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Security of supply challenges for a weather dependent electricity system in Great Britain: the role for storage at scale

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Clean Power 2030 – UK Government ambition

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Introduction

- UK government has set a highly ambitious target for "Clean Power" by 2030 (CP30)

Definition of "Clean Power"

"…an electricity system with the following characteristics in a typical weather year:

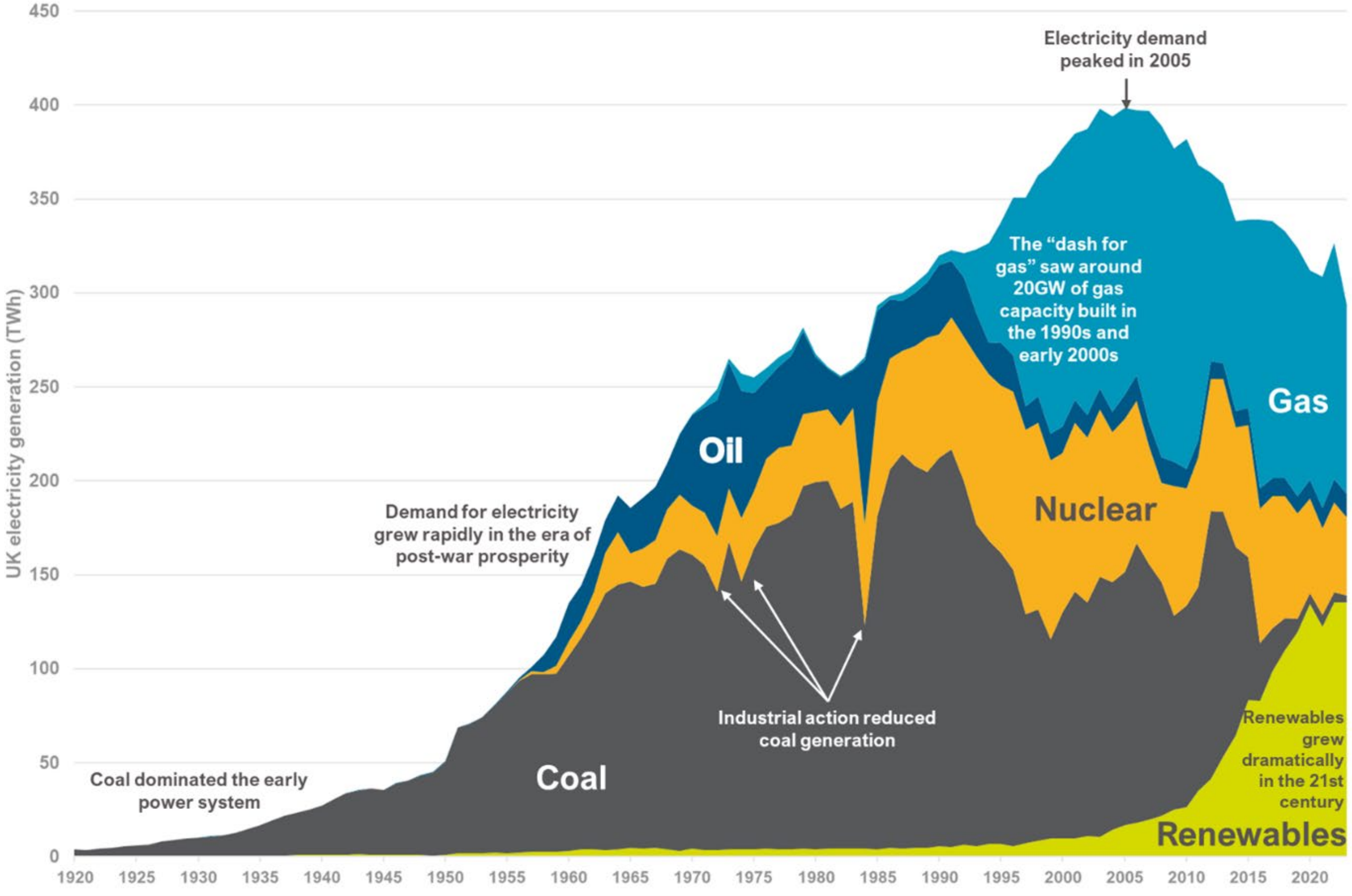
- Clean sources produce at least as much power as Great Britain consumes in total; and
- Clean sources produce at least 95% of Great Britain's generation"

Aim of Presentation

- Investigate Implications of running a "Clean Power" electricity system in Great Britain
- Assess weather dependency of system operation and storage requirements at different timescales
- Assess impacts on key security of supply metrics

Source: UK Gov, Clean Power 2030 Action Plan - https://www.gov.uk/government/publications/clean-power-2030-action-plan

UK Decarbonisation story to date



Pre-1990's – Coal dominated

1990's – "Dash for Gas"

