

# ERA 5 calibration to Elexon power

S. Gomez<sup>1</sup>

<sup>1</sup>School of Mathematics, University of Edinburgh

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# Table of contents I

1 Calibration to power

2 ERA5

3 Elexon data

4 Power conversion

Calibration to power

# Updates

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

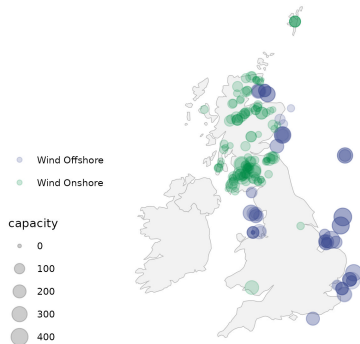
# ERA5 vs Elexon generation

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

**ERA5 at wind farms**



**Elexon wind farms map (2025)**

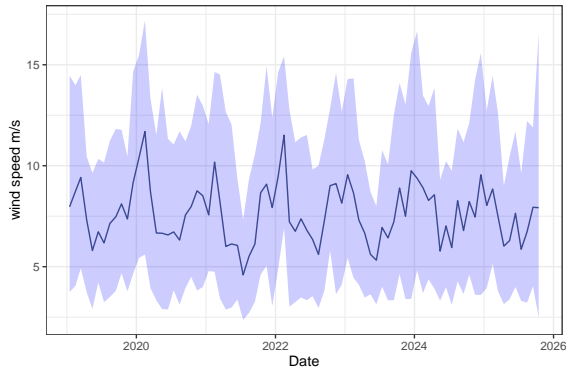


ERA5

# Characteristics

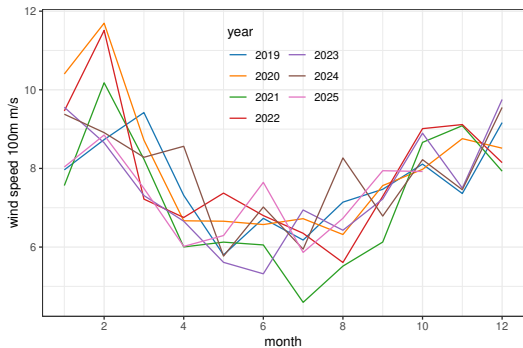
- 5th generation of ECMWF's global reanalysis
- Spatial resolution  $0.25^\circ \times 0.25^\circ$  (31km  $\times$  31 km at equator)
- Hourly temporal resolution
- Heights: 10m, 100m

Average monthly wind speed and 90 CI

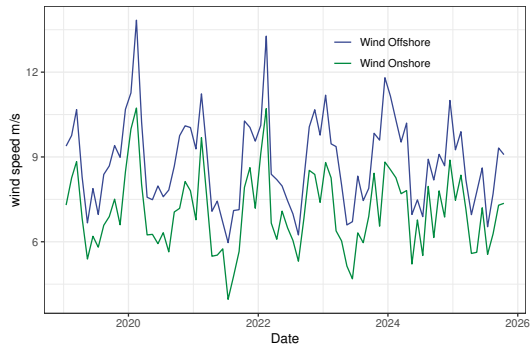


# ERA5 series

## Wind speed seasonality



## Wind speed by location type

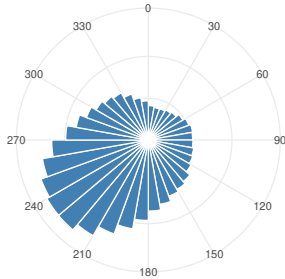




# ERA5 wind direction at wind farms

## Wind direction frequency

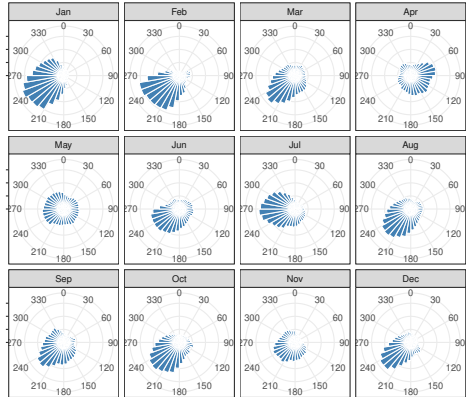
Radial Histogram of Wind Direction (100 m)



Wind direction ( $^{\circ}$  from North)

## Seasonal patterns

Radial Histogram of Wind Direction (100 m)



