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DTU Wind Energy

CREYAP 2021

Acknowledgements:

Orsted

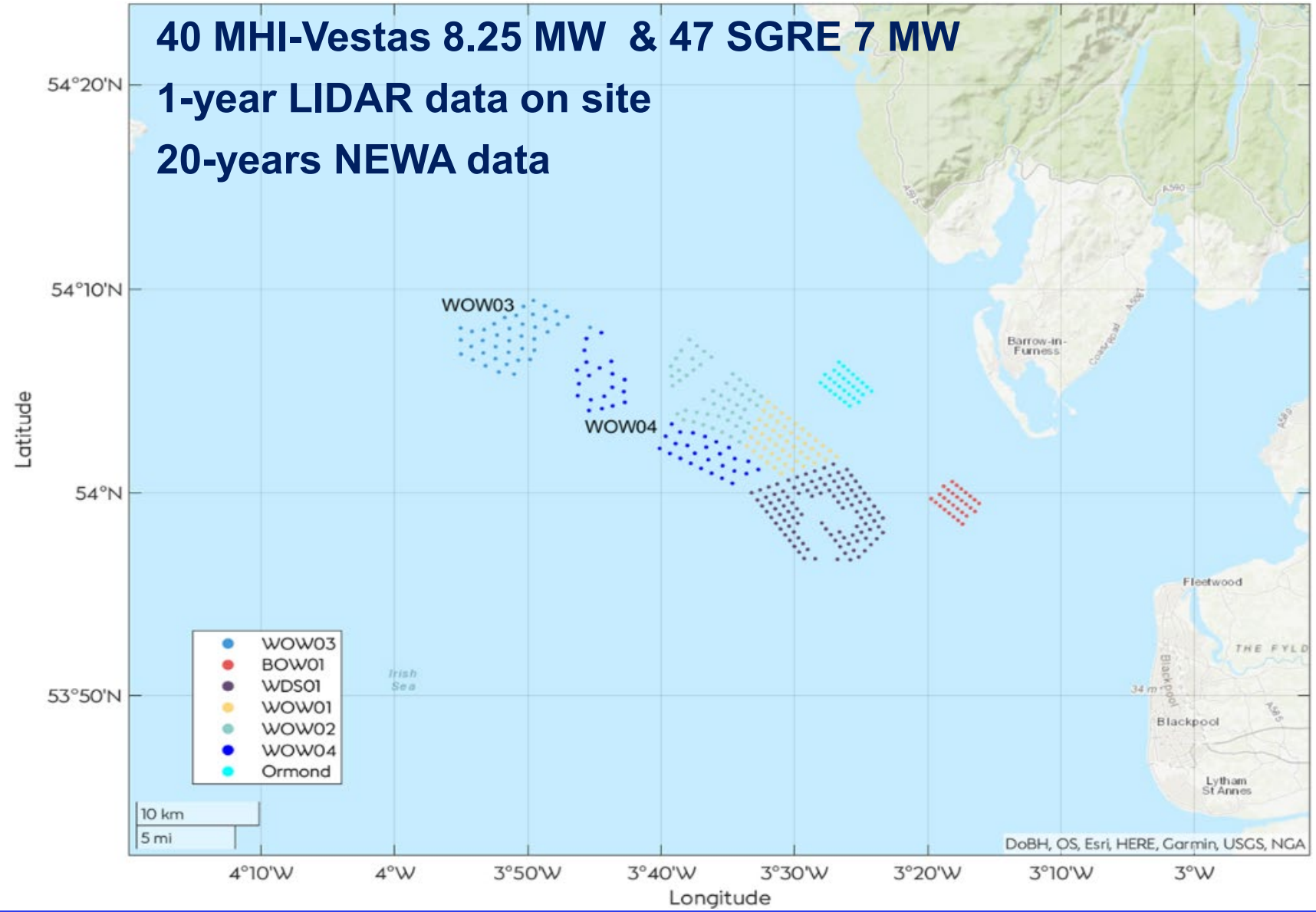
Miriam Marchante Jiménez, Guillermo Gonzalez Rilova, Nicolai Nygaard

Wind
EUROPE

Iva Tkalec, Rébecca Brulé, Lorenzo Morselli, Dominique Tenaerts

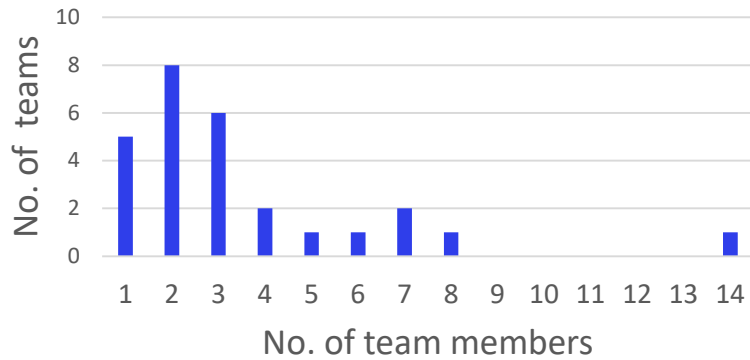


Subject wind farms: Walney 3 and Walney 4

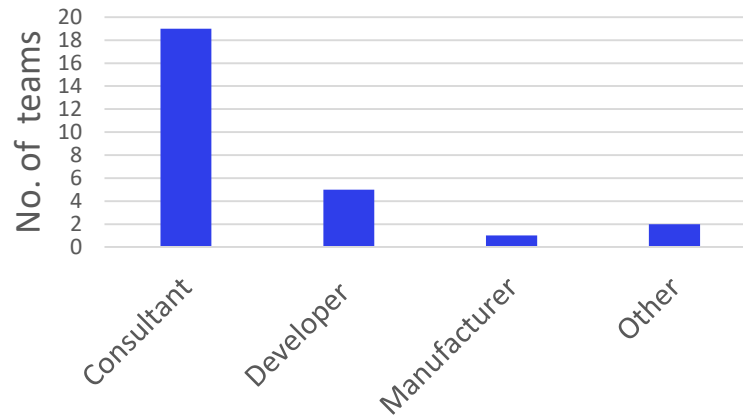


Team profiles (28 entries)