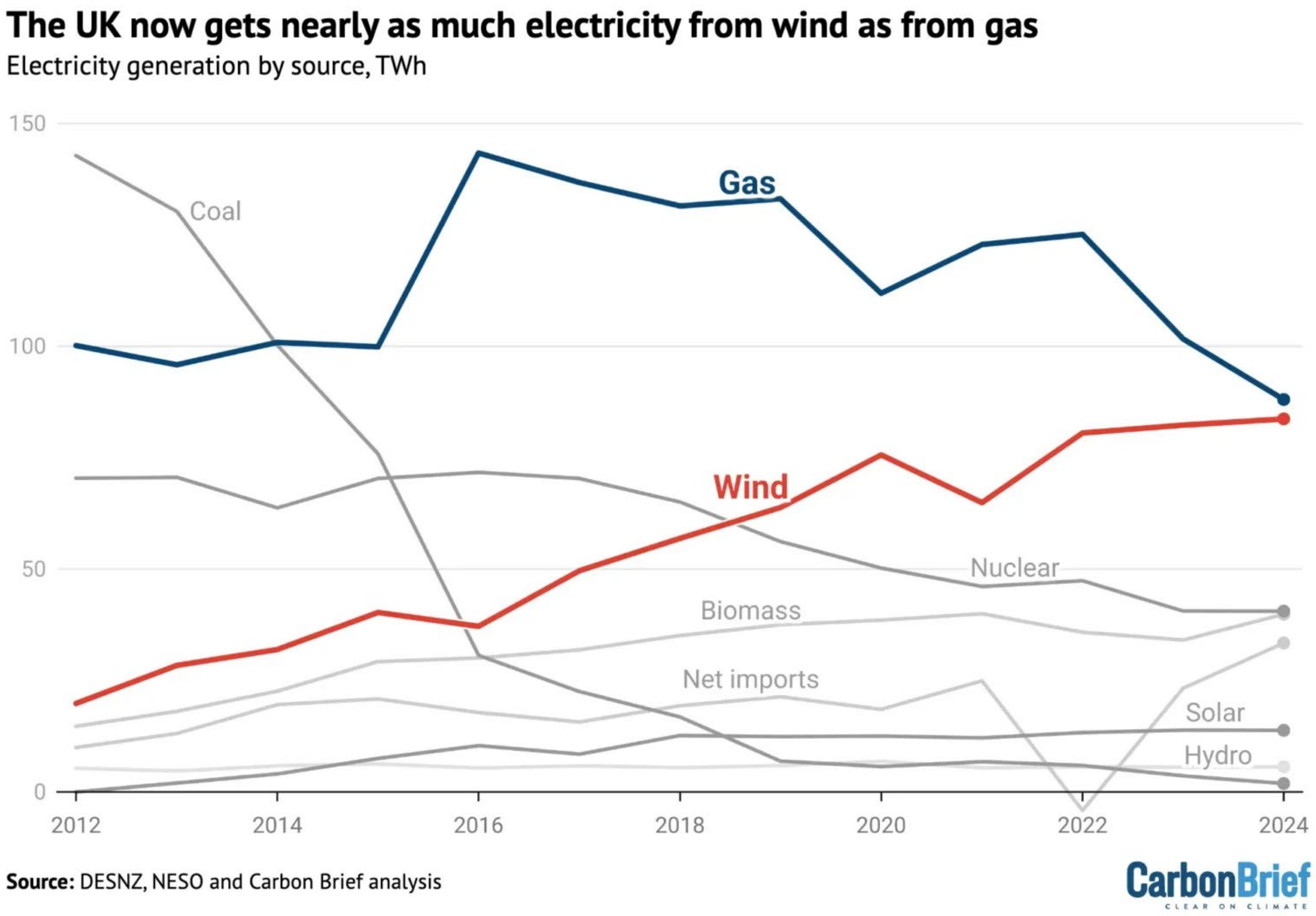
2000's – Coal / Gas / Nuclear

2010's – Renewables deployment and coal phase out

2020's – Renewables / Gas + Nuclear end of life

Source: Energy UK adapted from Our World in Data

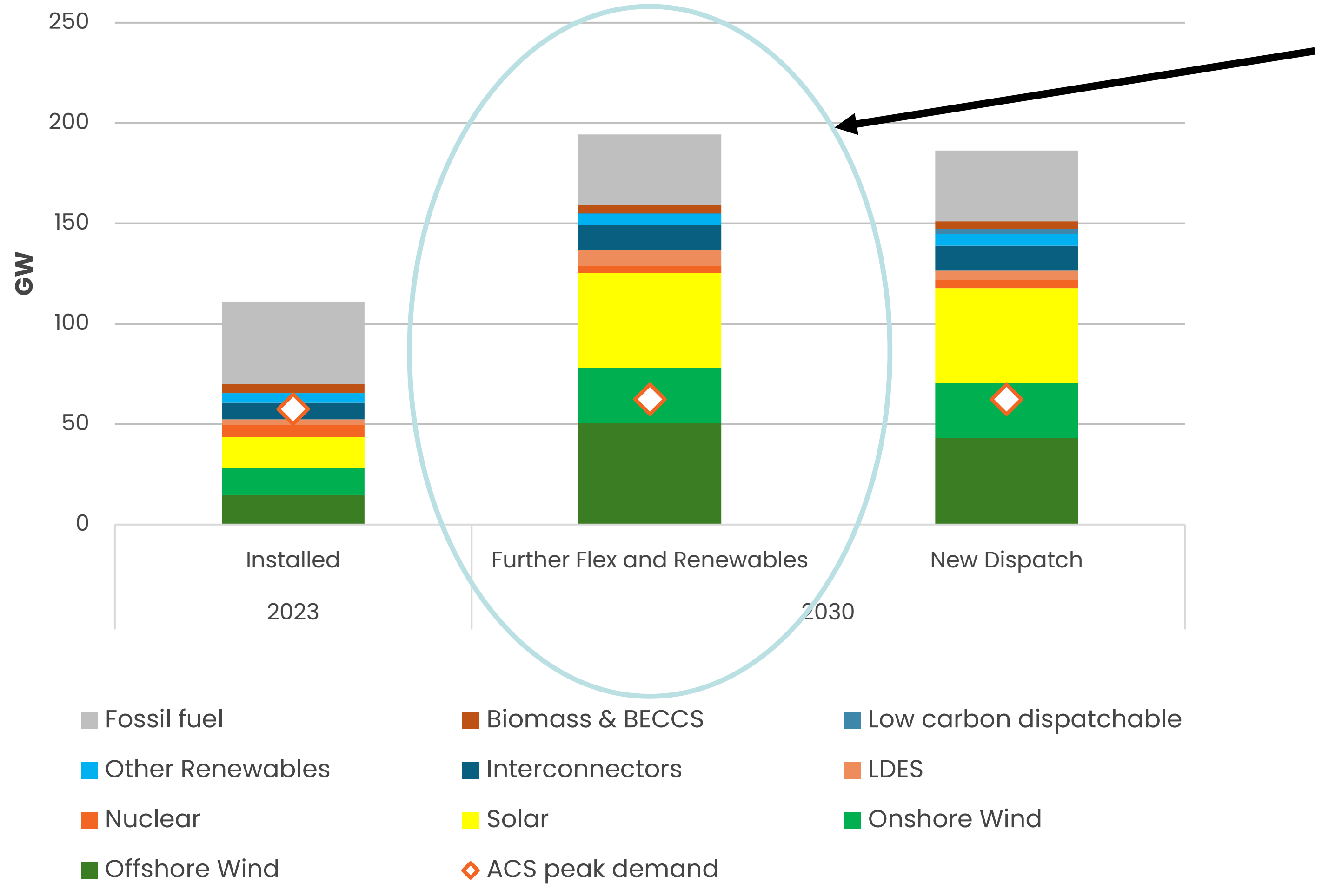
UK Decarbonisation story to date



Gas – 28%
Wind – 26%
Nuclear – 14%
Biomass – 14%
Imports – 11%
Solar – 4%
Hydro – 2%
Coal – 0.6%

Gas still the largest single source (and run in every hour) but at inflection point in transition to bring that down to 5%…

Clean Power by 2030 – What will it take?



