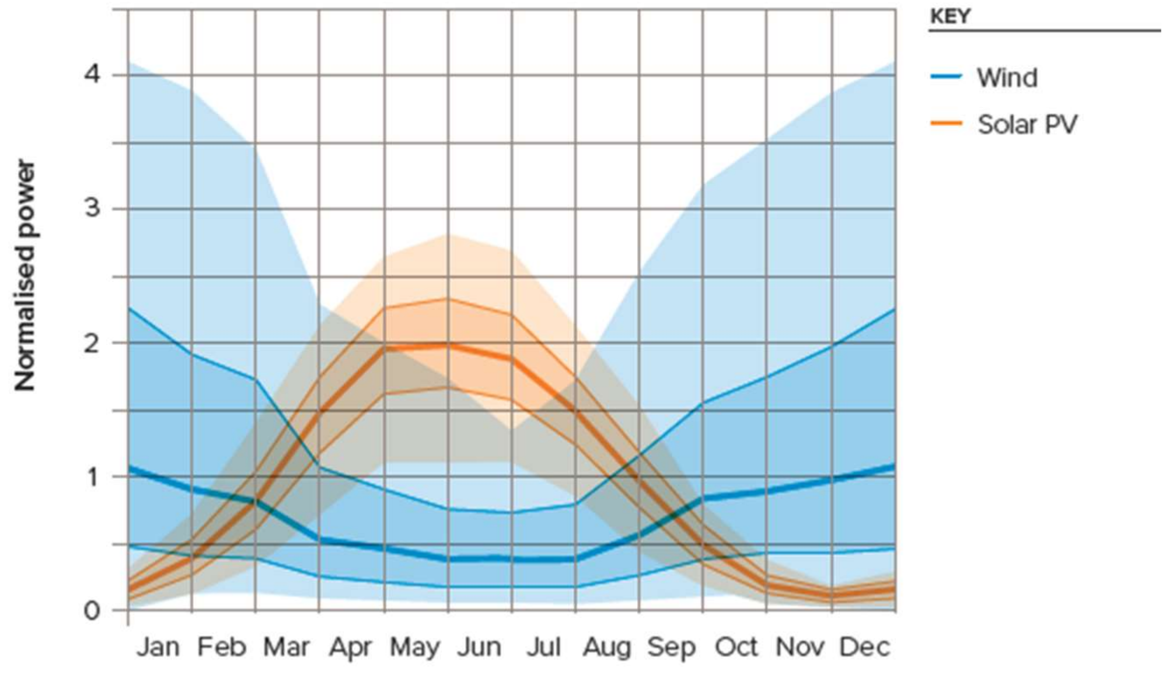
Demand & Supply - today's weather (2017) scaled for 2050 demand.



- 2050 demand (570 TWh) mean power 65 GW +/- 20 GW;
- Supply: Wind + Solar varies 10-180 GW;
- Grid's future role: from meeting demand to controlling supply;
- Many weather studies – How are ours different?
  - High renewable supply shares > 60%;
  - Net-zero -> no dispatchable fossil fuel to balance system;
  - Days, weeks, seasons & many years – continuous sequence of weather data;
  - Seeks to understand *physical behaviour* before *economics*;
  - System information visible - not lost in complex models – hard to interrogate.