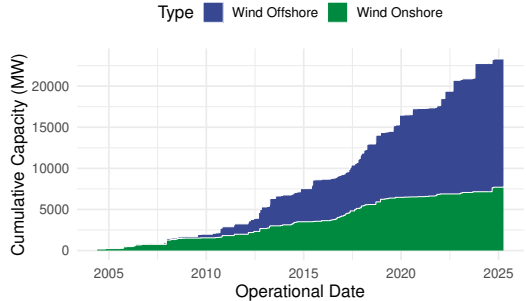
Wind direction ( $^{\circ}$  from North)

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

## Wind installed capacity



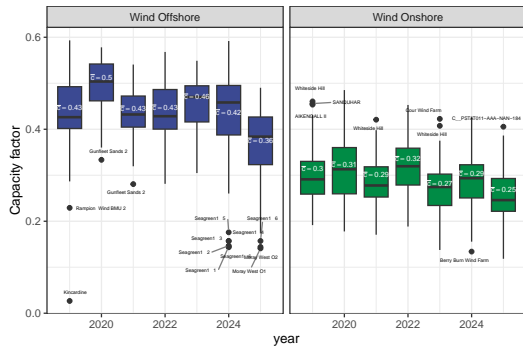
# BMU wind data

## BMU wind generation (2024)

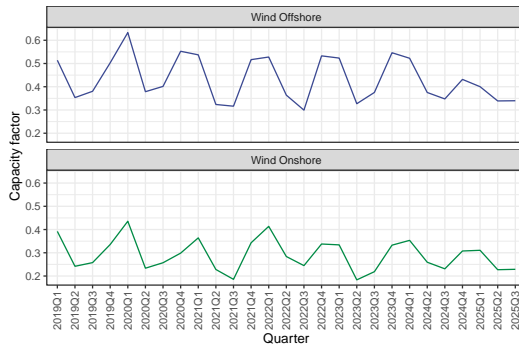
Type	Generation (GWh)	Curtailement	Potential	Capacity (MW)	Number of BMUs	CF	PF
Wind Offshore	46,907	4,902	51,810	15,563	80	0.42	0.47
Wind Onshore	16,254	3,363	19,617	7,860	123	0.29	0.34
Total	63,162	8,266	71,427	23,423	203	0.37	0.42