Installed generation capacity ↑~75%
Driven by new build renewables

- 3x ↑ offshore wind
- 2x ↑ onshore wind
- 3x ↑ solar

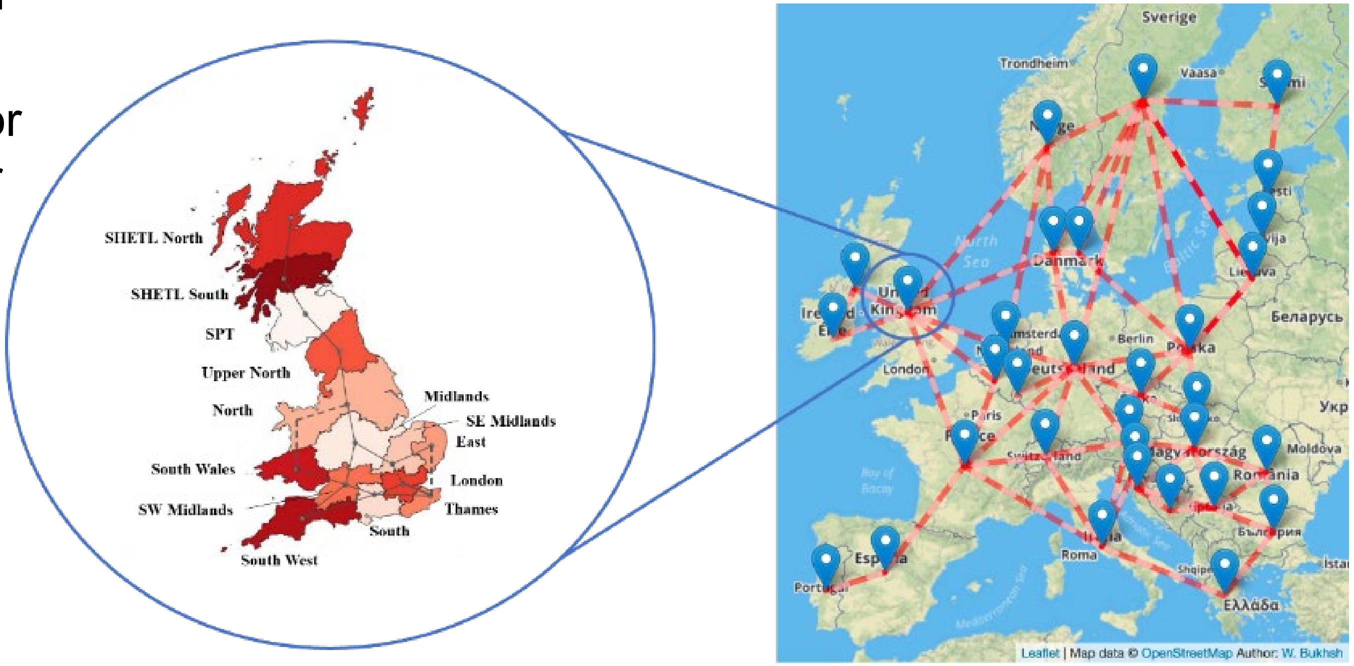
Clean Power by 2030 is a paradigm shift to a renewables dominated electricity system

It's also the 1st step on the way to a fully decarbonised energy system by 2050.

Source: NESO: Clean Power 2030 workbook https://www.neso.energy/publications/clean-power-2030