Team size



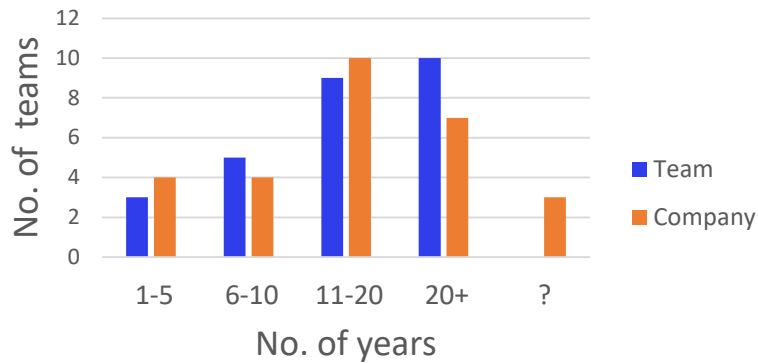
Company type



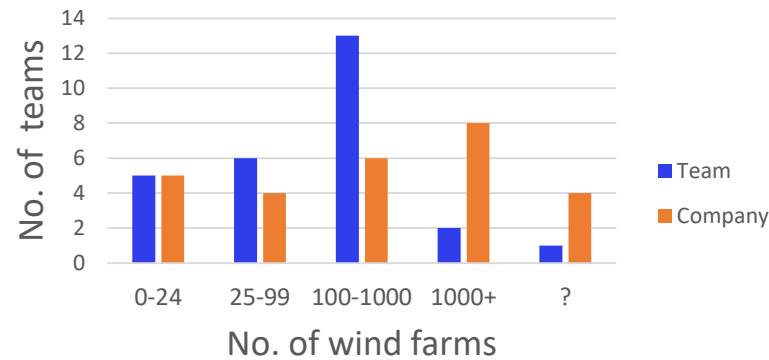
Education and training



Team experience

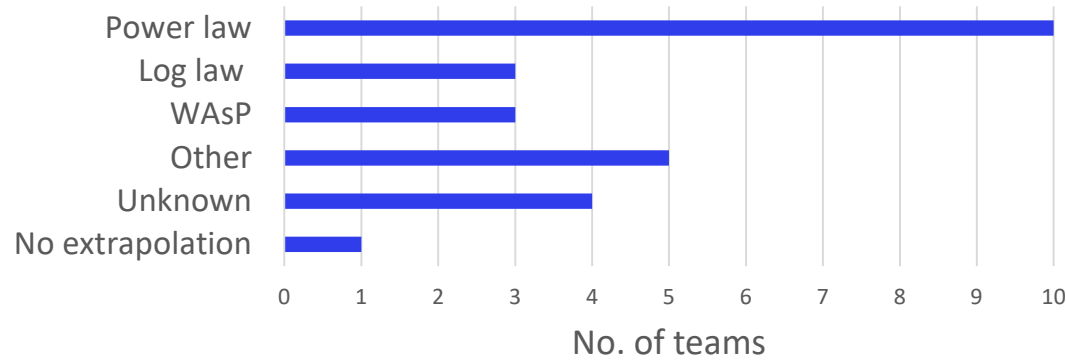


Project portfolio

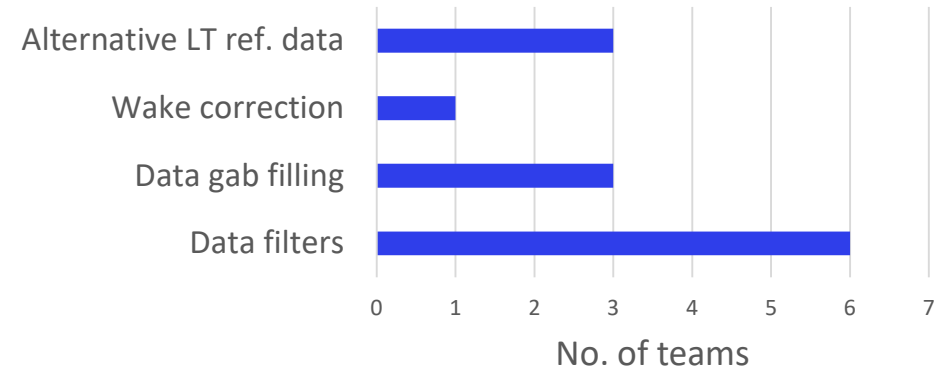


Methodology for wind climate assessment

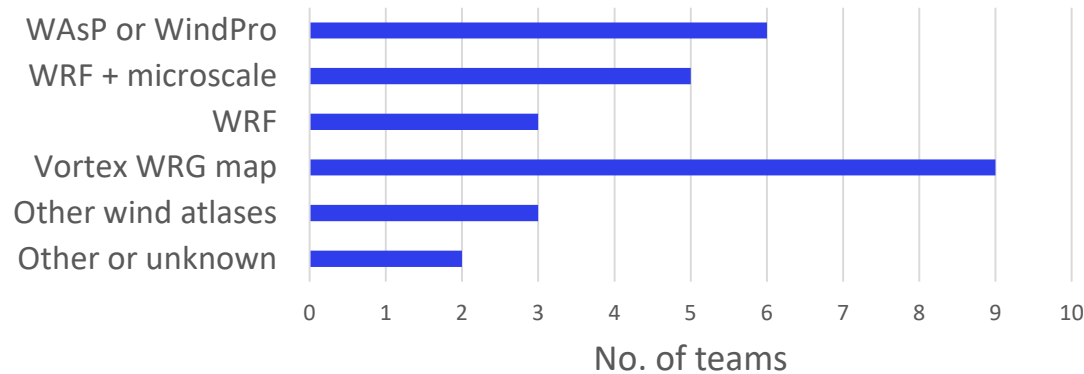
Vertical extrapolation



Alternative methods



Horizontal extrapolation

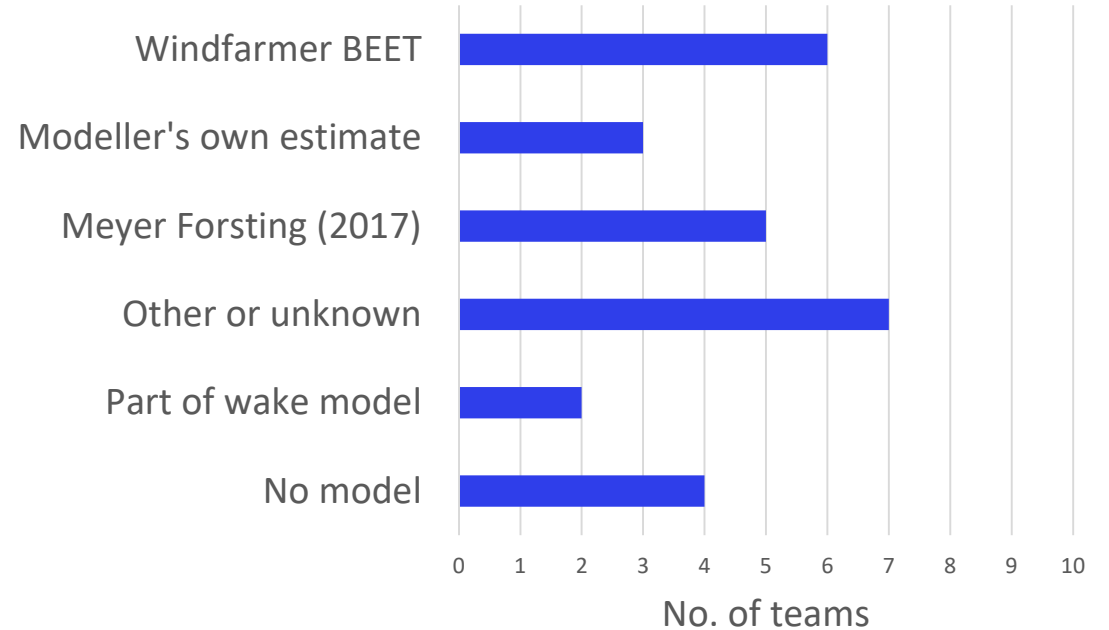


Methodology for turbine interaction

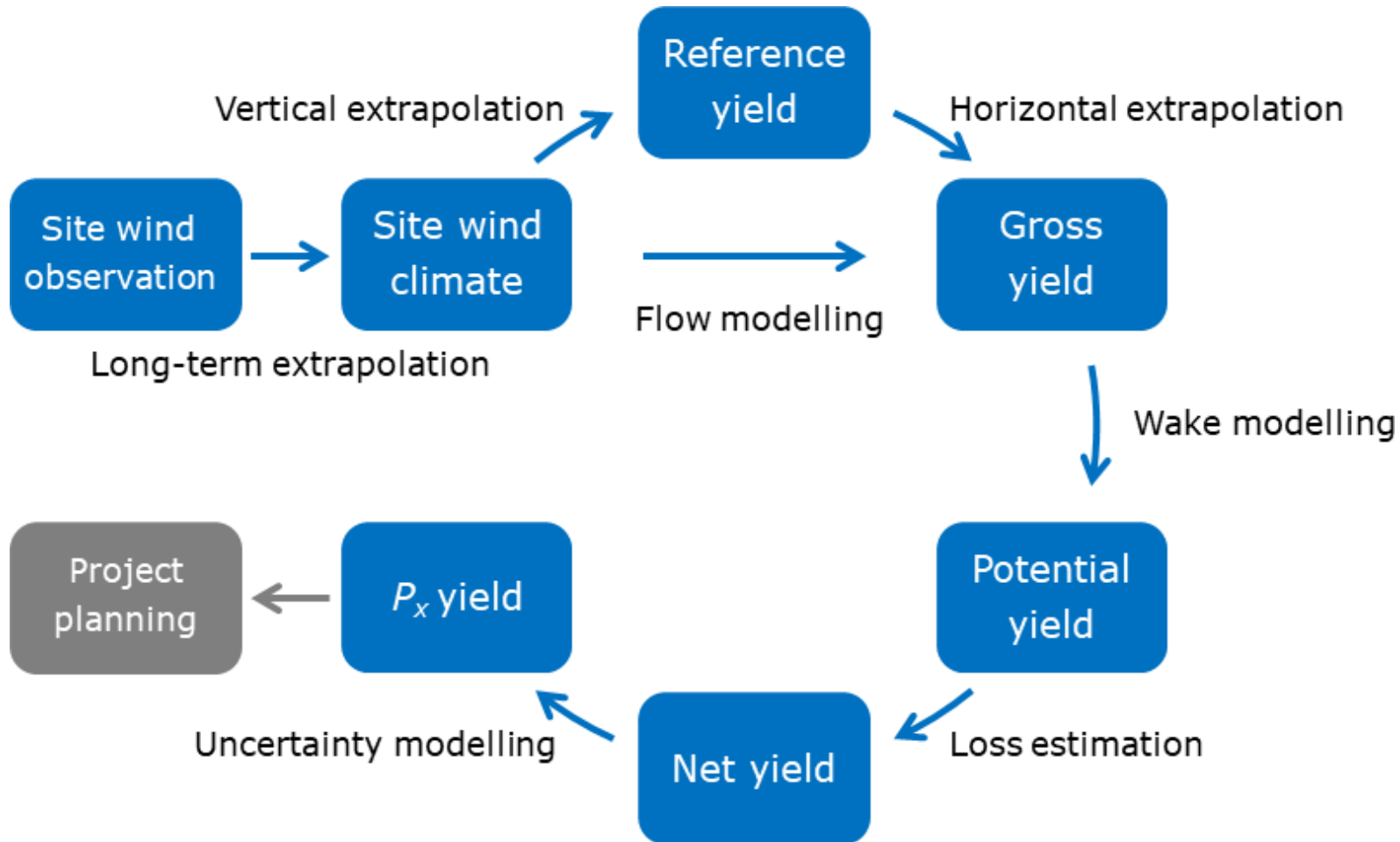
Wake model



Blockage model



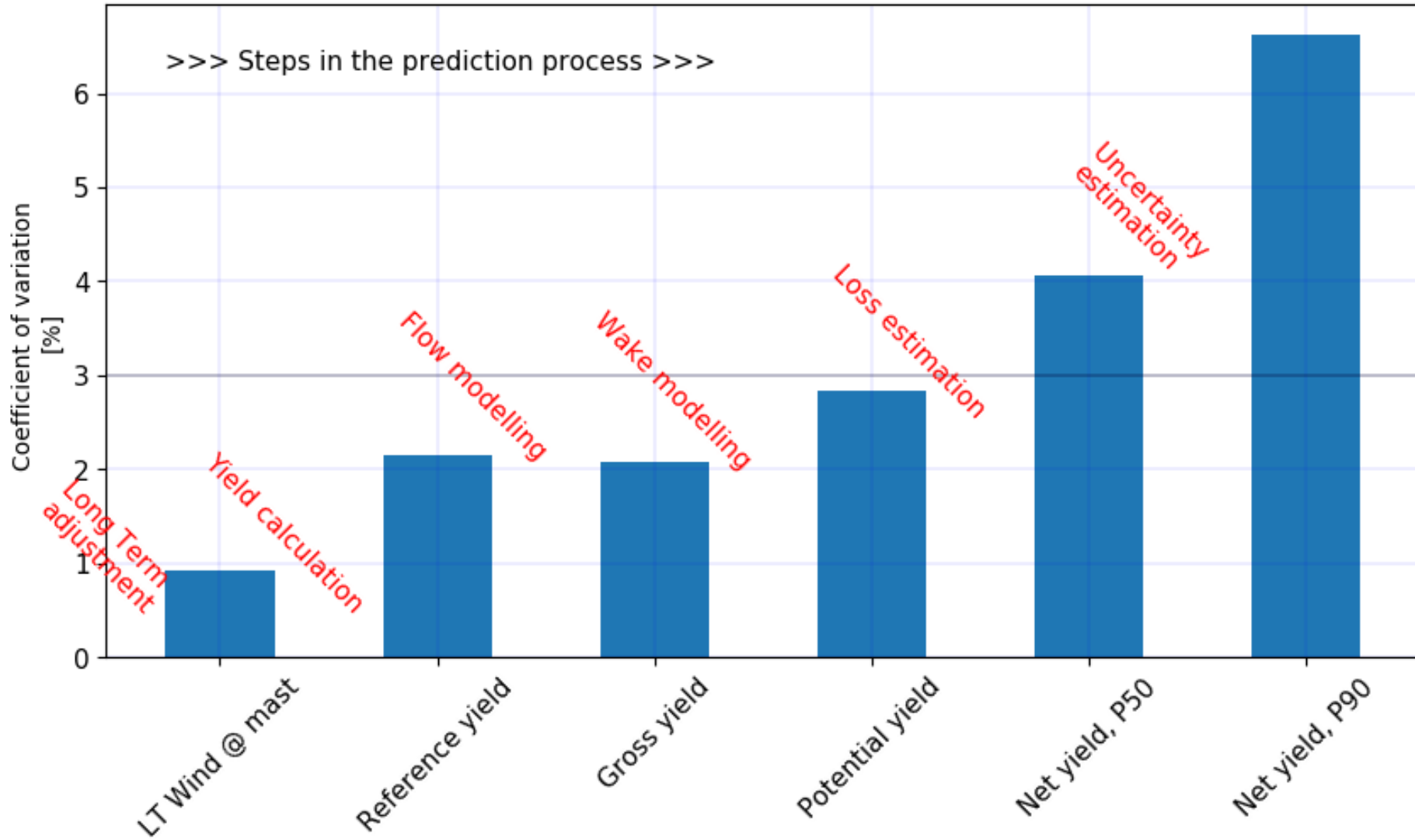
Wind farm energy yield assessment procedure



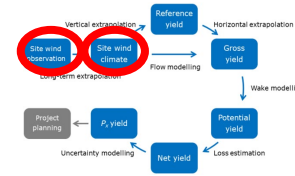
https://orbit.dtu.dk/files/110765218/Offshore_CREYAP_Part_2_final_results_1.pdf

Mortensen *et al.*, 2015

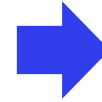
The development of variation across submissions



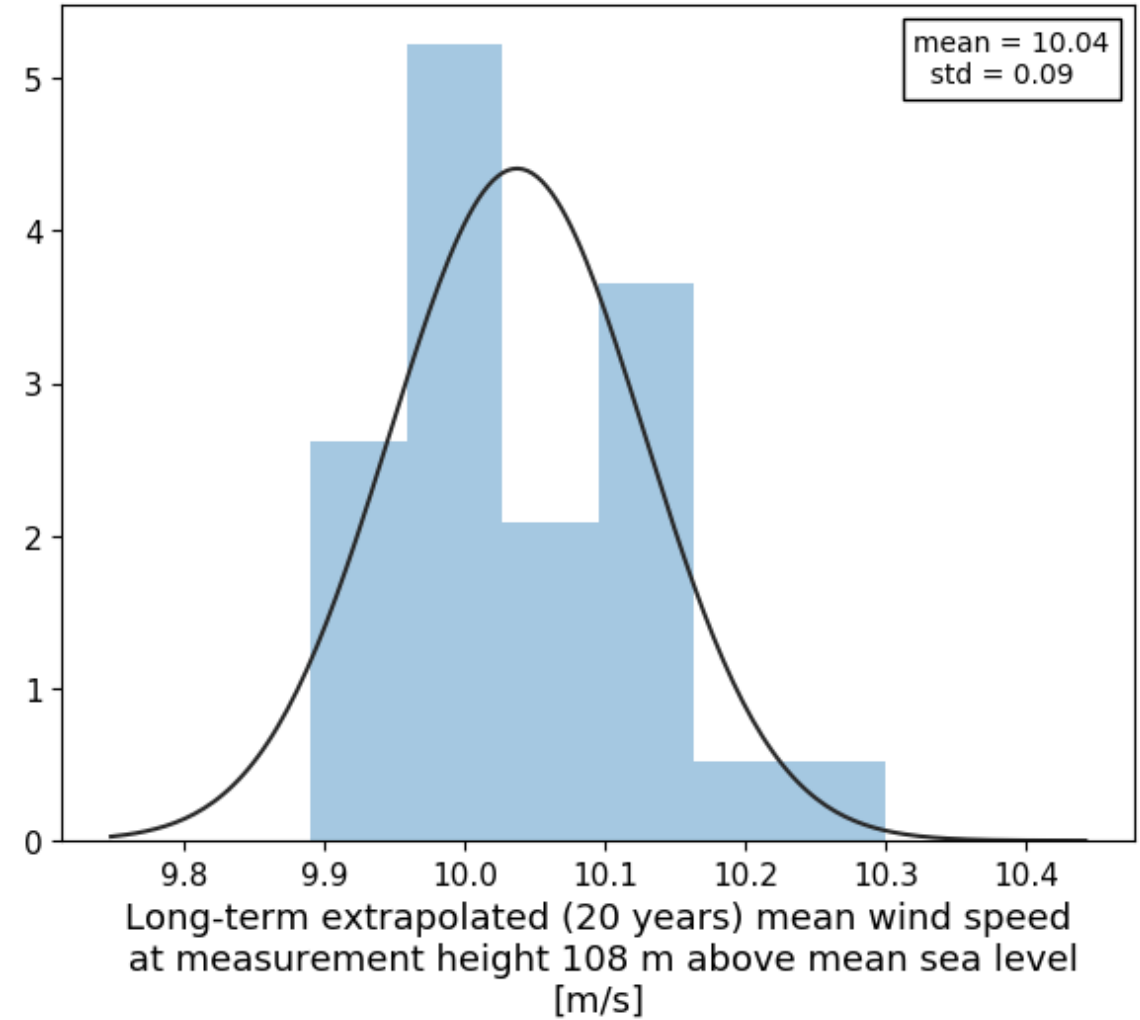
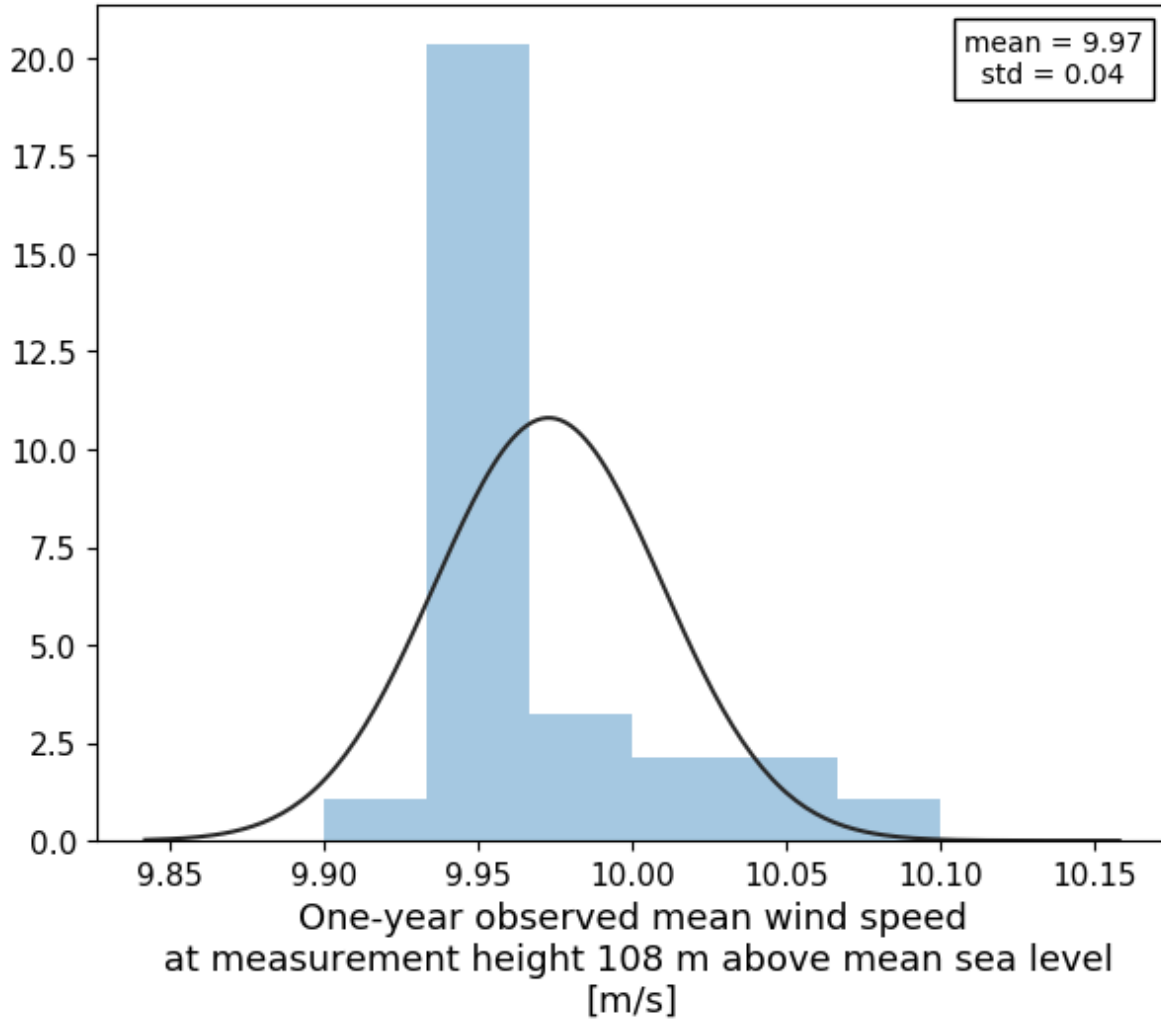
Lidar data and long-term extrapolation



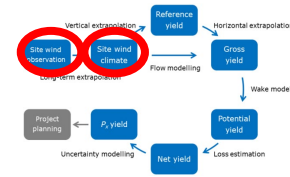
1-year observed mean wind speed at 108 m a.m.s.l.