# Capacity factor through time

## Capacity factor by year

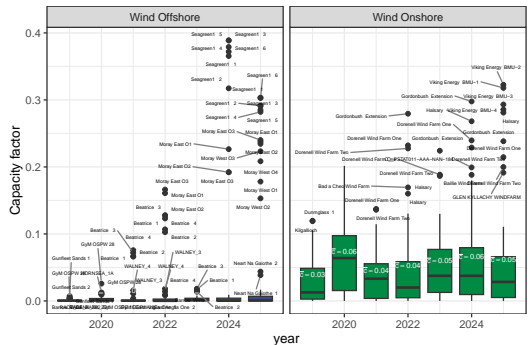


## Capacity factor by quarter

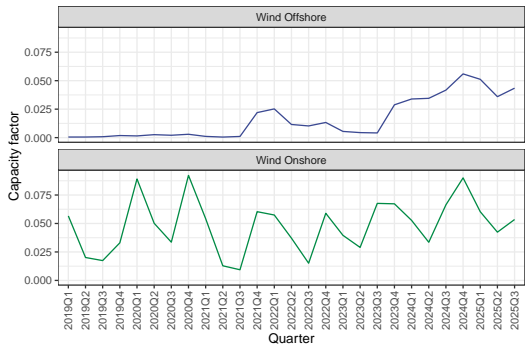


# Curtailment through time

Curtailment by year

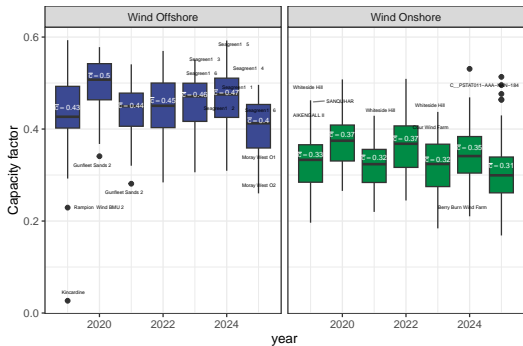


Curtailment seasonality

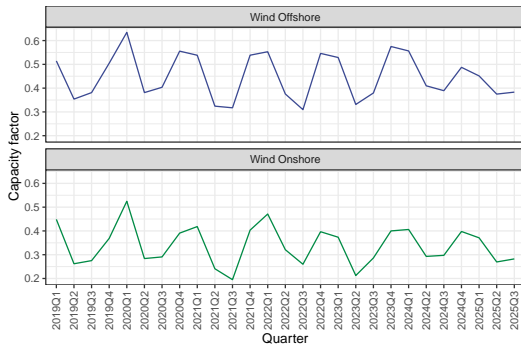


# Potential generation

## 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)

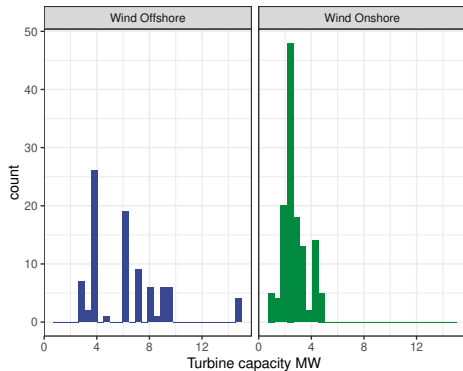
## REPD wind farms

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

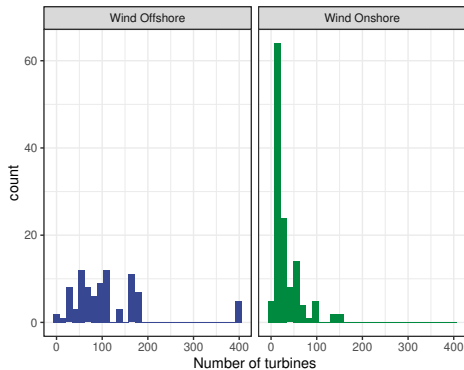


# Turbine data available

## Turbine capacity histogram



## Number of turbines histogram

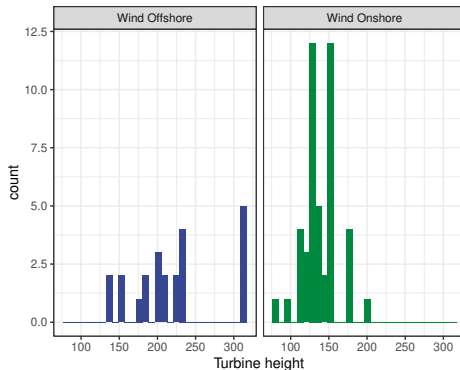


# Turbine data available

## 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

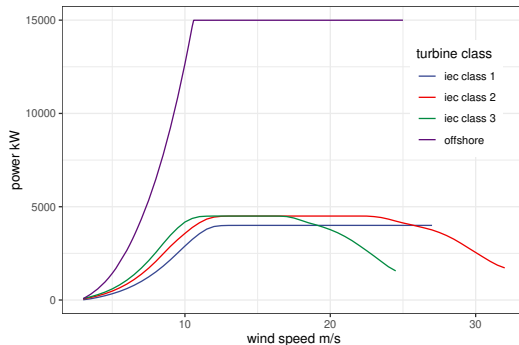
# Generic power curves

- 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

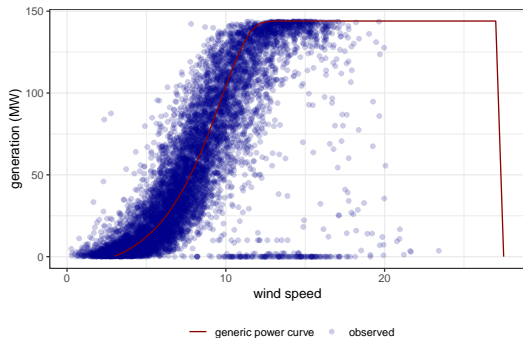
For each location  $i$  we have: observed power  $p_i$ , number of turbines  $n_i$ , turbine capacity  $c_i$ , turbine height  $v_i$ , and wind speed  $w_i$ .

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

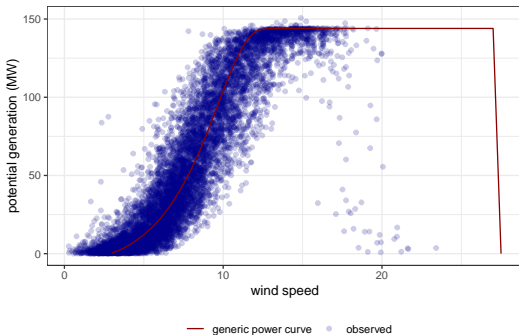
$$\tilde{p}_i = \widetilde{\text{PC}}_k(w_i) \times n_i$$