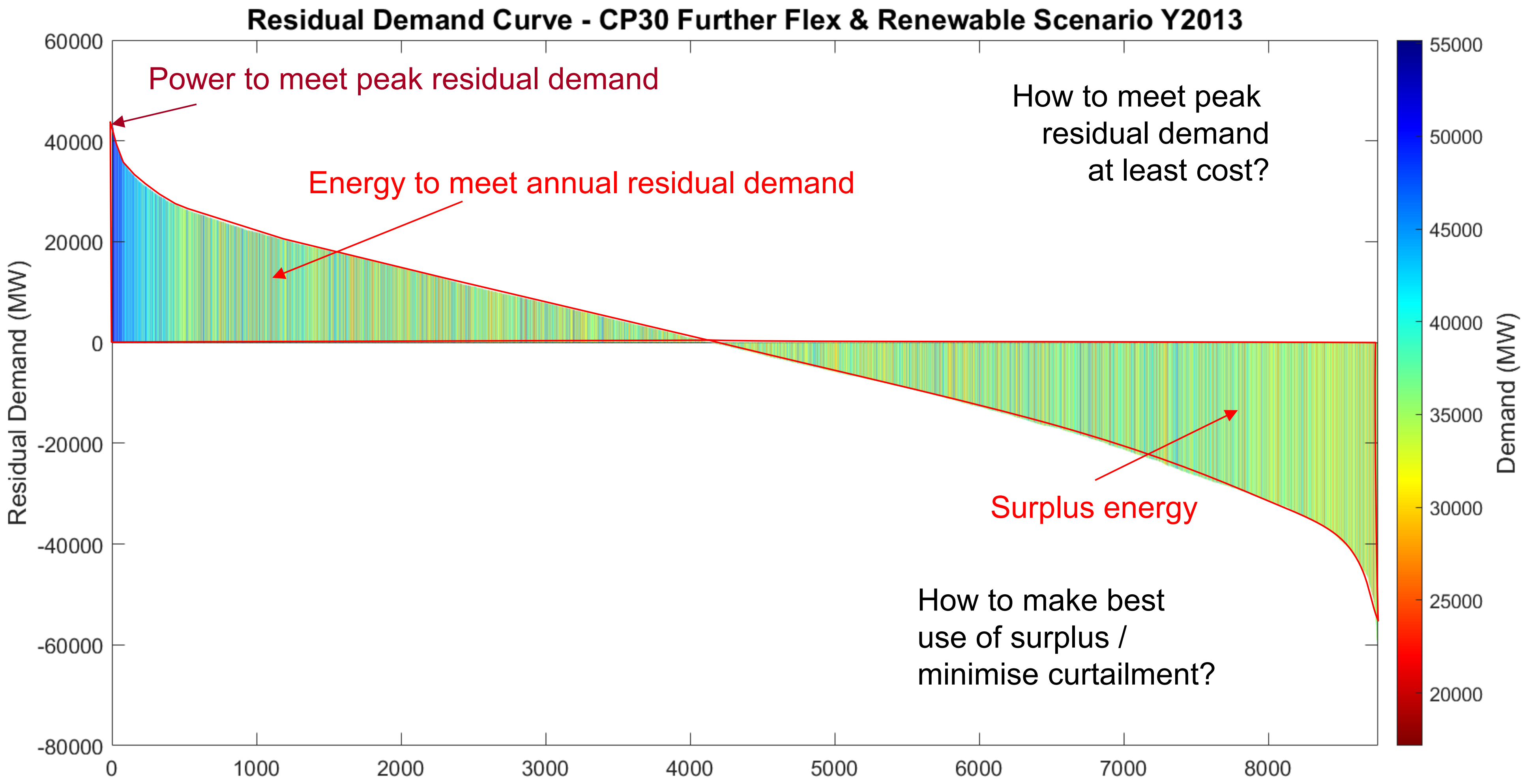
SEEMM – Strathclyde European Electricity Market Model

- Year-round hourly unit commitment model
- Models generation and demand backgrounds across Europe and solves for lowest cost system dispatch for each hour of year
- GB disaggregated into 14 zones representing main transmission boundaries
- Requires spatially disaggregated wind, solar and demand profiles – important to examine different weather years
- Can examine future pathways for adequacy, emissions, curtailment, system cost, imports/exports etc



Useful tool for assessing the challenge facing the new government and sense checking their ambitions for 'clean power' by 2030!

New paradigm: System no longer demand driven – 'residual demand' key metric



- In each hour residual demand = demand – (wind + solar)
- Does not include electrolysis demand

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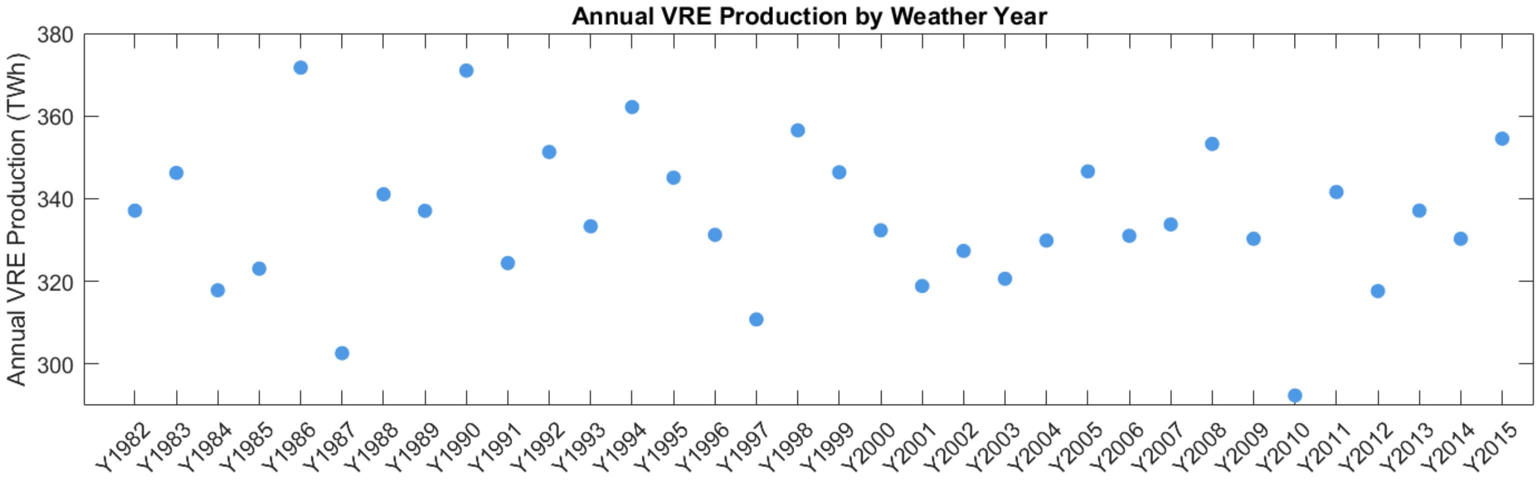
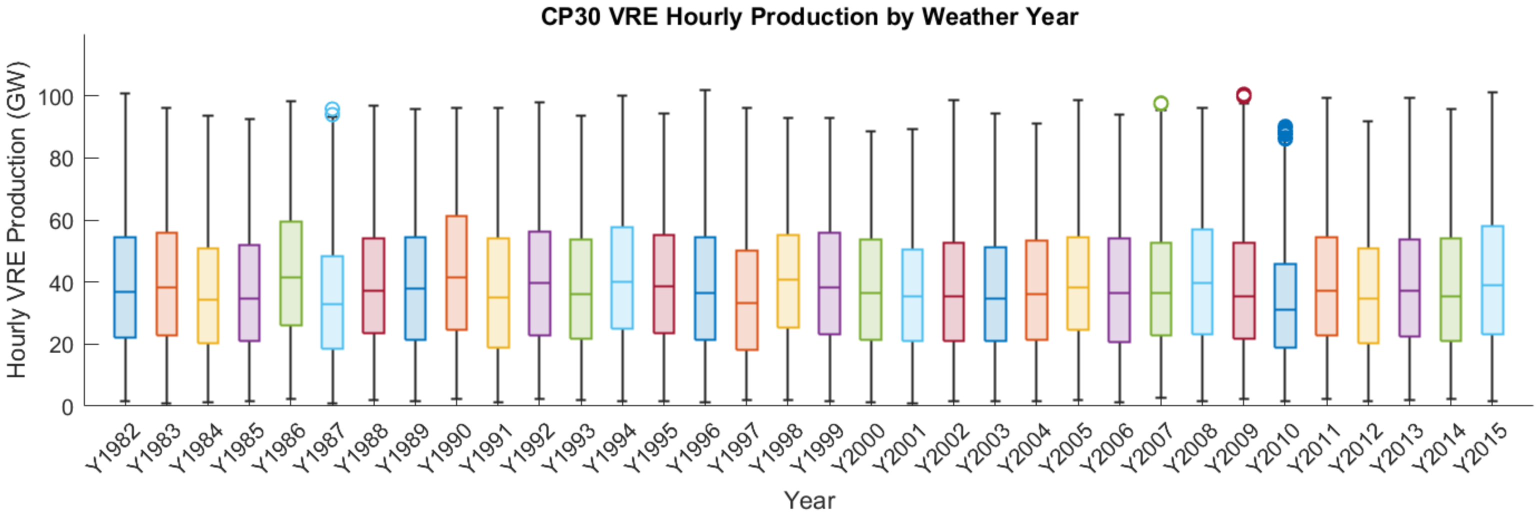
What is the impact of weather variability?