20-year mean wind speed at 108 m a.m.s.l.



Lidar data and long-term extrapolation



1-year observed mean wind speed at 108 m a.m.s.l.

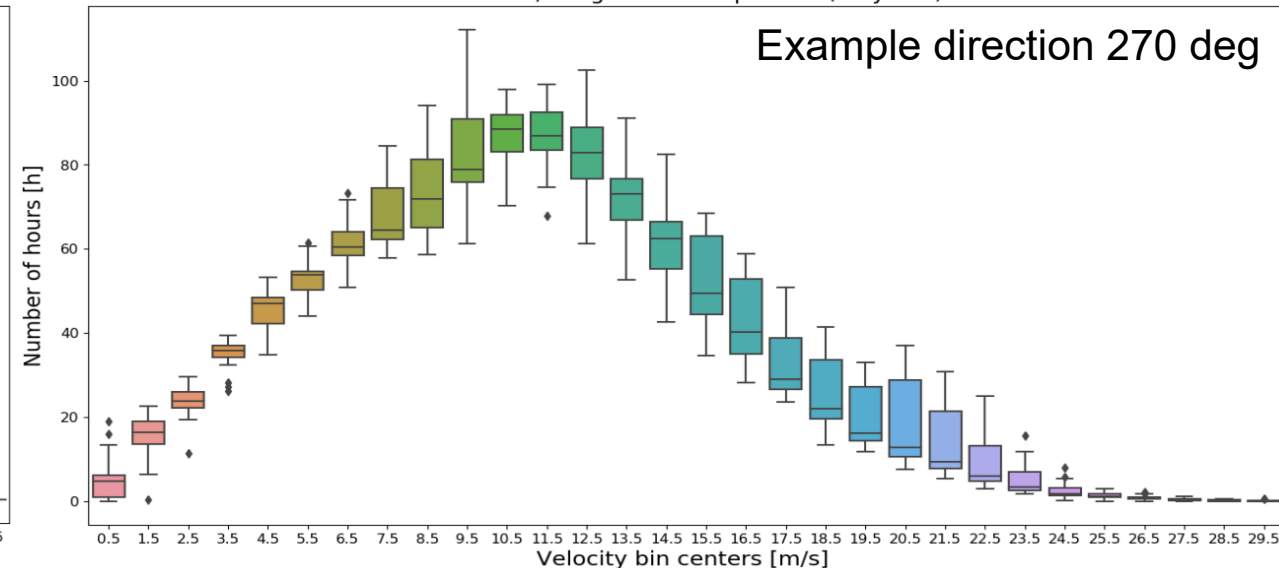
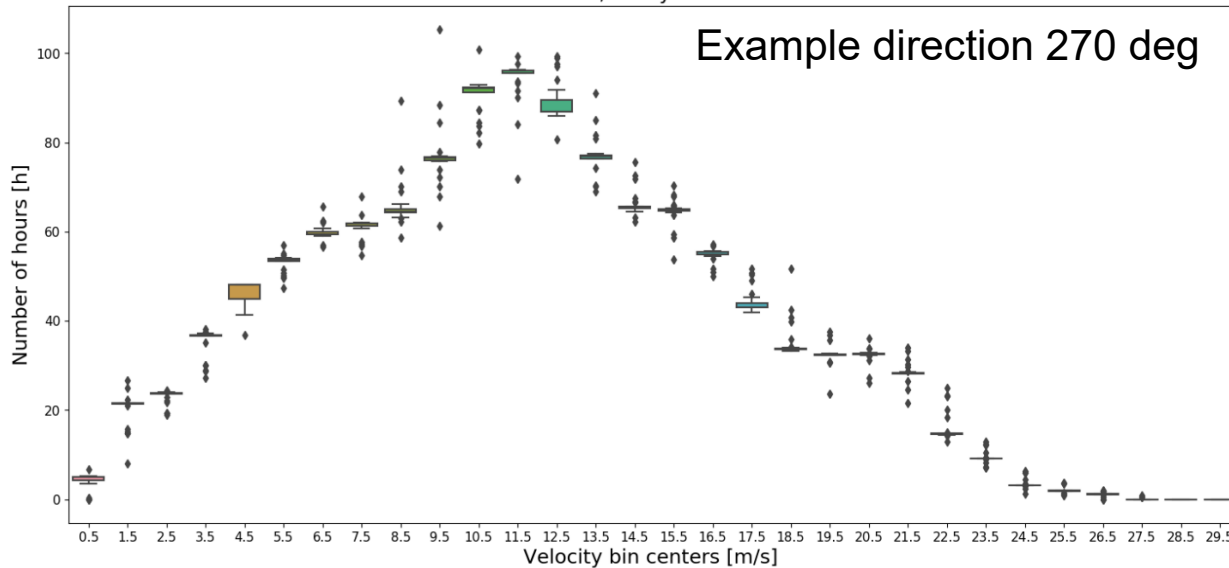
20-year mean wind speed at 108 m a.m.s.l.

Number of hours per year in different wind speed bins and 270 direction bin, One-year observed distribution

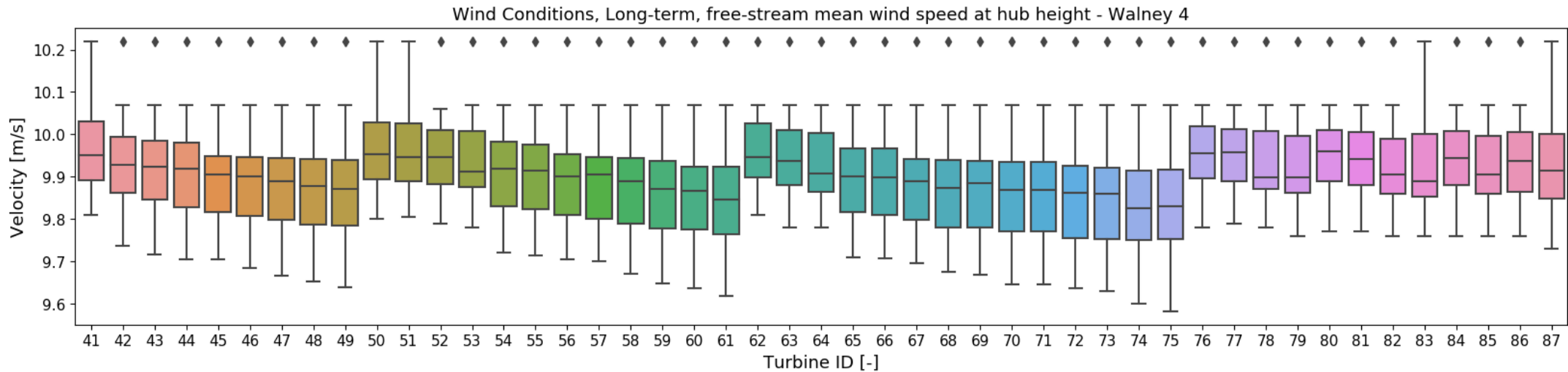
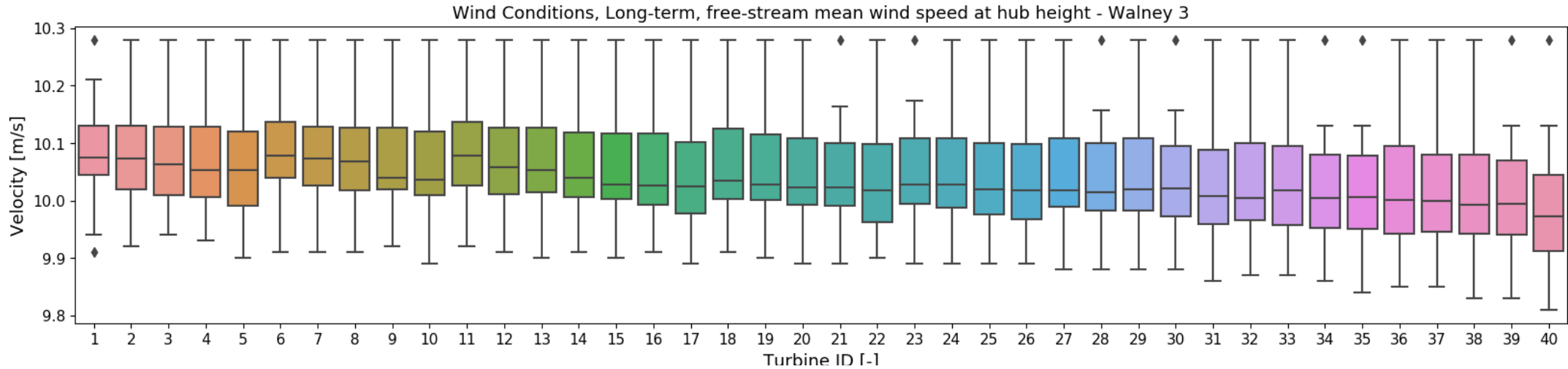
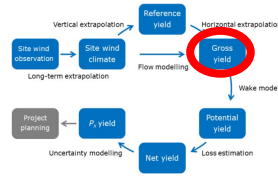
Number of hours per year in different wind speed bins and 270 direction bin, Long-term extrapolated (20 years) distribution

Example direction 270 deg

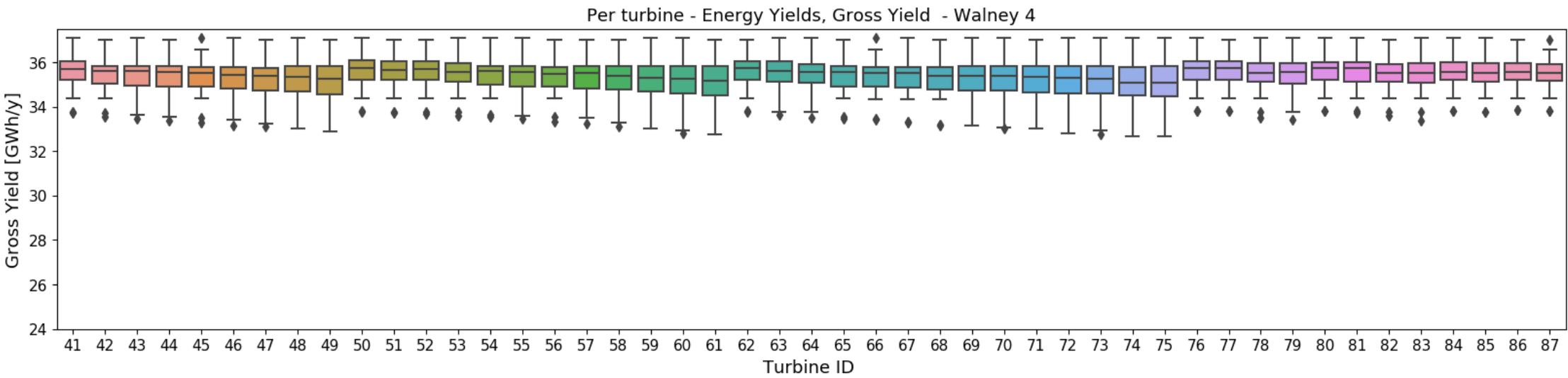
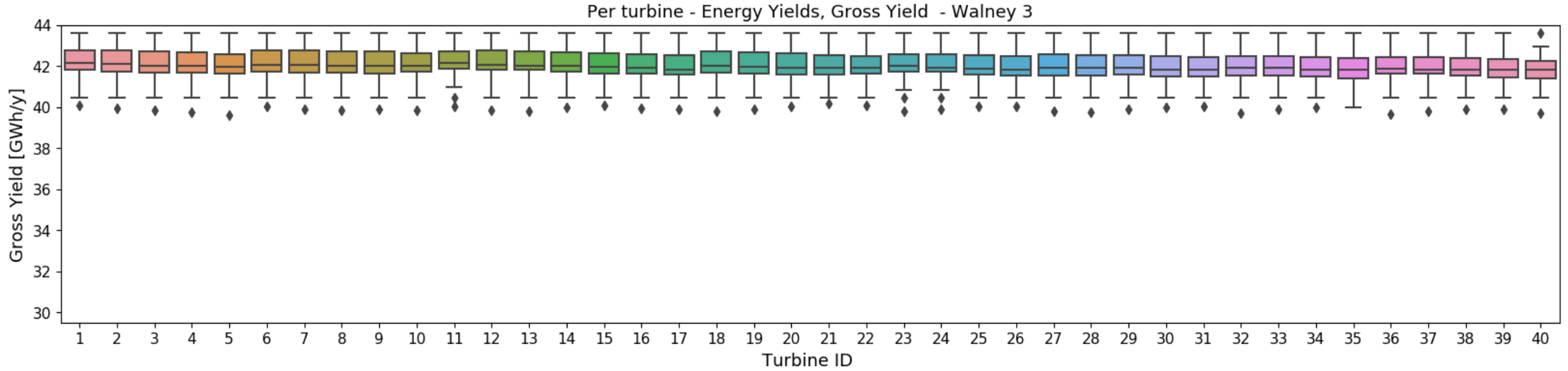
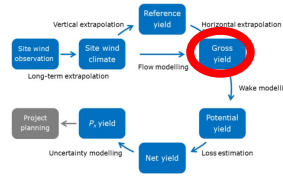
Example direction 270 deg