Renewable supply variability

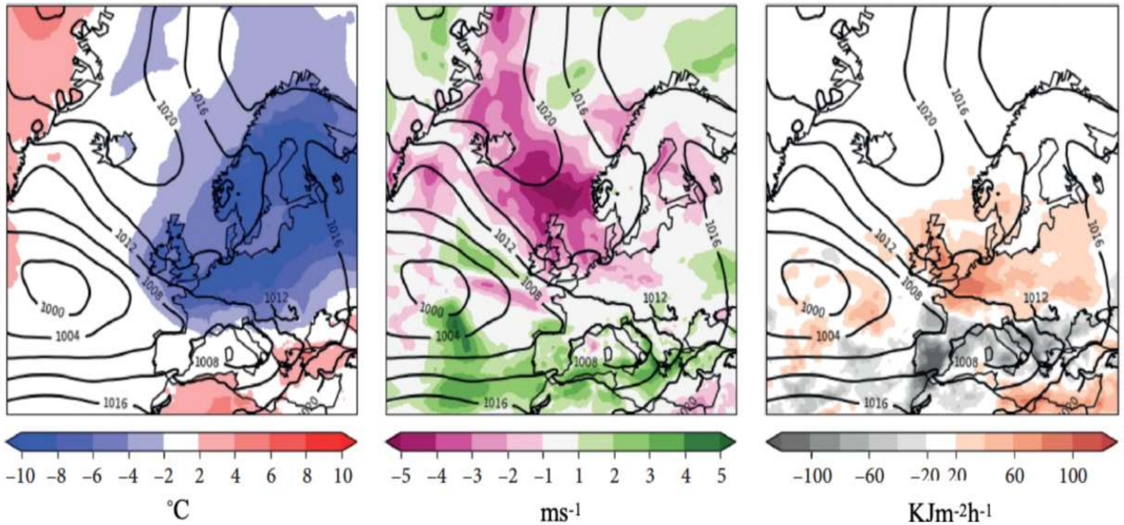
- Range of daily-mean variations within month (5th percentile) - large:
  - Solar x 2.5
  - Wind x 8
- Annual range (5th percentile) larger:
  - Solar x 25
  - Wind x 40
- Mean wind and solar power are to some degree complementary;
- Hence solar/wind mix is important – 20/80 is found to be optimal – renewable supply deficit and energy storage size minimised.



Source: Met Office.

Distribution of normalised daily mean wind and solar generation 1979 to 2013 with 5th and 25th percentiles

Extreme weather stress events



Average of top ten periods of residual demand 1980-2019 - deviation from the mean:

Temperatures at 2 m, Wind speed at 100m, and Solar irradiance.

Met Office

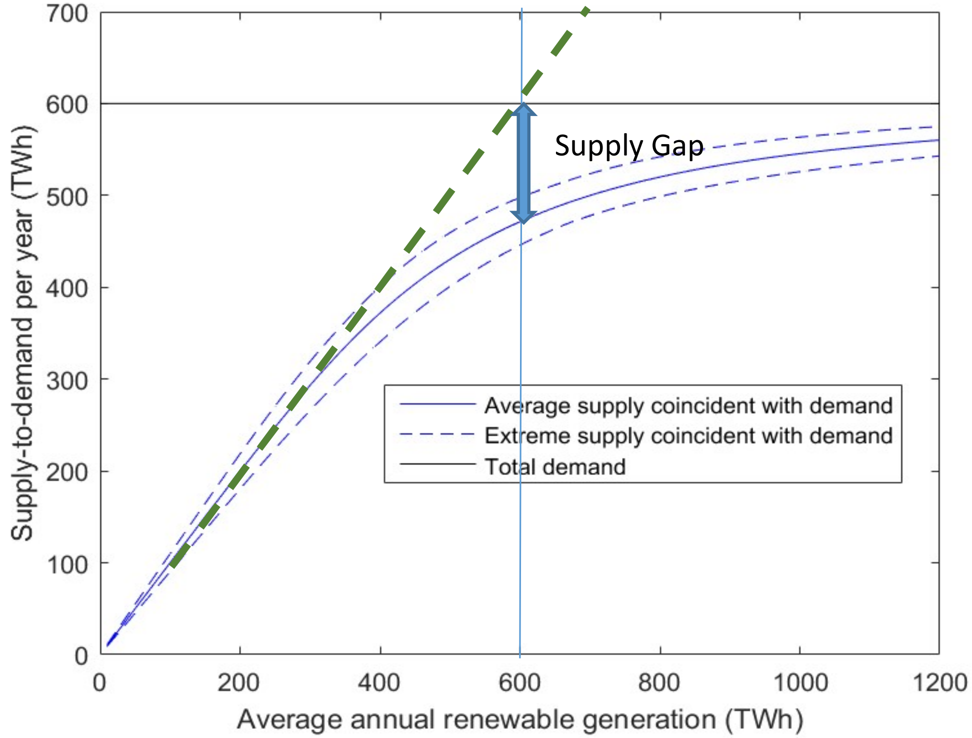
Stress events	Description	Frequency
Summer wind drought – frequent	One full day of very low wind speed in summer	One or two per year
Summer wind drought – infrequent	Up to four weeks of very low wind speed in summer	Once every 10 years
Winter wind drought	Up to a week of very low wind speed in winter	Every few years