# Generic power curves vs observed data - Fall Rig

## Comparison with raw generation

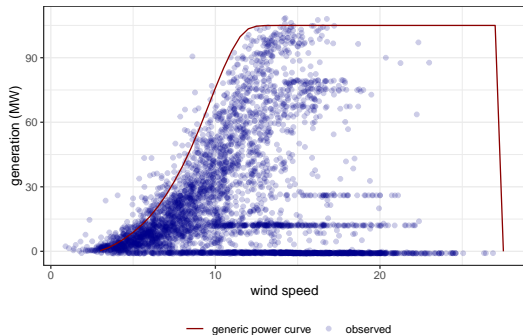


## Comparison with potential generation

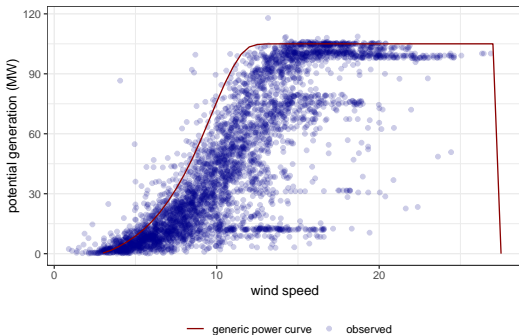


# Generic power curves vs observed data - Viking

## Comparison with raw generation

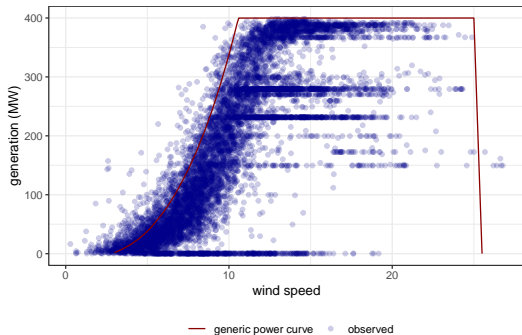


## Comparison with potential generation

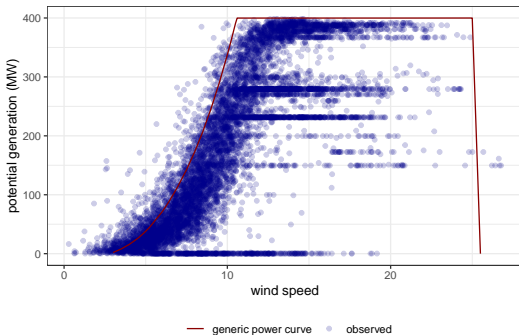


# Generic power curves vs observed data - Hornsea 1

Comparison with raw generation



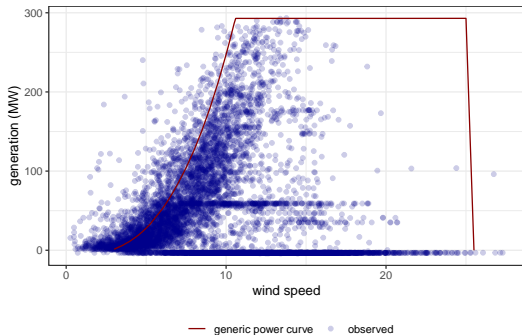
Comparison with potential generation



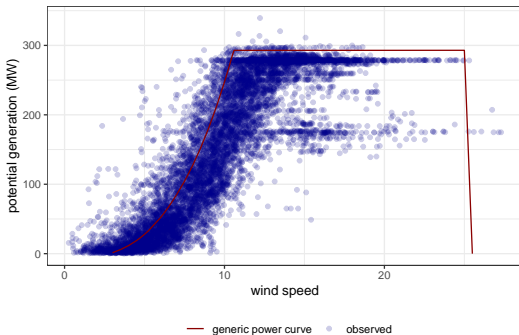


# Generic power curves vs observed data - Seagreen 1

## Comparison with raw generation



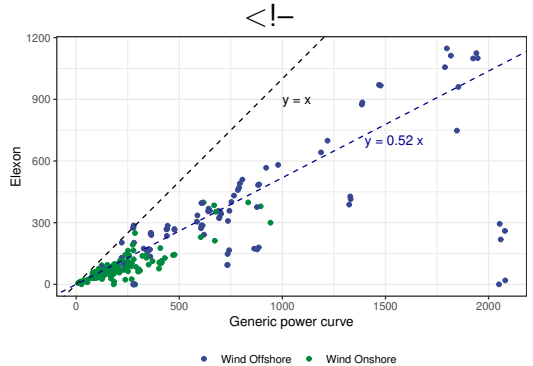
## Comparison with potential generation



# 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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# Next Steps

- Learn power curve from history
- Quantile mapping calibration