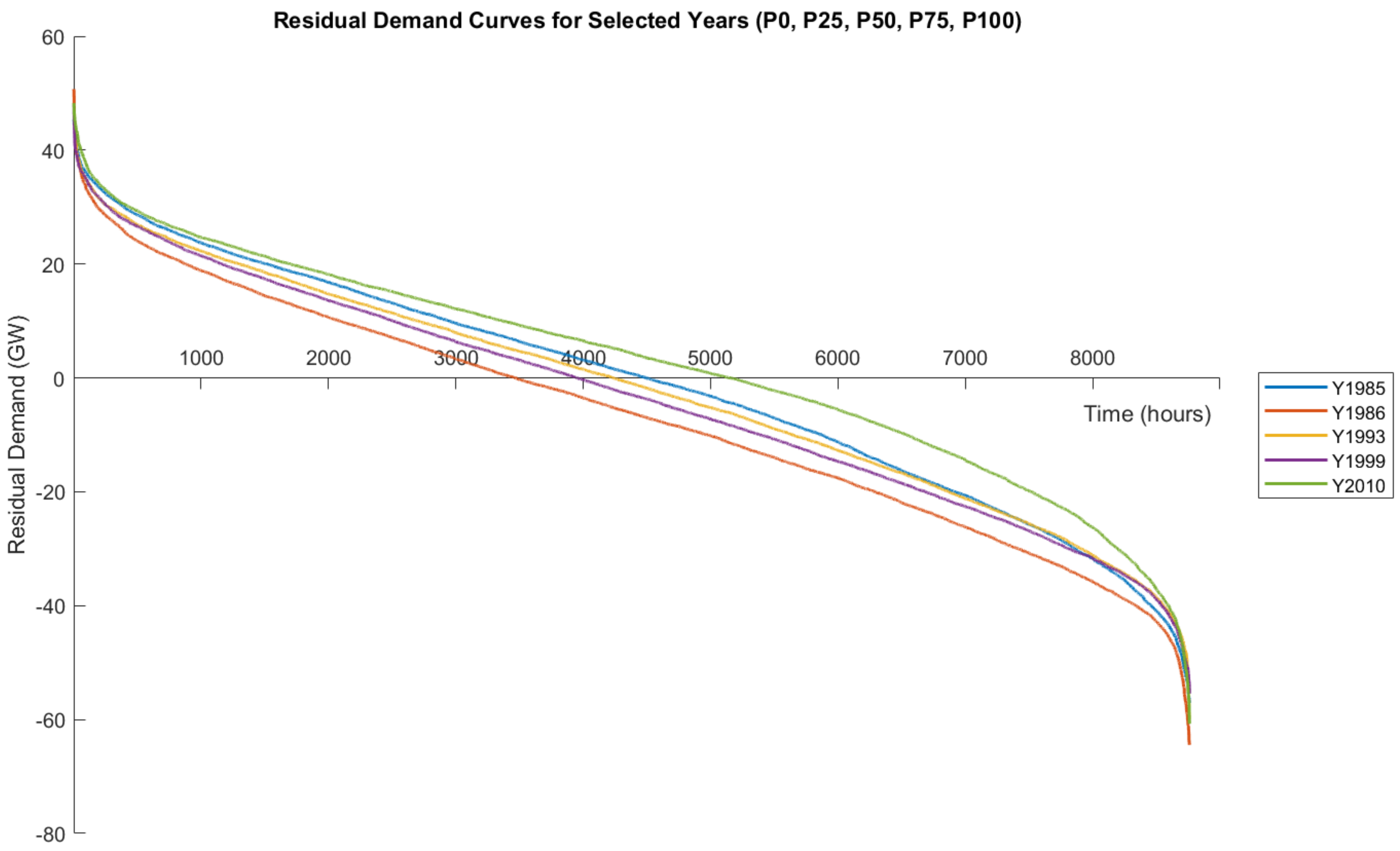




- Variable renewable energy output in GB modelled based on CP30 FFR scenario for 34 weather years (1982-2015)
- Builds on historical re-analysis data for wind and solar availability and heating demand by H. Bloomfield [1]
- Augmented with own view on EV and electrified heating profiles and with capacity factors matched to NESO
- Headlines:
  - Total VRE output on average similar to annual demand
  - But ~80 TWh variation in annual output
  - Large variation hour by hour between ~1 GW and ~100 GW