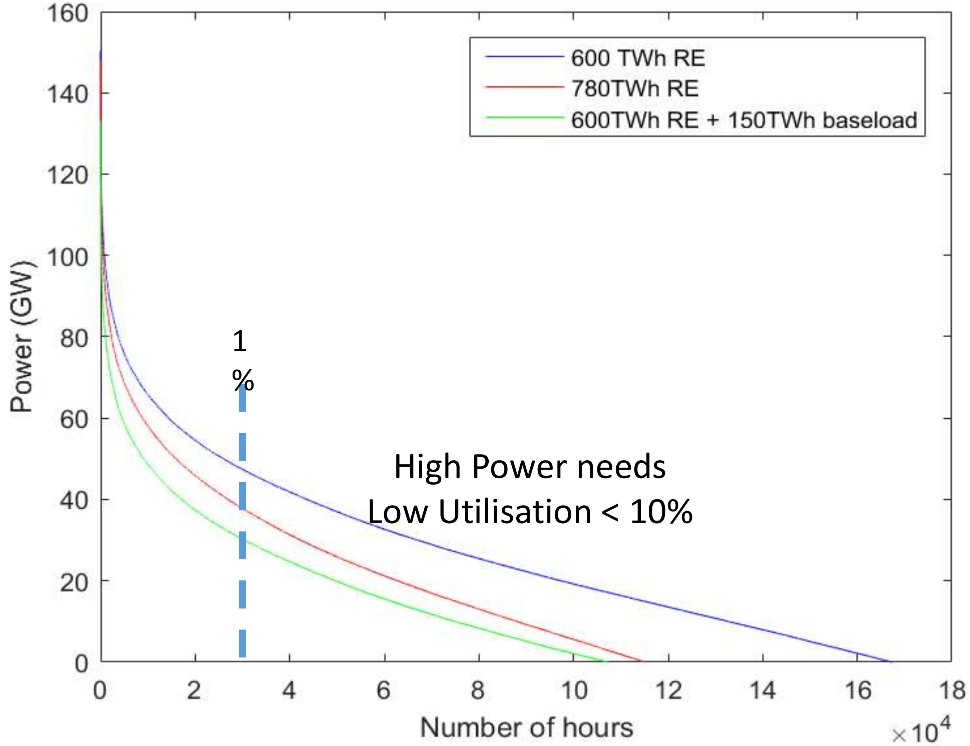
Weather – Extreme Stress Events

Met Office

Mistiming of renewable supply v demand

600 TWh
Solar/Wind: 20/80
On/Offshore: 30/70

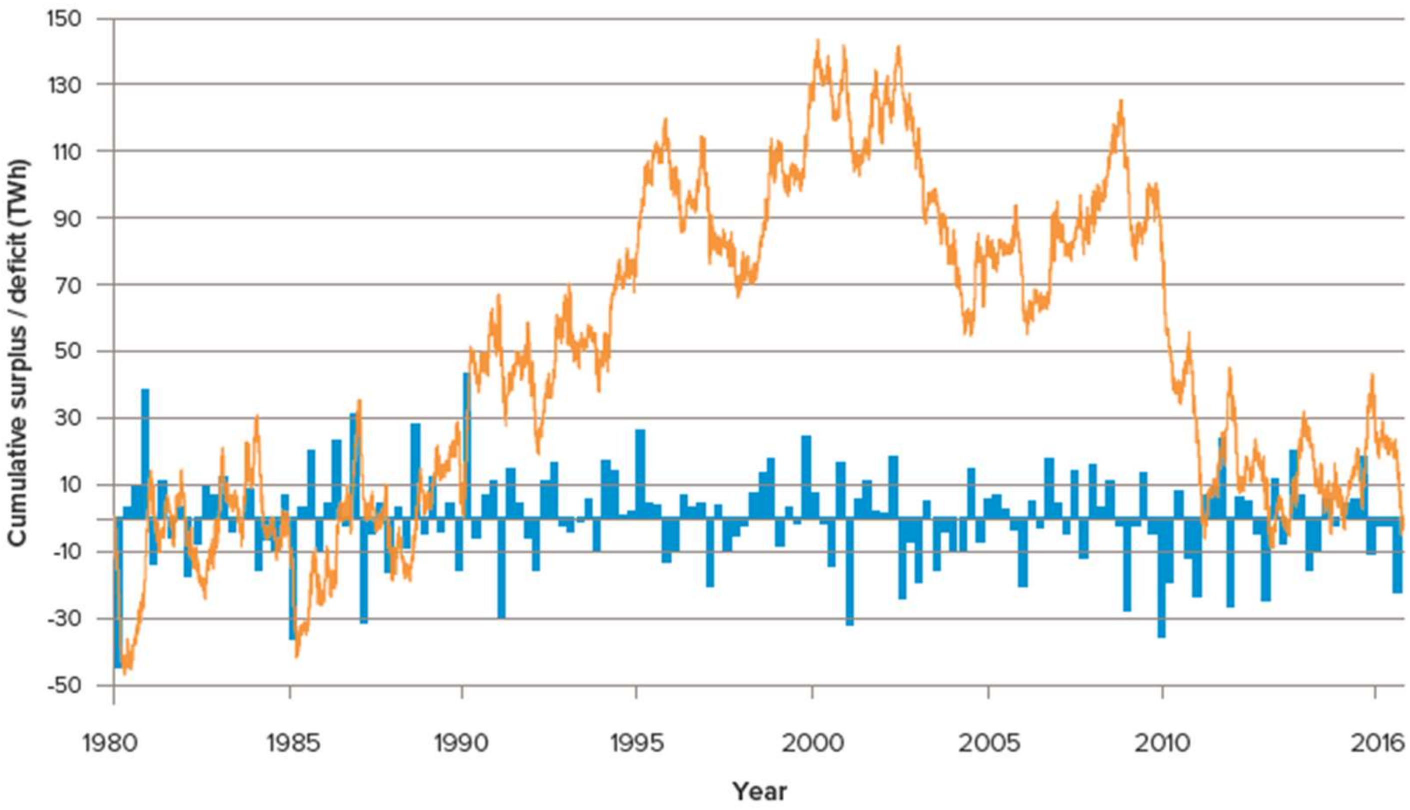




- When mean supply equals demand >120 TWh is mistimed – not available for supply and is surplus;
- High complementary power requirements - above 100 GW - very few hours in period 37 years.
- Grid to match generation (North) to demand (South) and much higher level of circulating power ~200 GW

Long term energy surpluses & deficits

- Variations in quarterly and annual residual supply not evenly distributed;
- Continuous sum of residual supply shows decadal trend – for 570 TWh pa supply system max deficit ~150 TWh;
- One year of data is not enough – multi-decadal studies (UK, Germany, US) show storage volume needs are double mean year;
- Deficit reduced but not eradicated by additional renewable capacity.



Cumulative differences between supply and demand for 2050 – quarterly & 37 years

Filling the gaps in renewable supply

Approach	Method	Scope	Pros	Cons
Ameliorate	**Demand-Side Response**	Peak-lop - incentives, digital grid & EV batteries. Emergency	Low cost Grid supply maintained.	Limited in power range & duration 20+GW few hours Can seldom be implemented – political risk.
	Interconnector to EU	20 GW planned 30 GW possible	Geographic dispersion - hedge against supply variability.	Extreme weather affect many countries across EU. Depend excess supply & capacity being available.
