ERA 5 calibration to Elexon power

S. Gomez[1]

[1]School of Mathematics, University of Edinburgh

2025-11-04

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Calibration to power

Updates

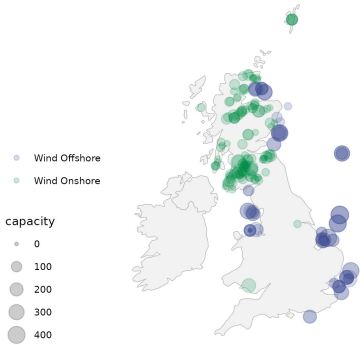
- Curtailment data to obtain potential generation
- ERA 5 wind speed conversion to power
- Power curve refinement

ERA5 vs Elexon generation

Calibrate a ERA5 driven estimate to actual observed output accounting for spatiotemporal properties.

ERA5 at wind farms

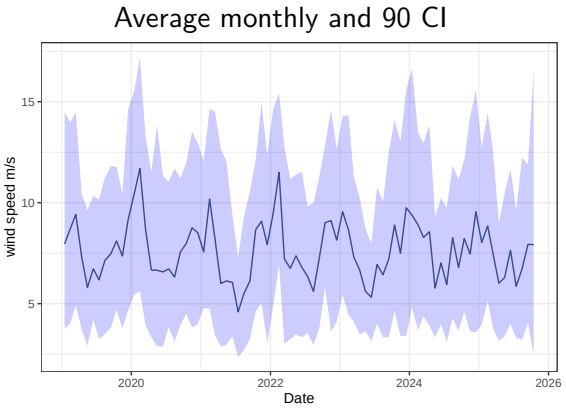
Elexon wind farms map (2025)



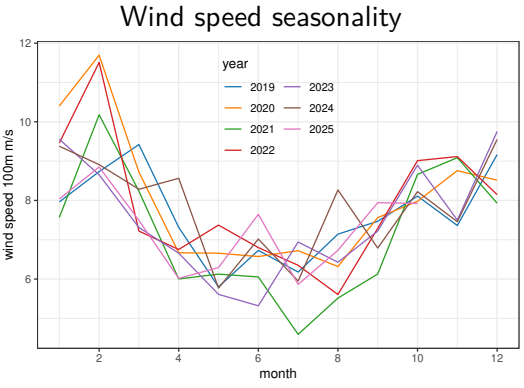
ERA5

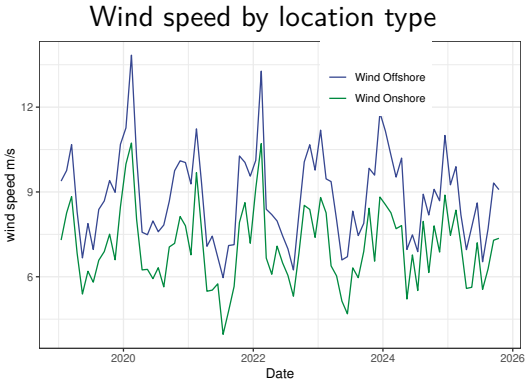
Characteristics

- 5th generation of ECMWF's global reanalysis
- Spatial resolution $0.25^\circ \times 0.25^\circ$ (31km $\times$ 31 km at equator)
- Hourly temporal resolution
- Heights: 10m, 100m



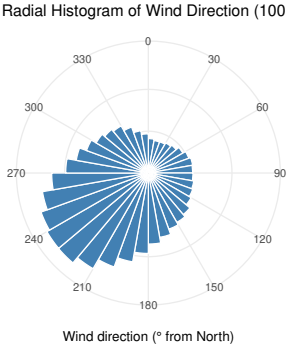
ERA5 series


Wind speed seasonality
year
2019
2020
2021
2022
2023
2024
2025
wind speed 100m m/s
month
12
10
8
6
2
4
6
8
10
12


Wind speed by location type
Wind Offshore
Wind Onshore
wind speed m/s
Date
12
9
6
2020
2022
2024
2026

ERA5 wind direction at wind farms

Wind direction frequency

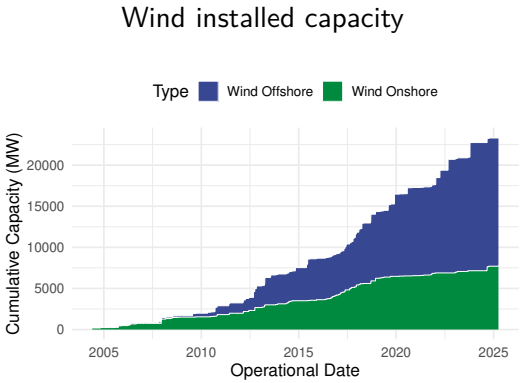


Seasonal patterns

Elexon data

BMU wind data

- 150 wind farms split in over 216 units
- Total capacity: 27 GW
- Half hourly resolution
- Records starting in 2019
- Curtailment (pending)
- Location / turbine data unavailable