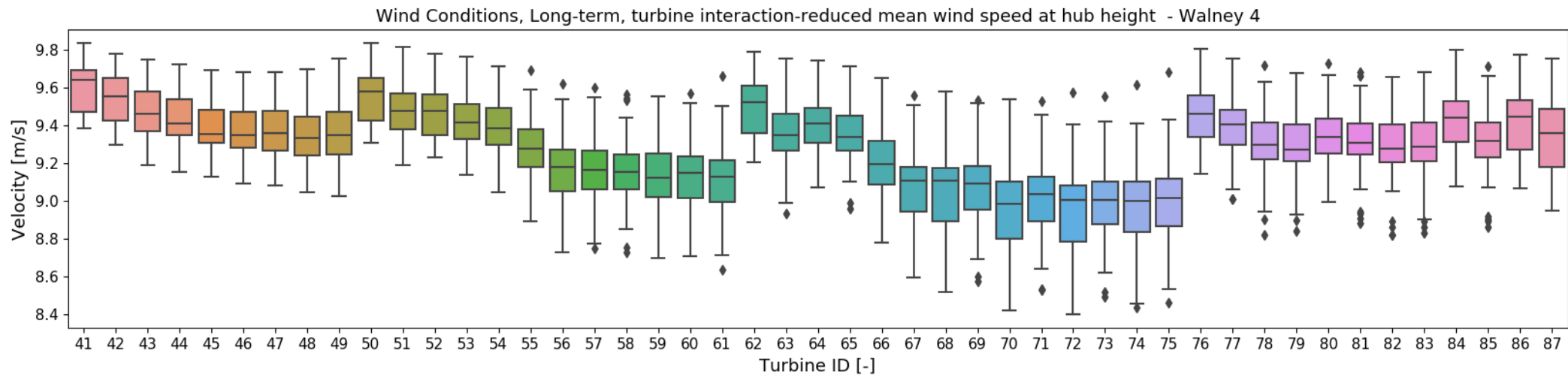
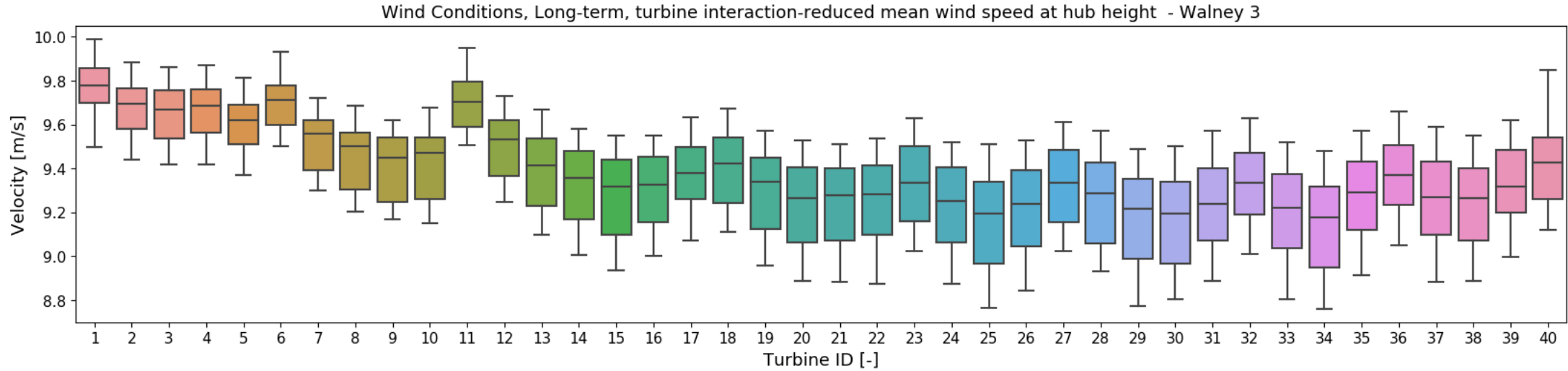
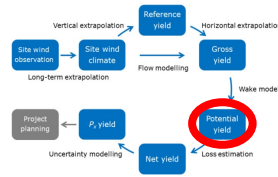
20-y free-stream mean wind speed (per turbine): no wakes



Gross Yield (per turbine): based on climate at each turbine location and power curve

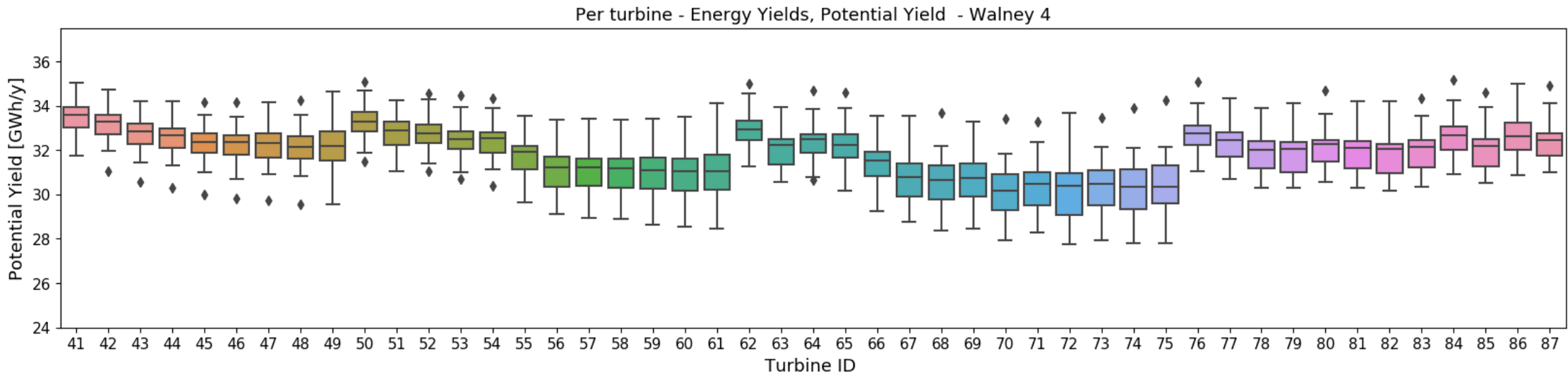
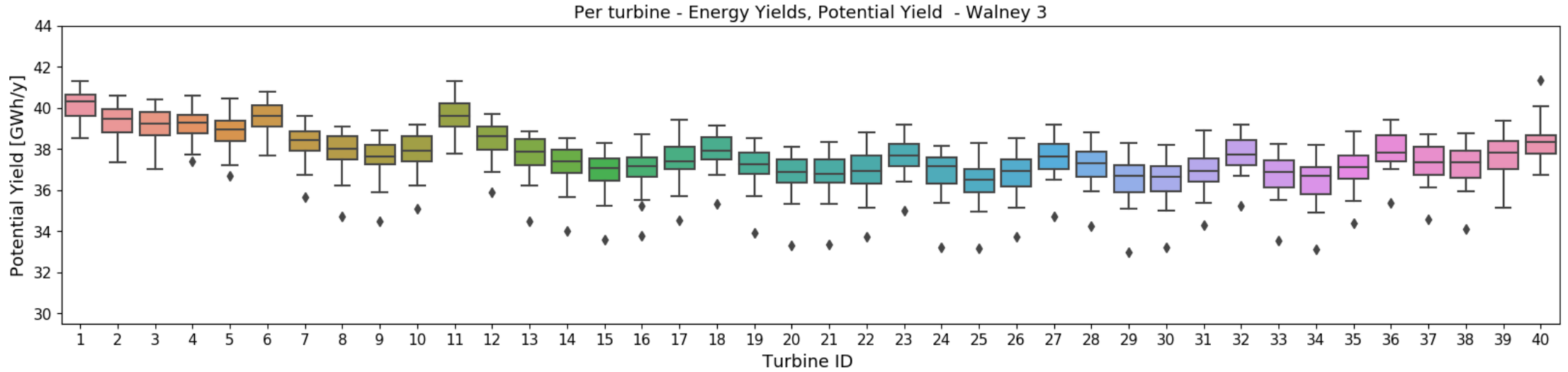
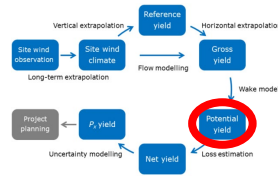


20-y mean wind speed (per turbine): includes reduction due to turbines

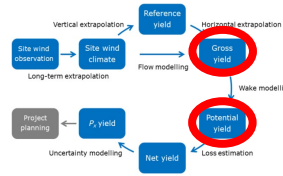


Potential Yield (per turbine)

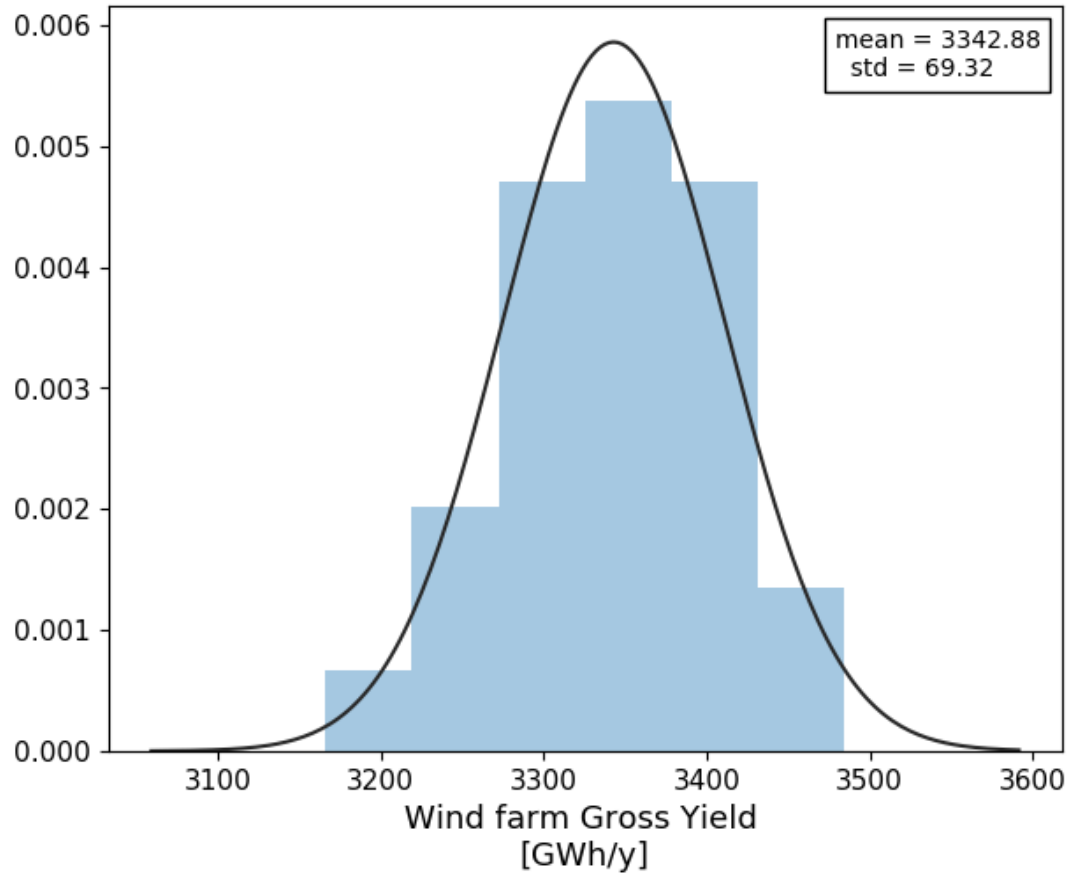
estimate includes losses due to turbine interactions



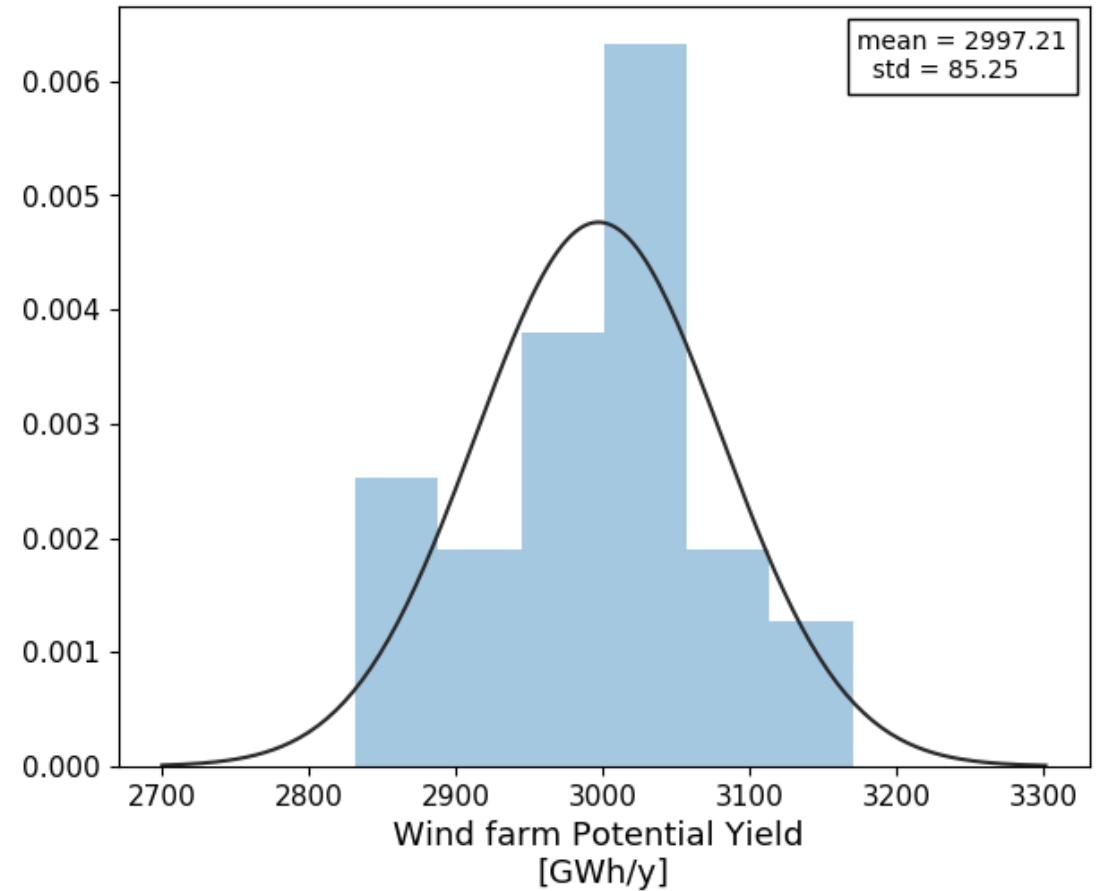
Accounting for losses due to turbine interactions