[1] H. Bloomfield, D. Brayshaw, and A. Charlton-Perez, “Era5 derived time series of european country-aggregate electricity demand, wind power generation and solar power generation,” https://doi.org/10.17864/1947.272, 2021

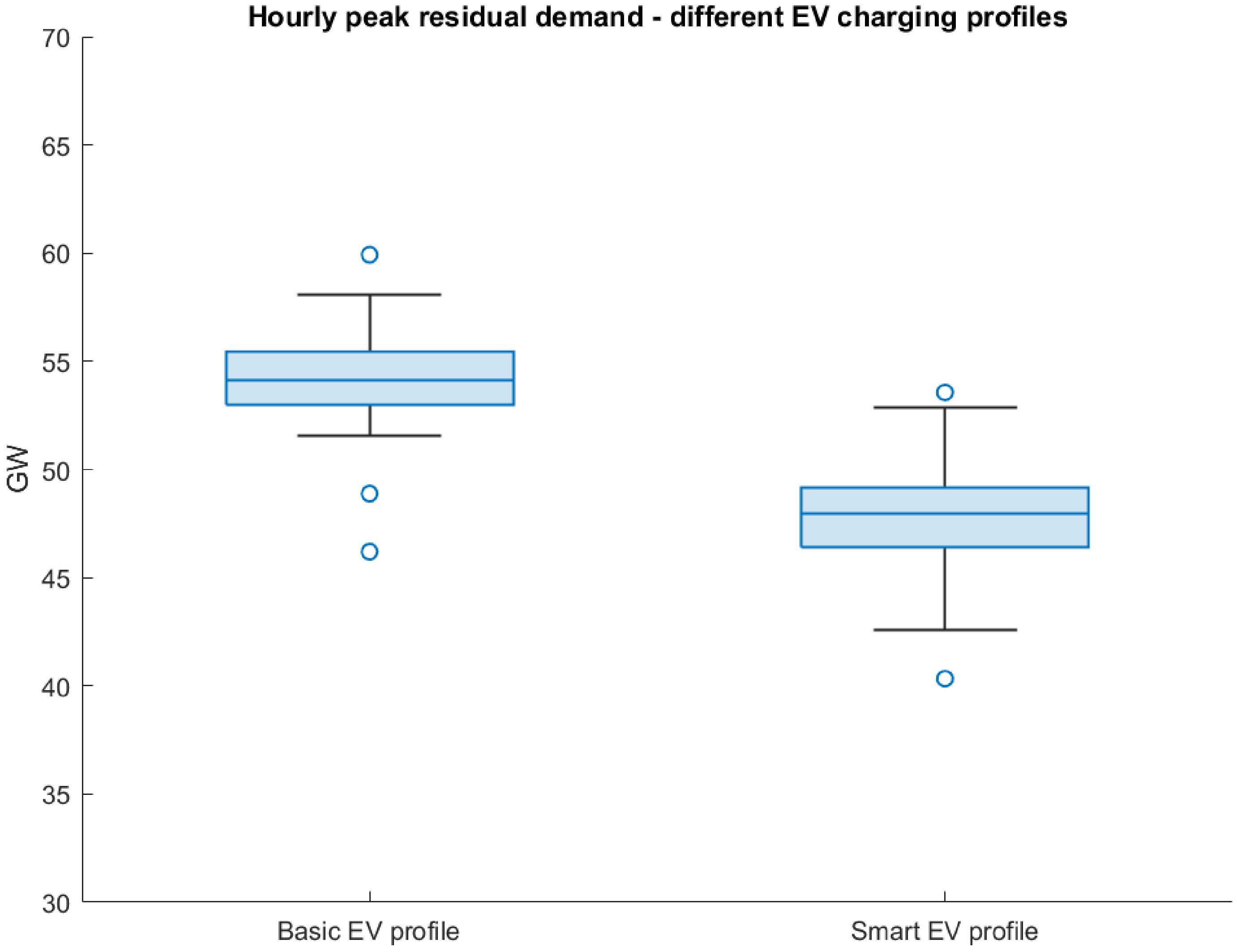
Impact of weather on residual demand?



- Taking P0, P25 … P100 VRE weather years shows significant variation in the resulting residual demand curves
- System operator must be able to plan for multiple outturn scenarios, not just a central case

How does this translate at different timescales?