Baseload	**Bio-Energy CCS**	50 TWh pa limited by fuel availability	Scale of supply variation reduced. Secures a share of supply.	Power costs higher. Uncertainty of timely delivery of new capacity.
	Nuclear	Plans for 25% nuclear supply before 2050		
Flexible complementary	**CCGT & CCS**	100 GW of new plant – utilisation <10%	Technology demonstrated at scale	Some carbon & upstream fugitive emissions. High energy cost.
	Energy Storage	100 TWh of storage with 100 GW power	Not require new technology	Not demonstrated at scale. High capital costs.

Storage needs - Weather-driven periodicity

- Storage moves energy from time of excess to times when there is a deficit

  How much energy and How long stored?

  Storage Volume proportional to **Power range** x **Duration** of storage/Output **efficiency**
- Characteristics of daily, weekly and seasonal/multi-year storage needs for three selected periods
- Fully renewable - 30% overcapacity & 20/80 Solar/Wind - implicit period efficiencies 90/70/40%

Storage period	Stored volume	Power needs	Energy from store pa	Full cycles pa
Short - 6 hours	200 GWh	60 GW	8 TWh pa	40-50
Medium – 1 week	2.8 TWh	> 100 GW	52 TWh pa	22
Long term	55 TWh	> 100 GW	22 TWh pa	Less than one

- Minimum storage volume 26 days of mean demand but large power overlap –> uneconomic.
- Very few cycles of longer duration stores -> affects case for investment – smarter scheduling required.