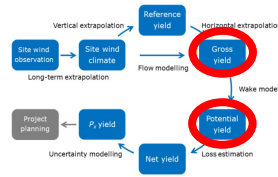
Gross Yield
no wakes



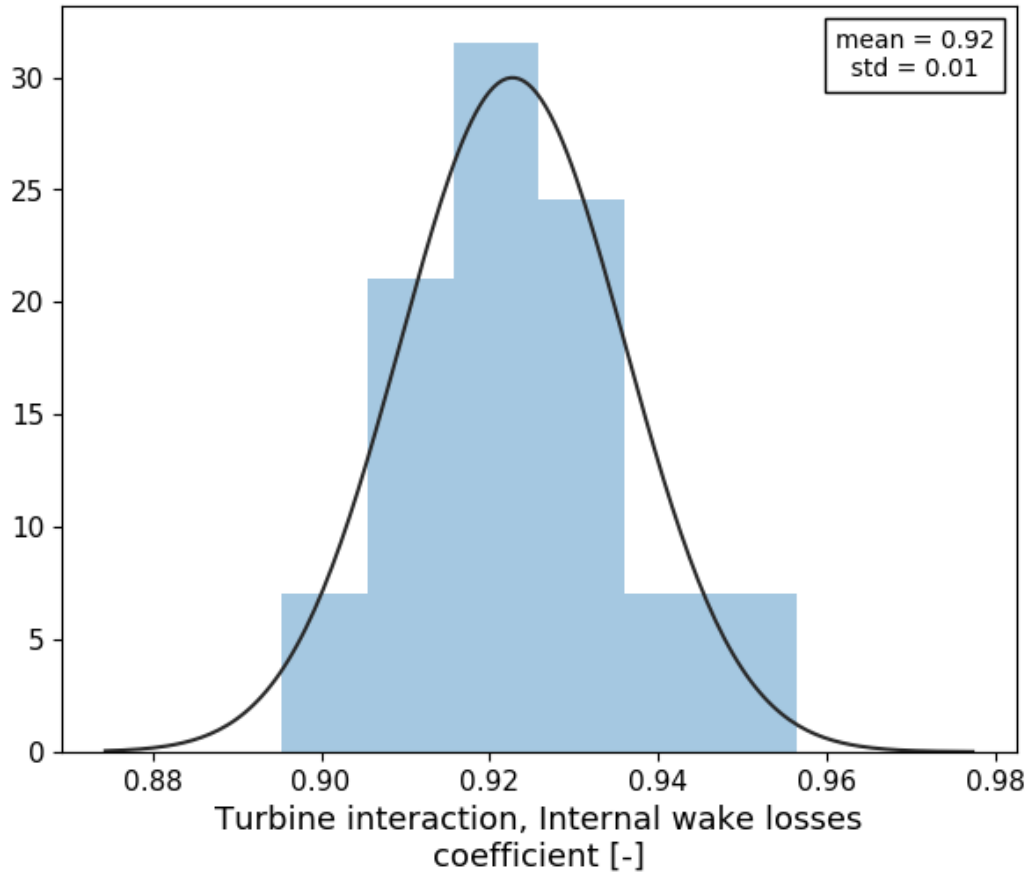
Potential Yield
estimate includes losses due to turbine interactions



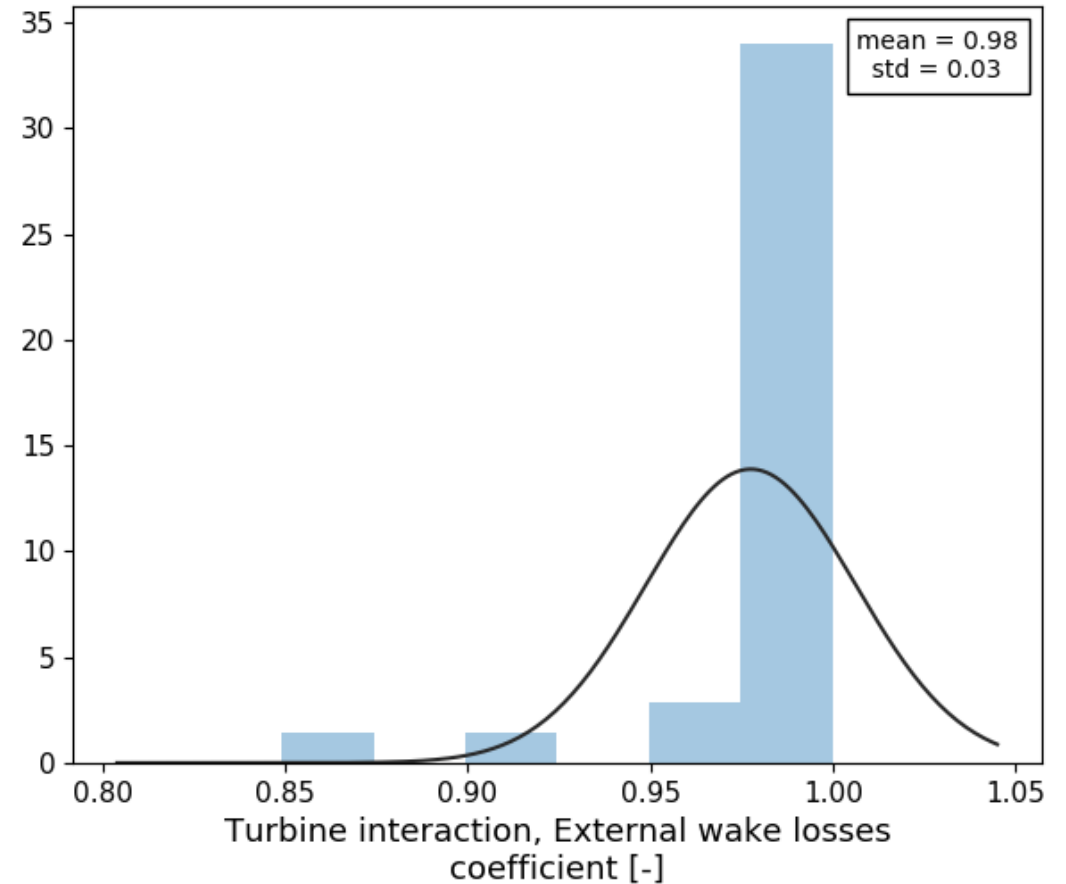
A closer look at turbine interaction losses