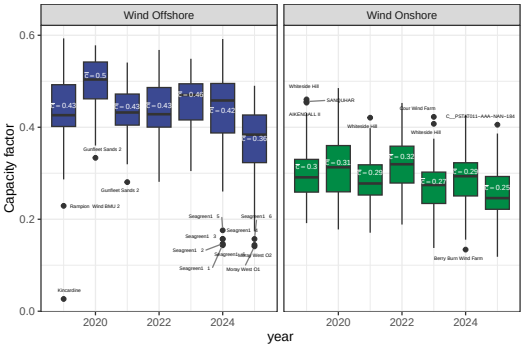
BMU wind data

BMU wind generation (2024)

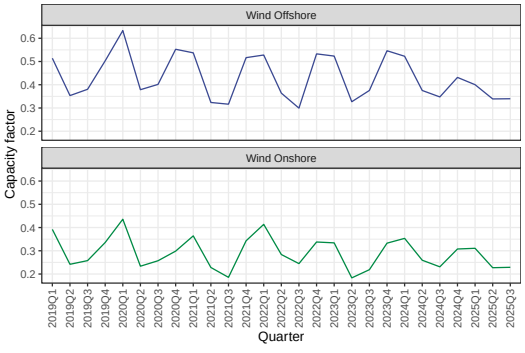
Type	Generation (GWh)	Curtailment	Potential	Capacity (MW)	Number of BMUs	CF	PF
Wind Offshore	46,907	4,902	51,810	15,563	80	0.42	0.47
Wind Onshore	16,254	3,363	19,617	7,860	123	0.29	0.34
Total	63,162	8,266	71,427	23,423	203	0.37	0.42

Capacity factor through time

Capacity factor by year

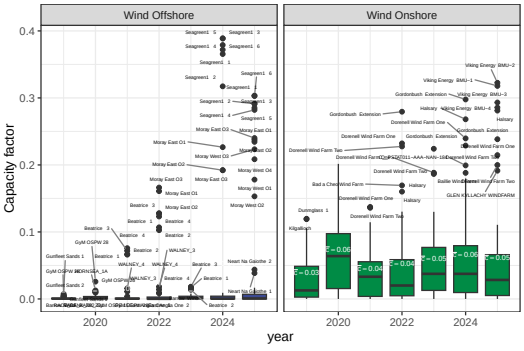


Capacity factor by quarter

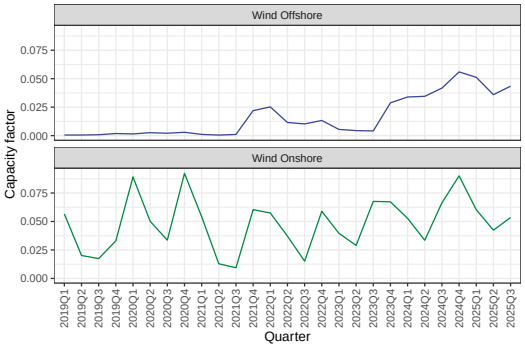


Curtailment through time

Curtailment by year

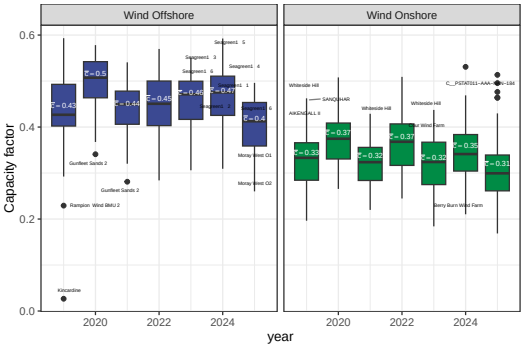


Curtailment seasonality

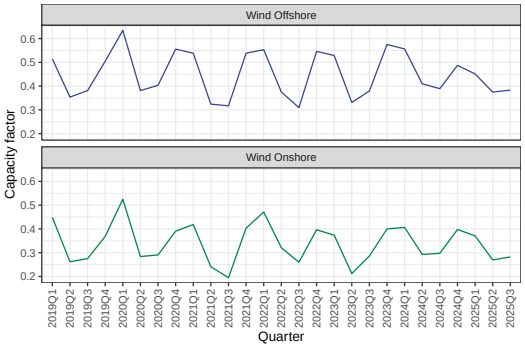


Potential generation

Potential by year



Potential seasonality



Renewable energy planning database (REPD)