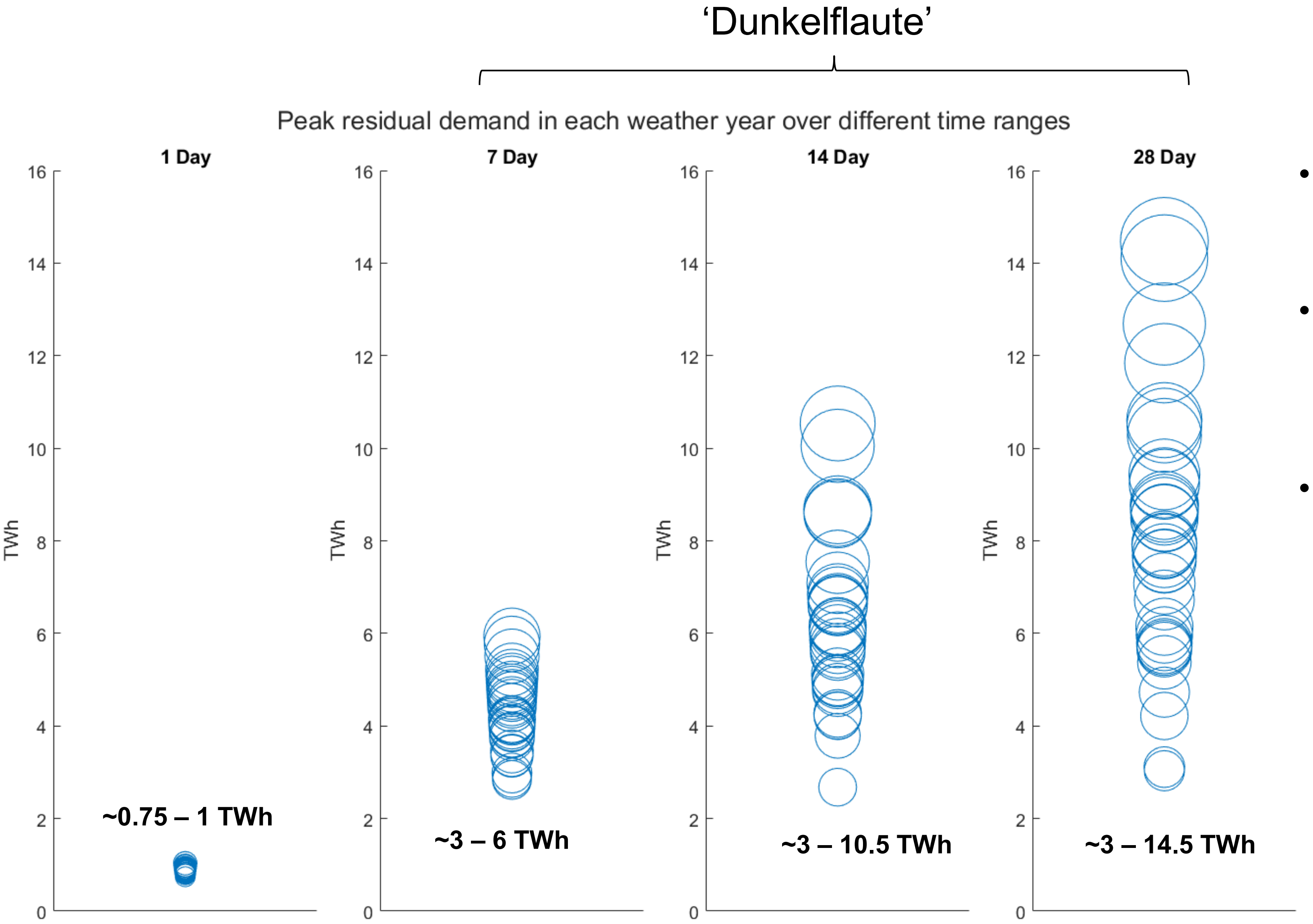
Peak hourly residual demand



- Critical for informing system dispatchable capacity needs
- ~15GW variation in peak hourly residual demand
- Overlap between low VRE periods and high demand periods varies significantly year on year
- Covering for a 'normal' year not enough

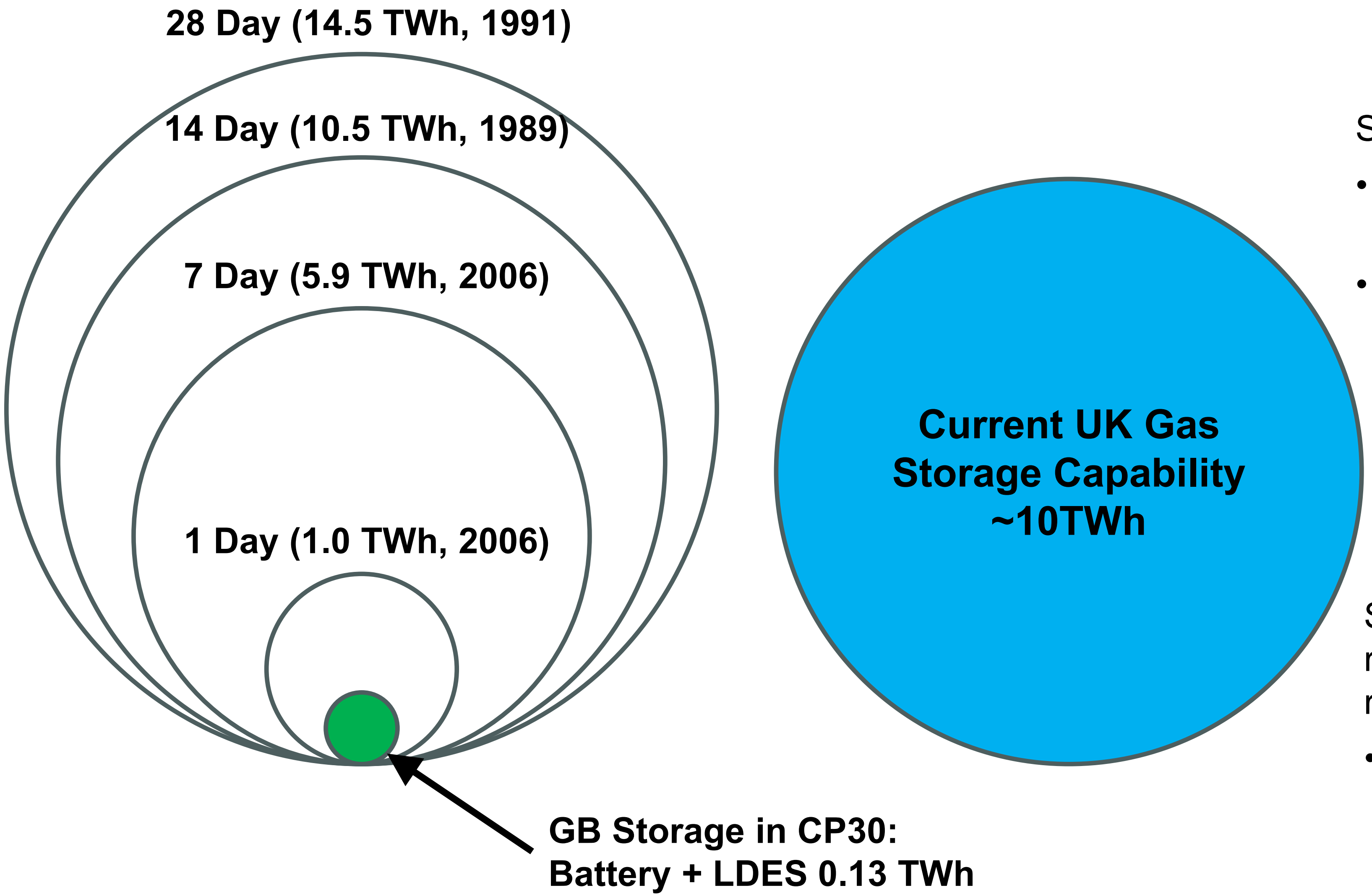
- <u>Demand assumptions also key</u>
- basic fleet EV charging profile adds significantly to peak residual demand
- If 'smart' charging shifts demand off-peak, reduces the dispatchable capacity requirements significantly