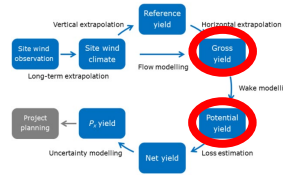
Internal Wake Losses



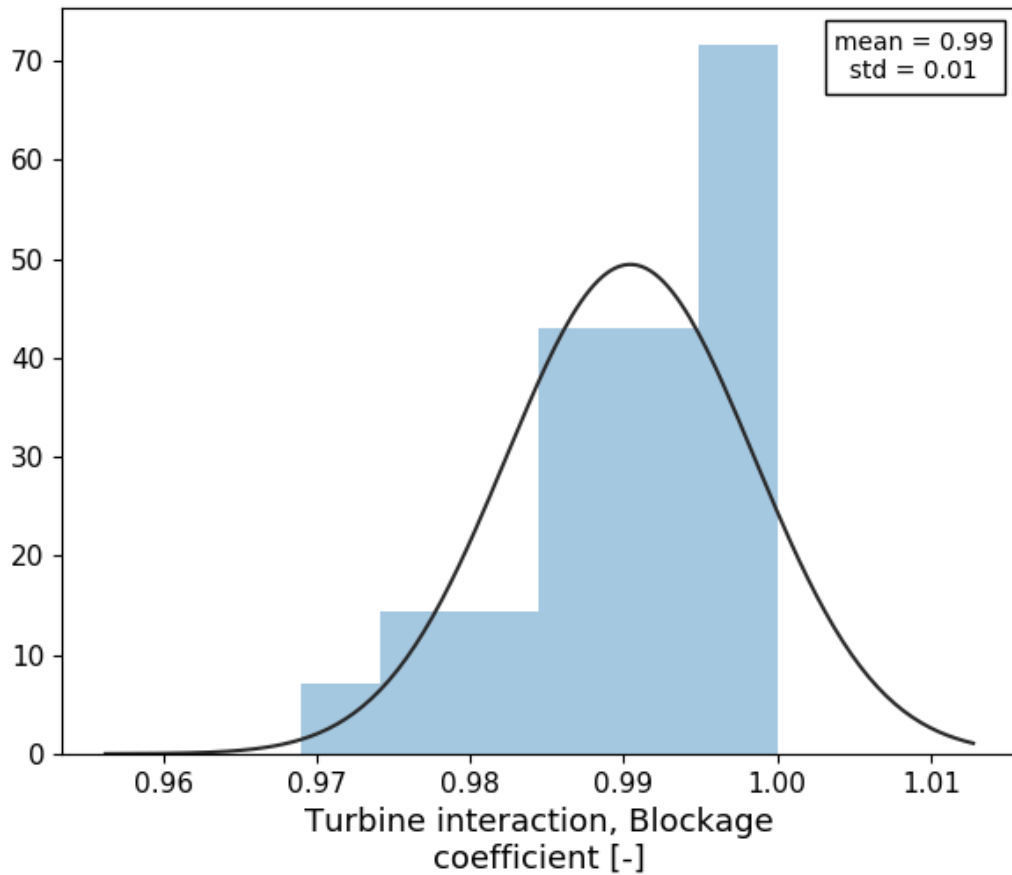
External Wake Losses



A closer look at turbine interaction losses

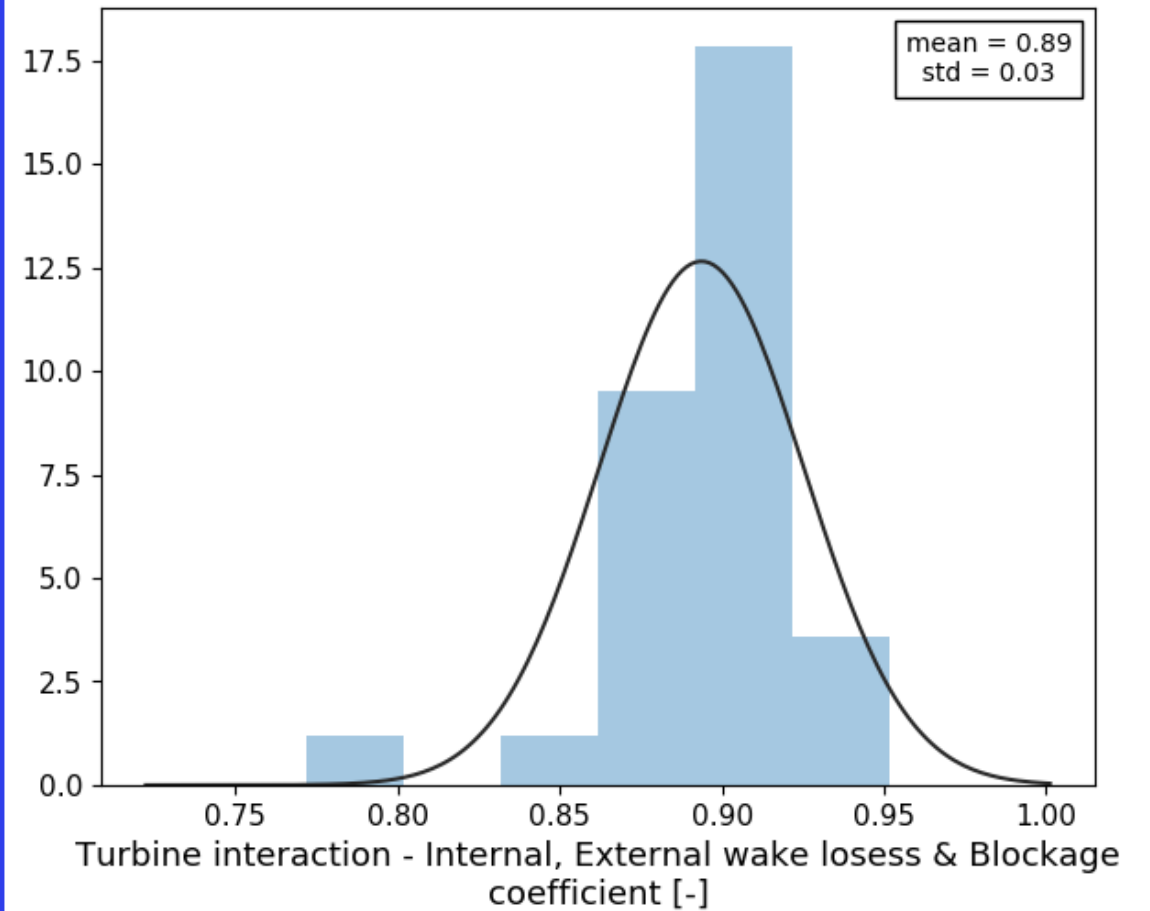


Blockage

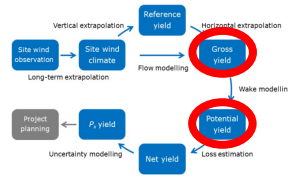


Internal, External and Blockage

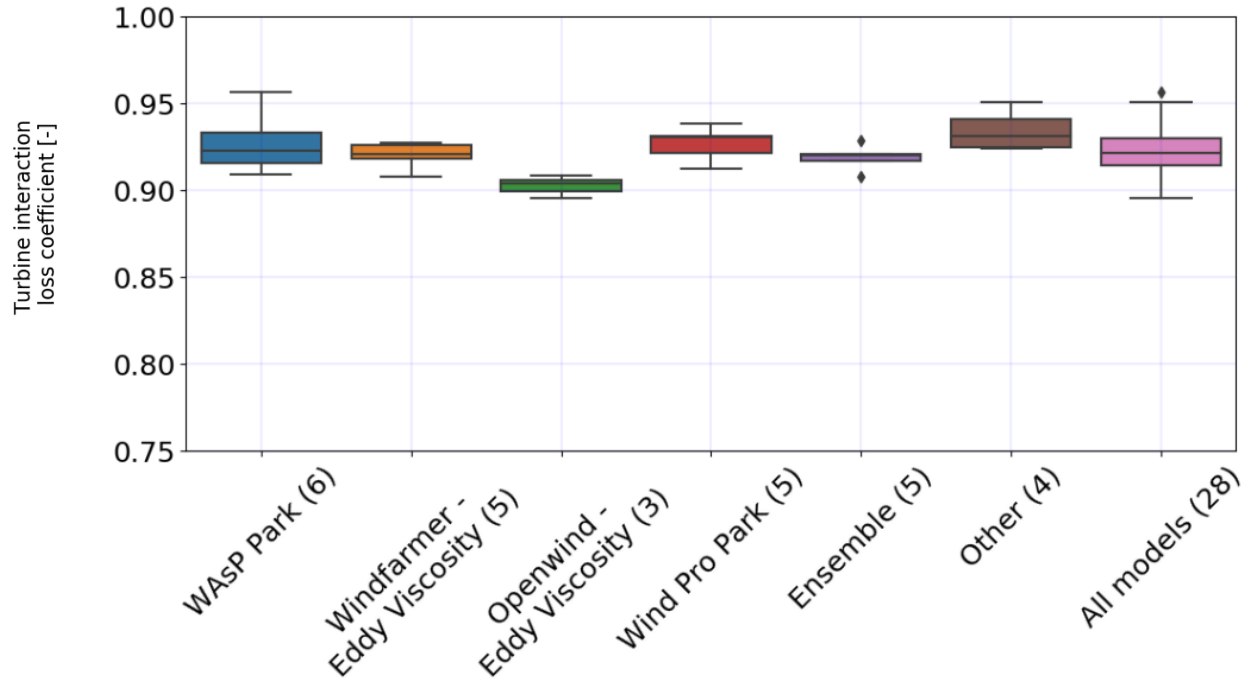
Combined



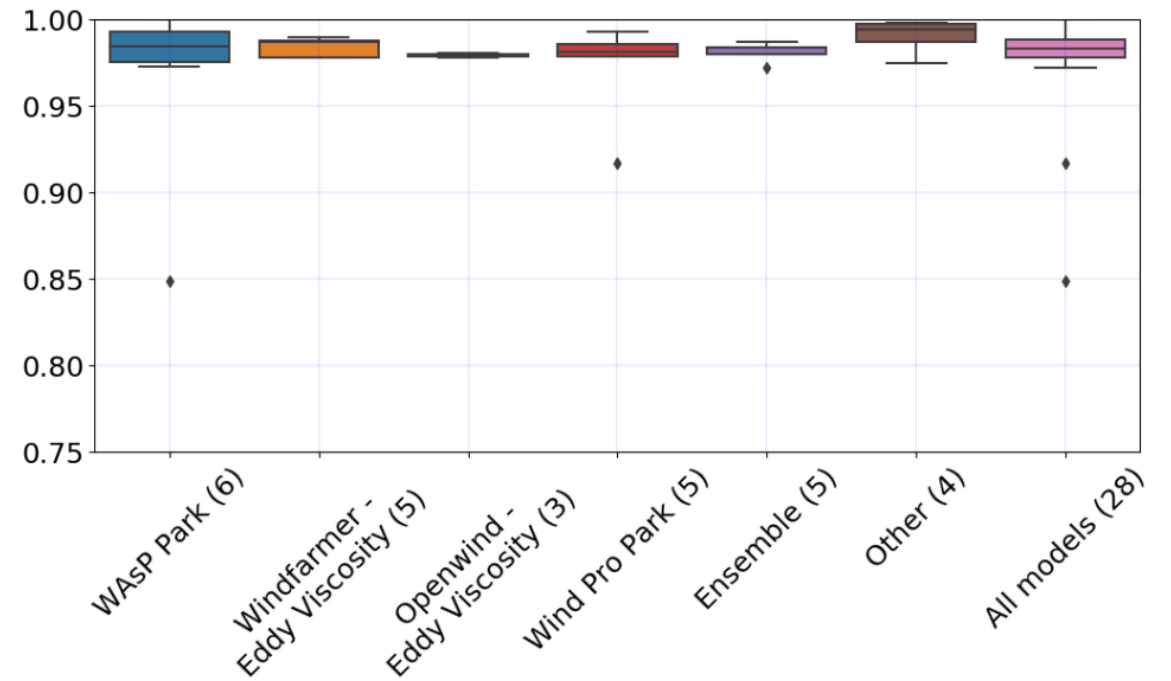
Estimates of losses as function of method



Internal wakes



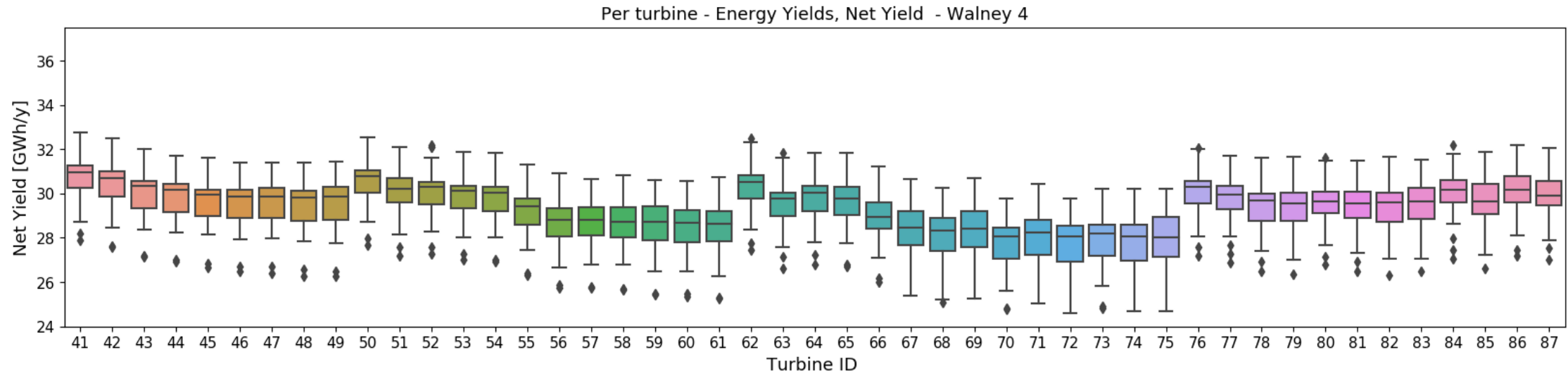
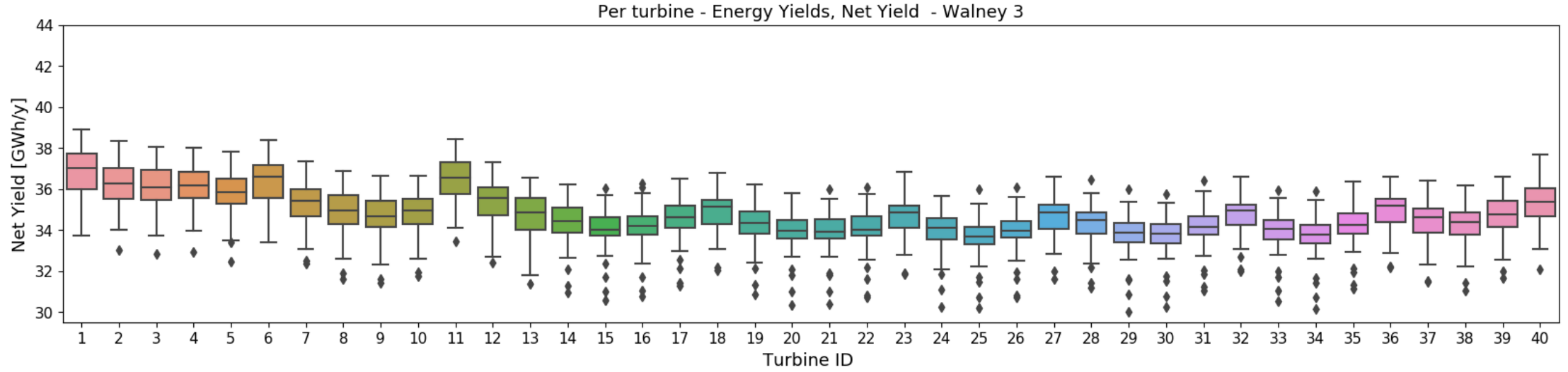
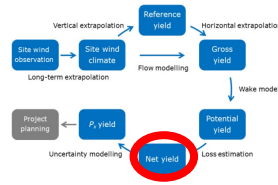
External wakes



Some of the variation within a single method may be down to specific users settings of model parameters.

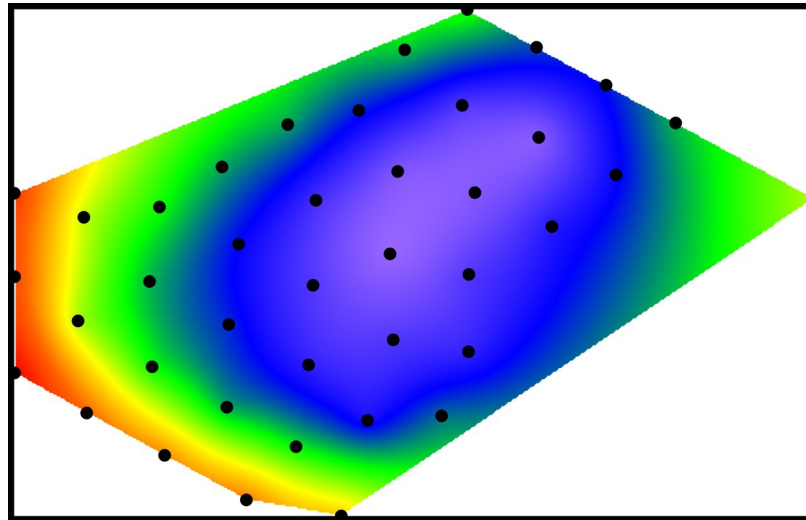
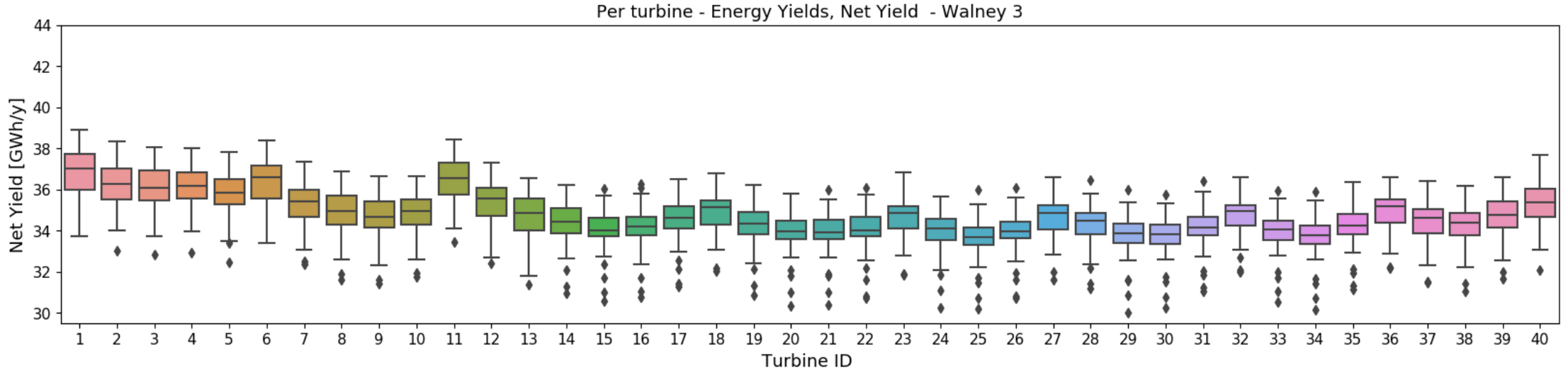
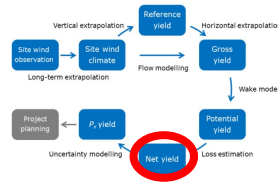
Net Yield (per turbine)

estimate includes losses due to technical losses



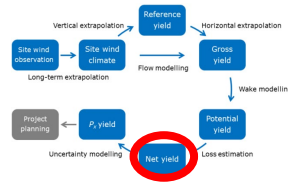
Net Yield (per turbine)

estimate includes losses due to technical losses

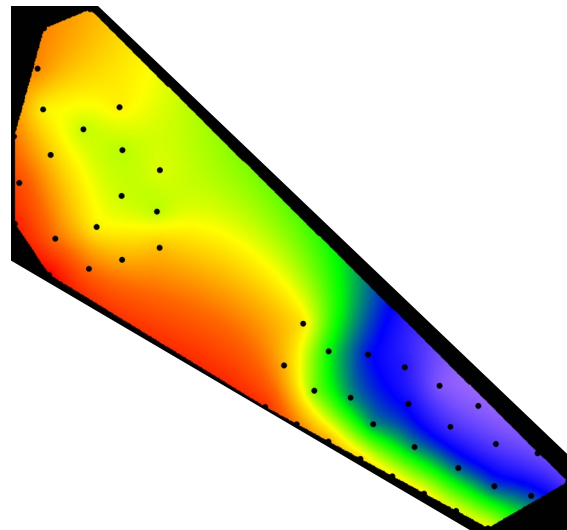
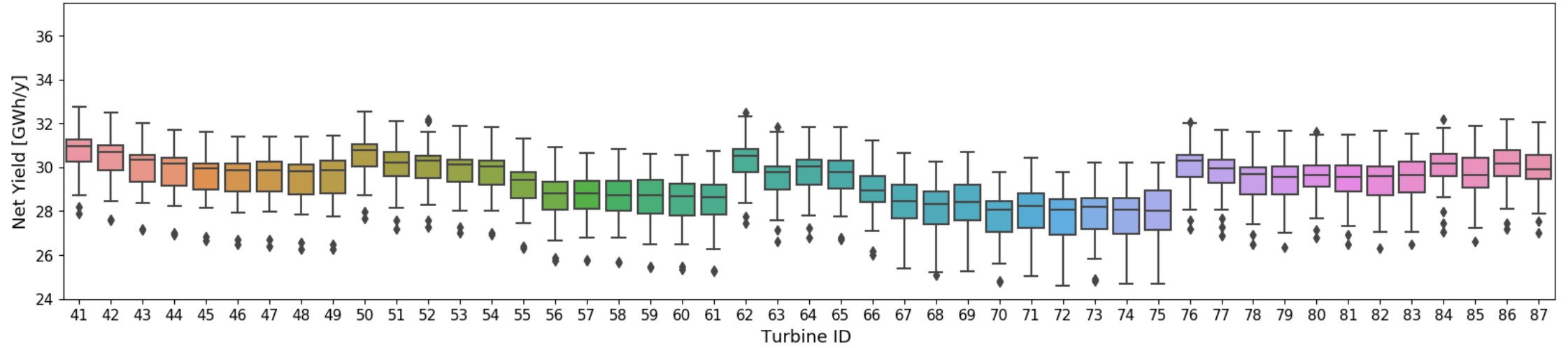