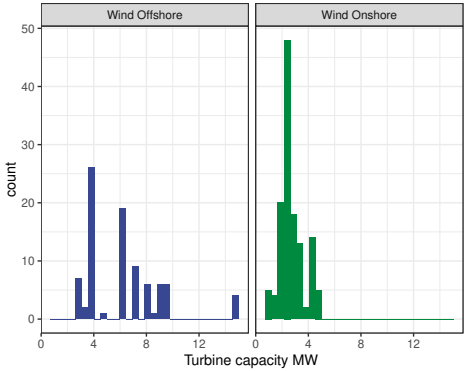
- Official UK government renewable data
- Over 800 wind farms listed as operational
- Coordinates available
- Also available:
  - Development status
  - Number of turbines
  - Turbine capacity
  - Turbine height (for some only)

REPD wind farms

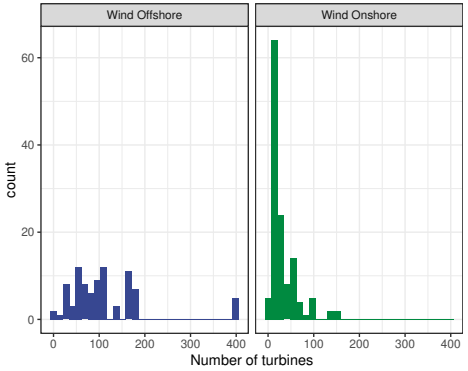
Type	Development Status	Count	Capacity MW
Wind Offshore	Operational	47	14,679
Wind Offshore	Under Construction	7	7,742
Wind Onshore	Operational	770	14,738
Wind Onshore	Under Construction	37	1,779
Total	-	861	38,938

Turbine data available

Turbine capacity histogram



Number of turbines histogram

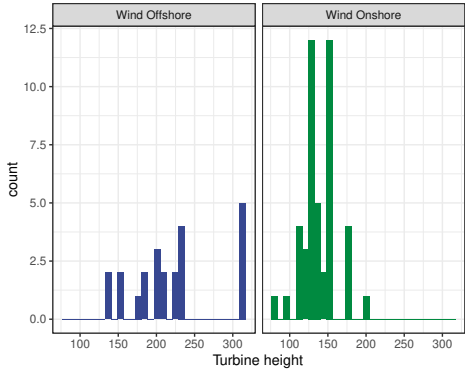


Turbine data available

Turbine Height availability

Type	Height available	Average height (m)	count
Wind Offshore	FALSE	222.0	23
Wind Offshore	TRUE	NaN	64
Wind Onshore	FALSE	137.7	45
Wind Onshore	TRUE	NaN	84

Turbine height histogram



Power conversion

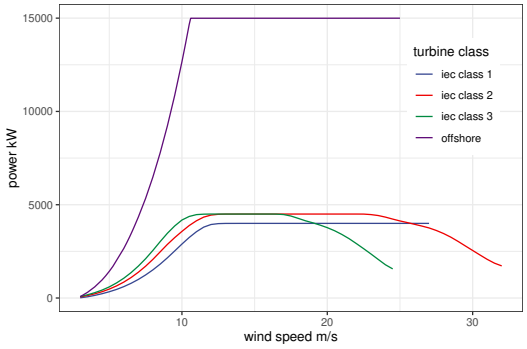
Generic power curves

- Using 3 generic power curves
- Offshore plus the IEC 3 classes
- Assigning class based on GWA mean wind speed at location
- Rescaling rated power to turbine capacity

IEC classification

Class	Mean wind speed at hub height (m/s)	Extreme 10-min gust (m/s)	Typical sites
I	10	70	Very windy / exposed sites
II	8.5	59.5	Moderate wind sites
III	7.5	52.5	Low-wind / inland sites

Generic power curves (PC_k)



Power estimate based on generic power curves

For each location i we have: observed power p_i, number of turbines n_i, turbine capacity c_i, turbine height v_i, and wind speed w_i.

- Map location to a rescaled power curve $\widetilde{\mathsf{PC}}_k$
- Estimate wind farm power in GWh

$$\tilde{p}_i = \widetilde{\mathsf{PC}}_k(w_i) \times n_i$$

ERA5 based estimates vs Elexon 2025

PC on GWA mean wind speed $\tilde{p}_i$

Estimate using Weibull distribution $\hat{p}_i$

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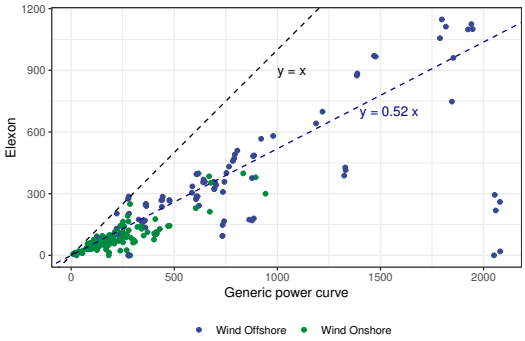

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Next Steps

- Learn power curve from history
- Quantile mapping calibration