Residual demand at different timescales



- Large variation in 'worst case' energy requirements over longer timescales year on year
- Uncertainty over extent to which demand destruction would reduce burden in extreme periods
- High prices may lead to turn down of some industrial demand (total industrial demand ~7.5 TWh / month in 2030)

Energy requirements to ‘meet the peak’



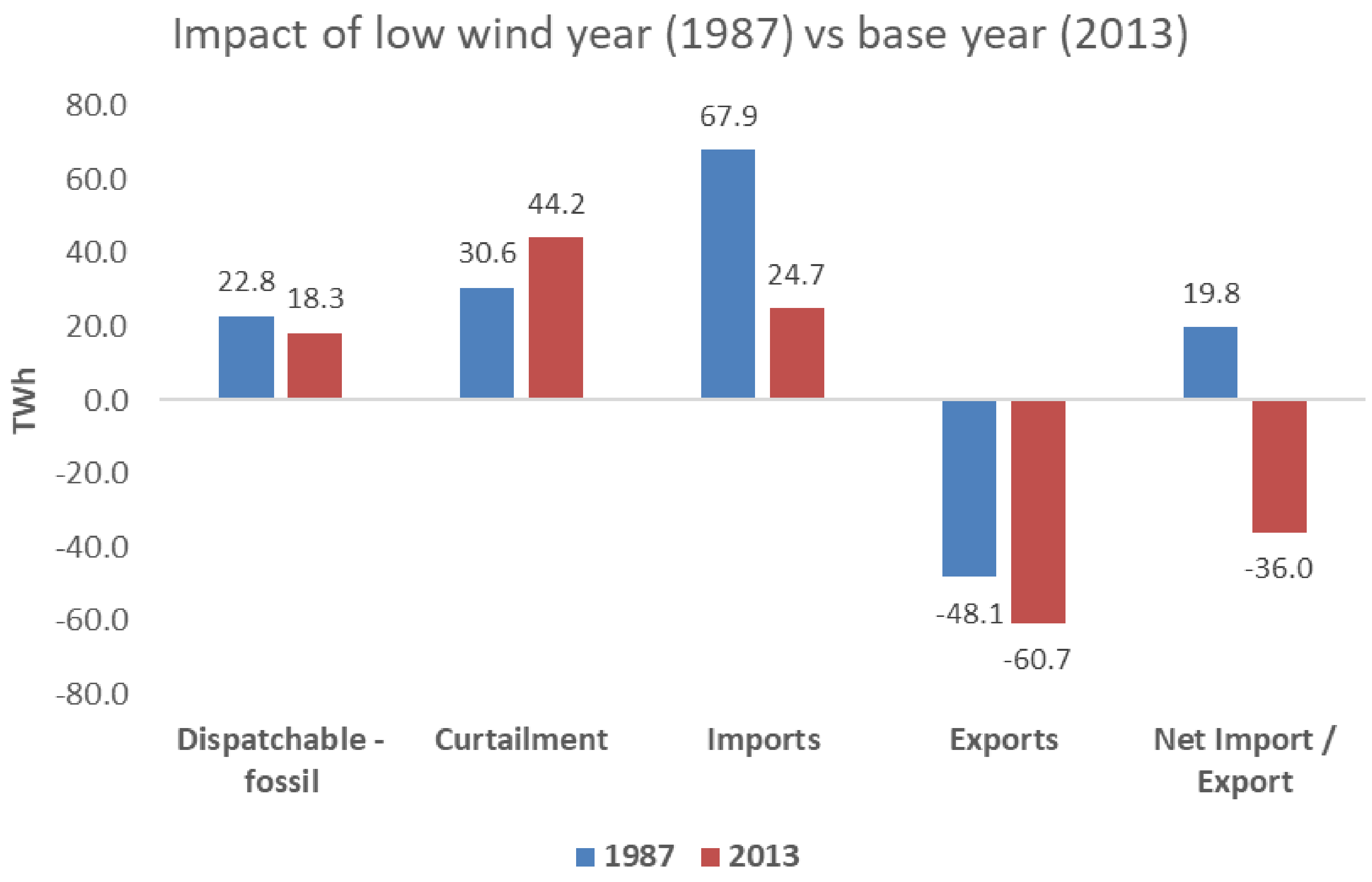
Short term storage:

- Great for near term flexibility
- Won’t solve long term energy deficits

Seasonal scale storage or readily accessible fuel sources required:

- Key role for Gas + CCS or Hydrogen power in future

System Impact – low renewables year



- 25% increase in dispatchable gas burn
- Total emissions up 10%
- Curtailment down
- Imports up significantly (how clean?)
- Exports down
- GB net importer compared with large net exporter
- Large impact from interconnectors, driven by market prices and comparative renewables availability in rest of Europe.
- Recent history shows risks associated with reliance on imports.

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Conclusions 1

- Future GB electricity system dominated by weather dependent wind & solar
- Annual variability in renewable output can be large
  - > ±10% swings around the mean
- Intersection of low renewables output and high demand determines scale of energy deficit challenge – highly variable year on year.
  - Hourly peak residual demand determines instantaneous capacity requirement
  - Sensitive to shape of new demand vectors like EV charging and electrified heating

Key points

1. Annual variations lead to significant changes in modelled system behaviour
2. Single year analysis not adequate to understand system challenges
3. Clear role for short-duration storage to manage system peaks at hourly / daily level

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Conclusions 2

- At scale of weeks and months - residual energy deficits can be very large
  - Truly long duration storage or dispatchable power backed by readily accessible fuel sources are required
  - Role for clean 'dispatchable' power sources like Gas CCS or Hydrogen for Power to replace continuing reliance on unabated gas in medium term.

International lessons

- Conclusions presented are specific to a wind dominated GB system
- Likely similar lessons for other countries seeking to decarbonise but the scale and nature of the challenge is likely to be different region to region.
- Solar dominated system may be more synergistic with batteries than wind