Net Yield (per turbine)

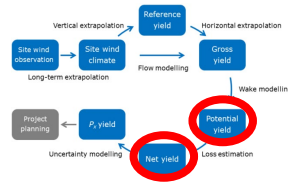
estimate includes losses due to technical losses



Per turbine - Energy Yields, Net Yield - Walney 4

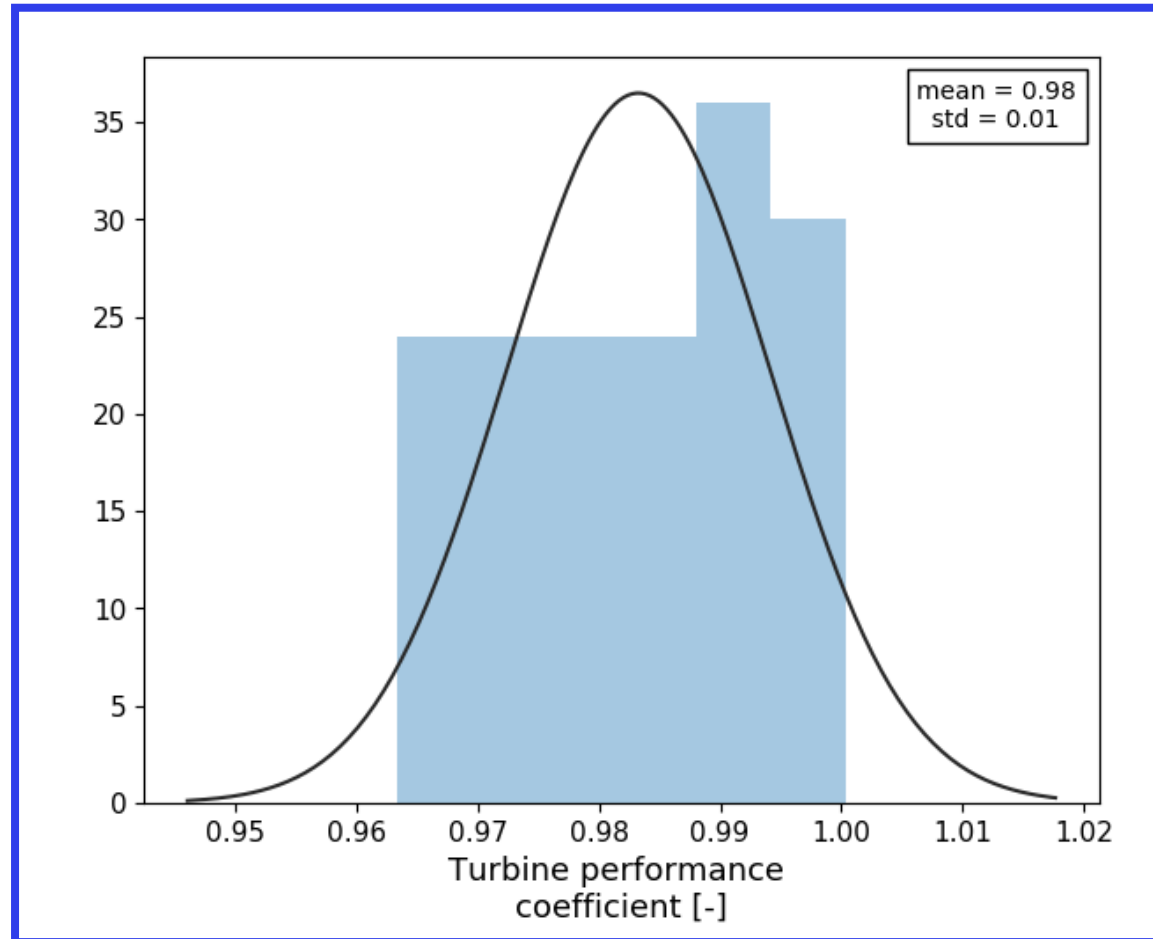


A closer look at turbine performance losses

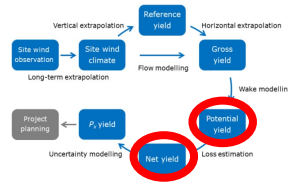


Combined coefficients from:

- Sub-optimal wind farm performance
- Site-specific power curve adjustment
- High wind hysteresis
- Participant specified



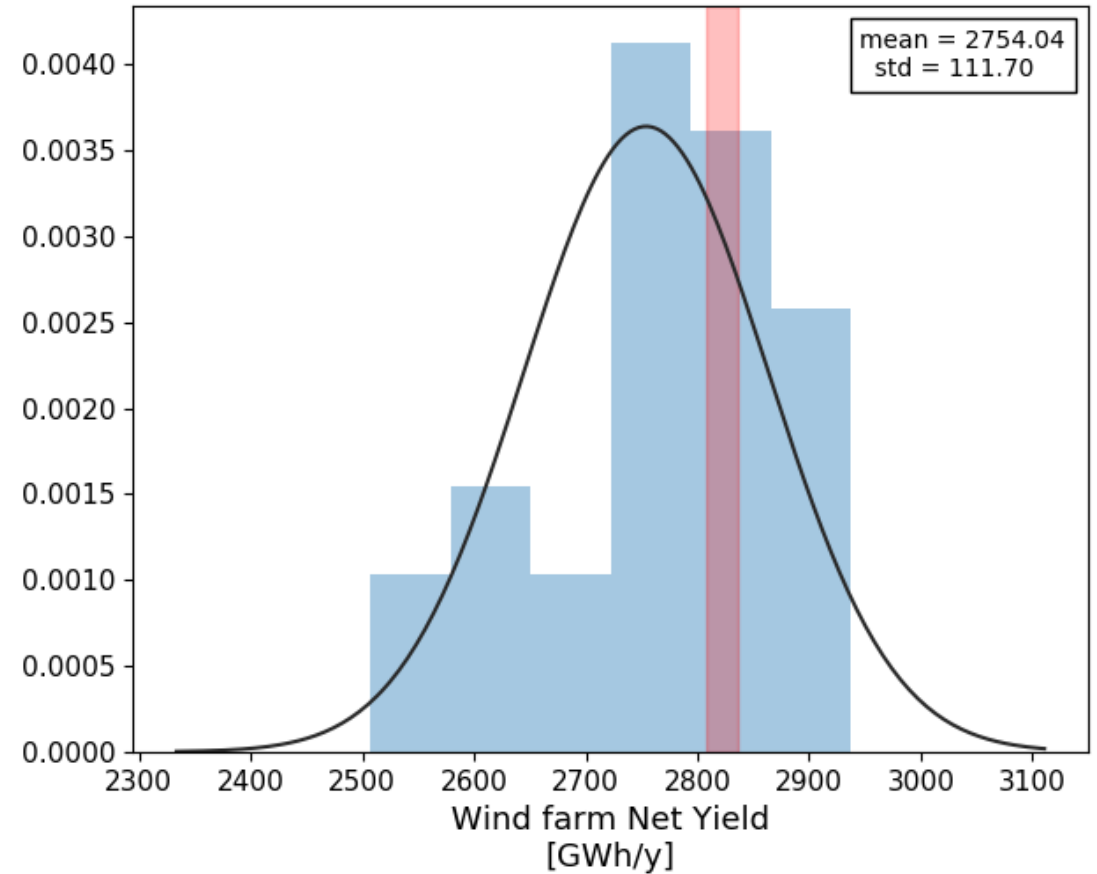
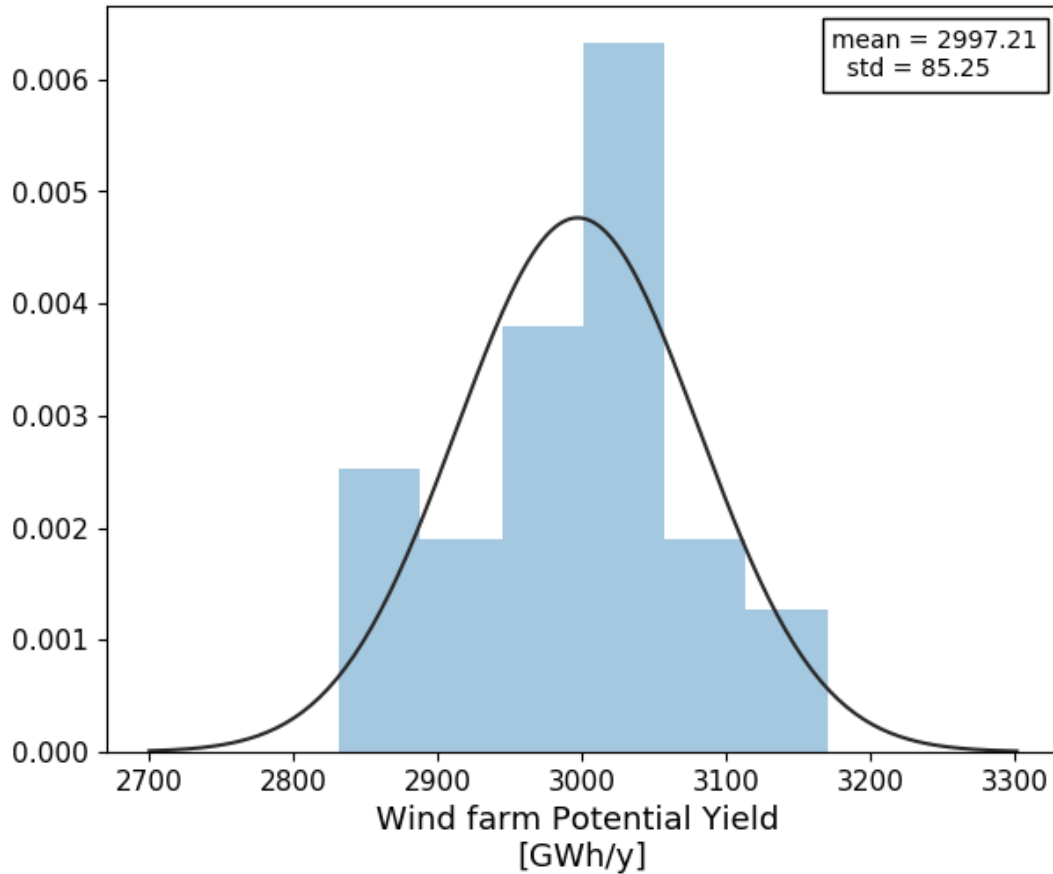
Accounting for technical losses



Potential yield
estimate includes losses due to turbine interactions

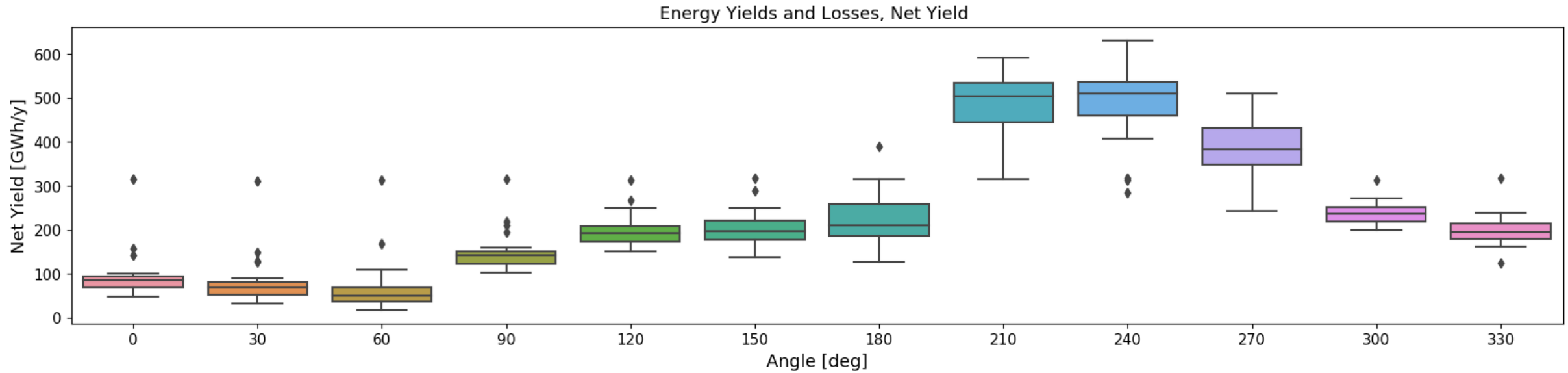
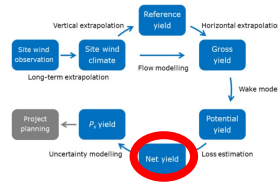


Net yield (P50)
estimate includes losses due to technical losses



Net production by wind direction

estimate includes losses due to technical losses

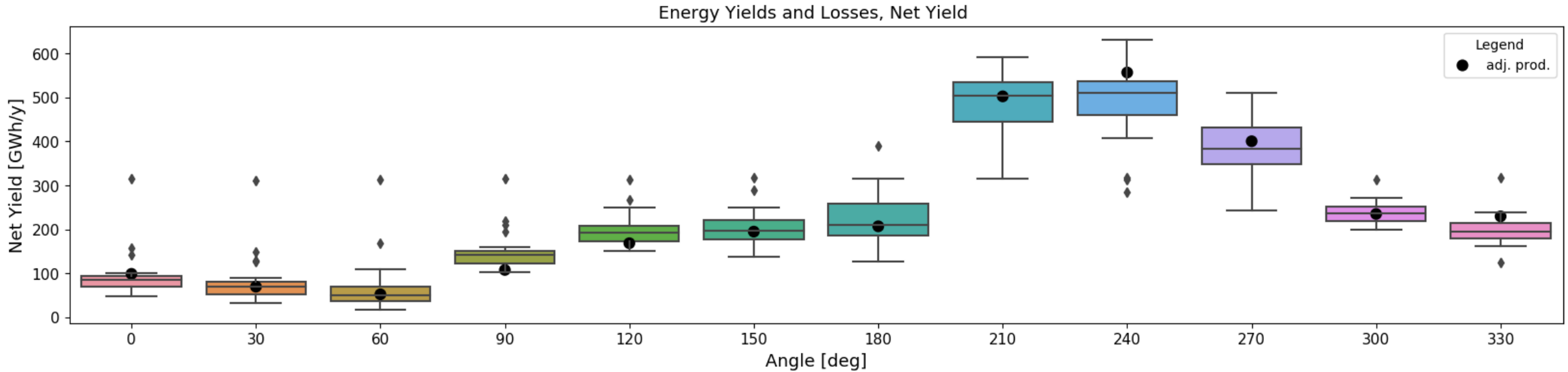
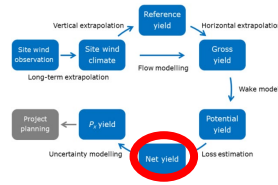


Most effected sector for external wakes 120 deg

No indication that this sector has larger spread in estimates

Net production by wind direction

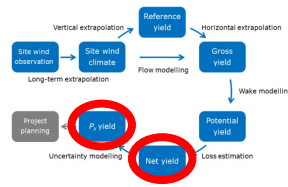
estimate includes losses due to technical losses



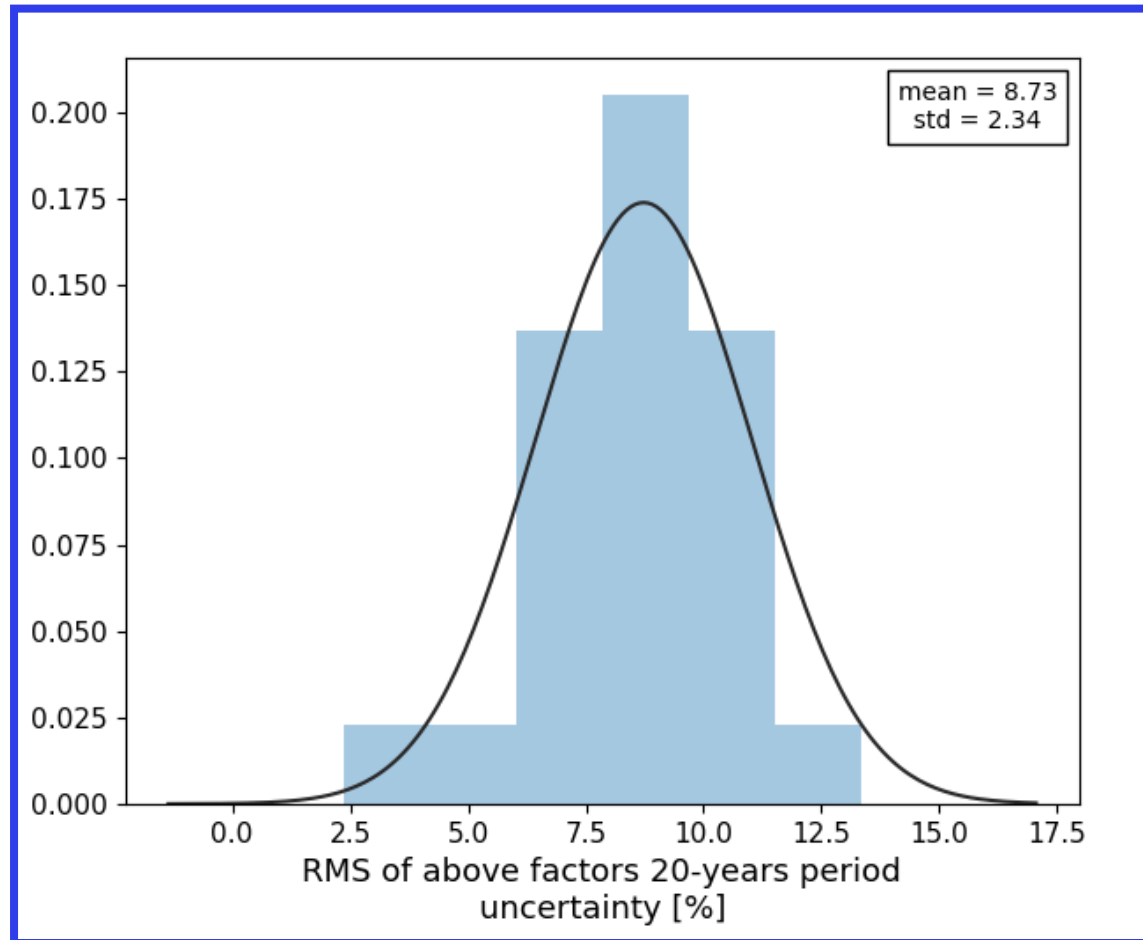
DTU's estimate of actual production adjusted to 20-y, based on Ørsted data and a long term adjustment

Good agreement of the directional dependency of the production.

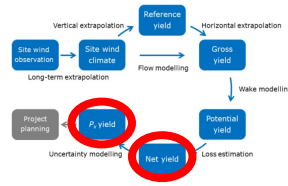
A closer look at uncertainty estimate



Uncertainty on energy yield total



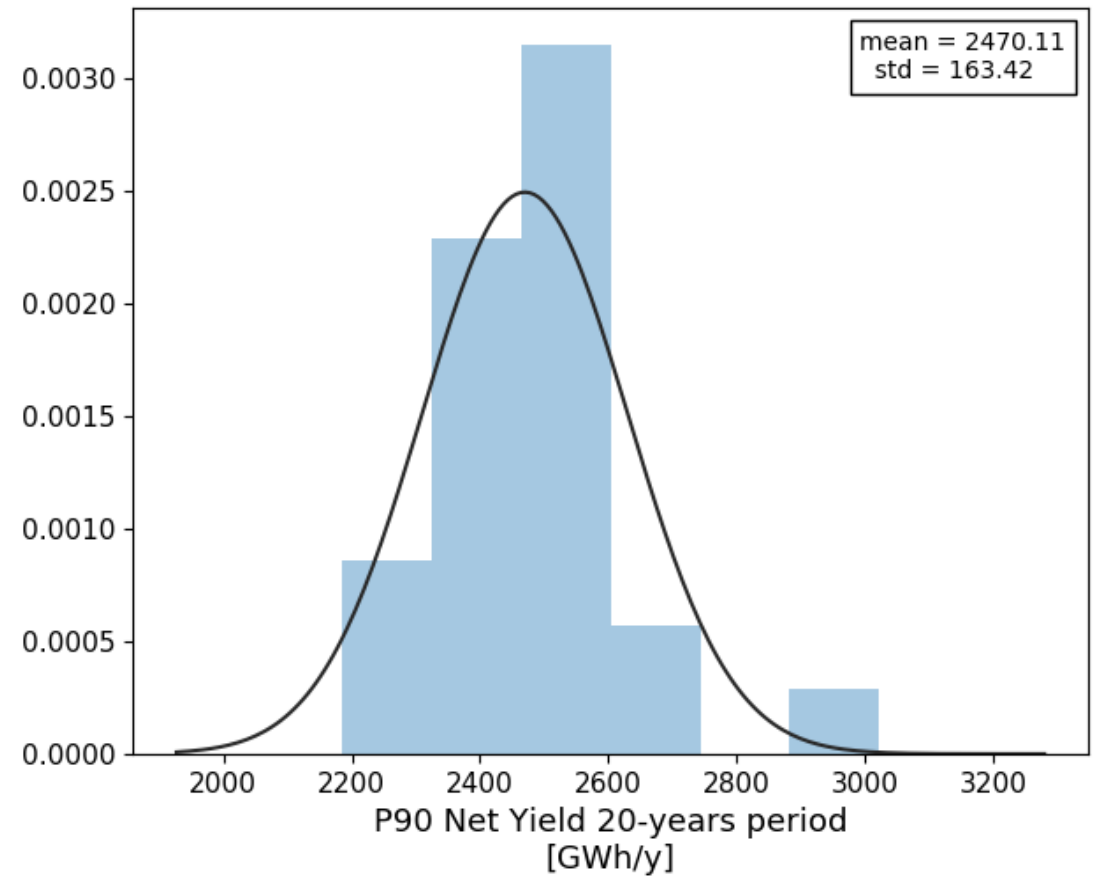
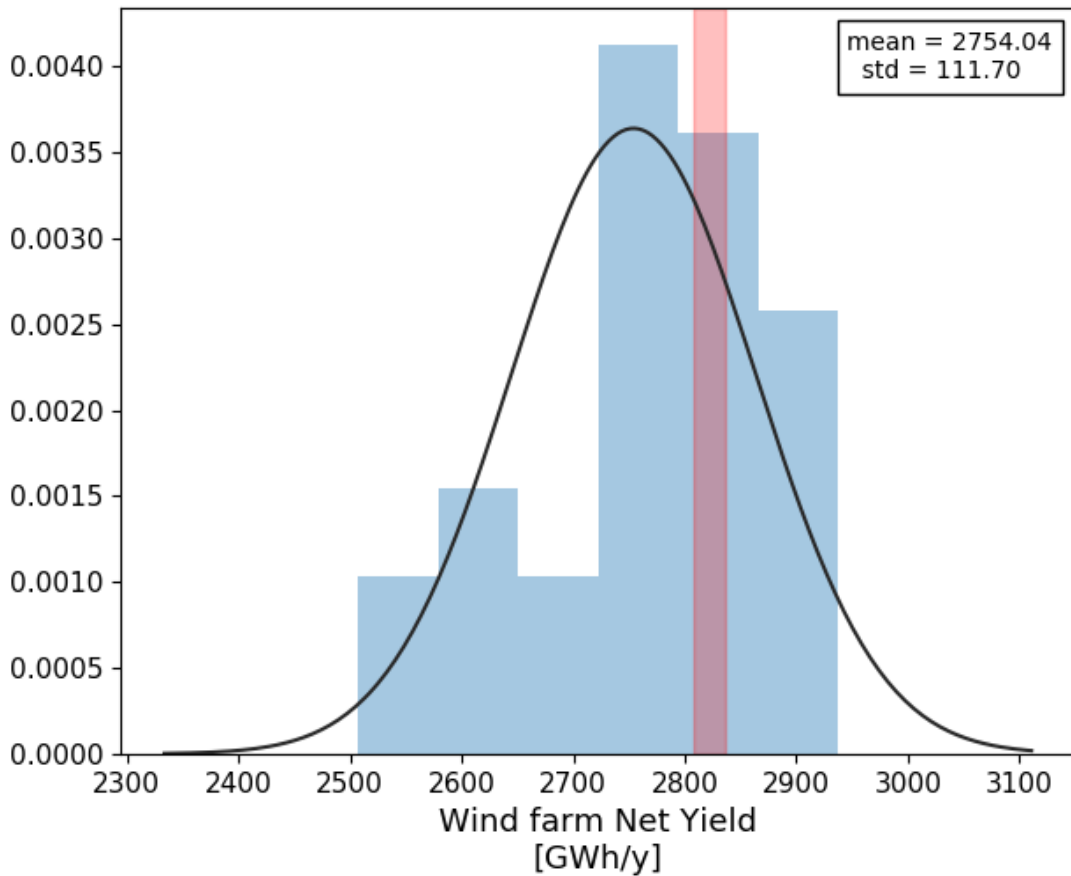
A closer look at uncertainty estimate



Net yield (P50)
estimate includes losses due to technical losses

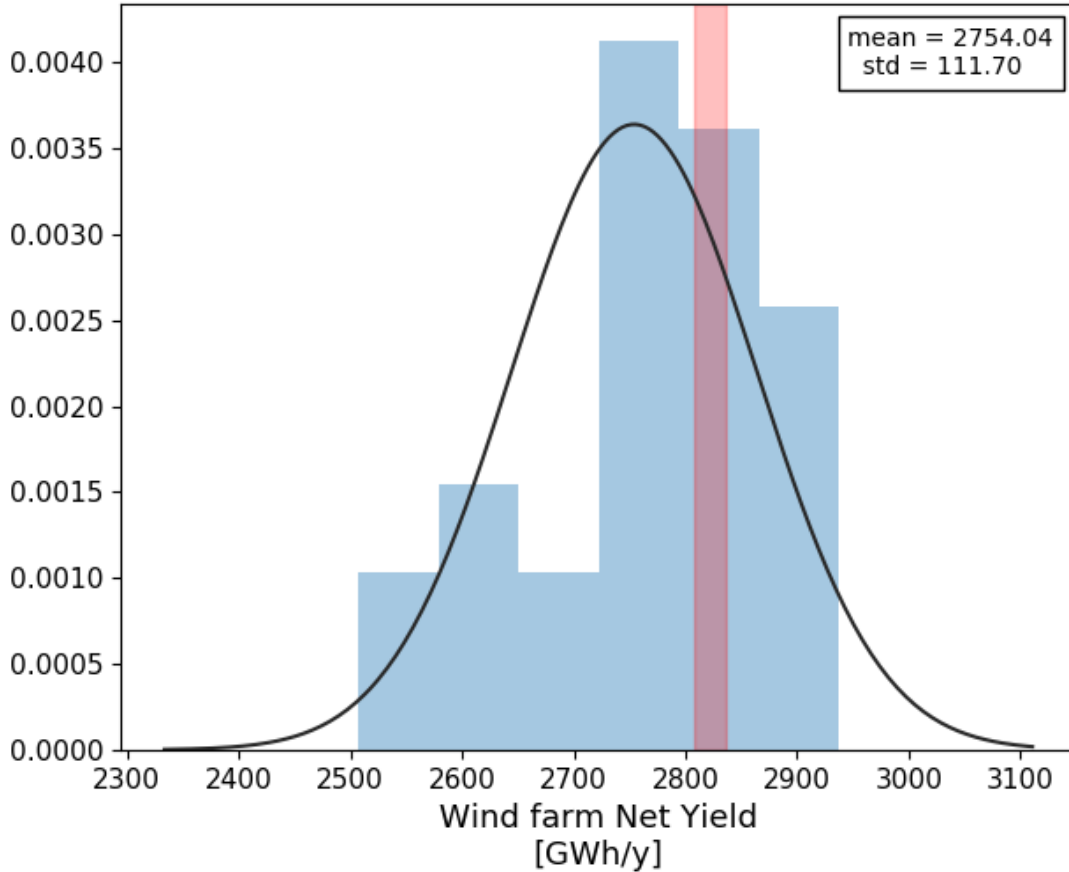


Net yield (P90)
estimate with 90% exceedance



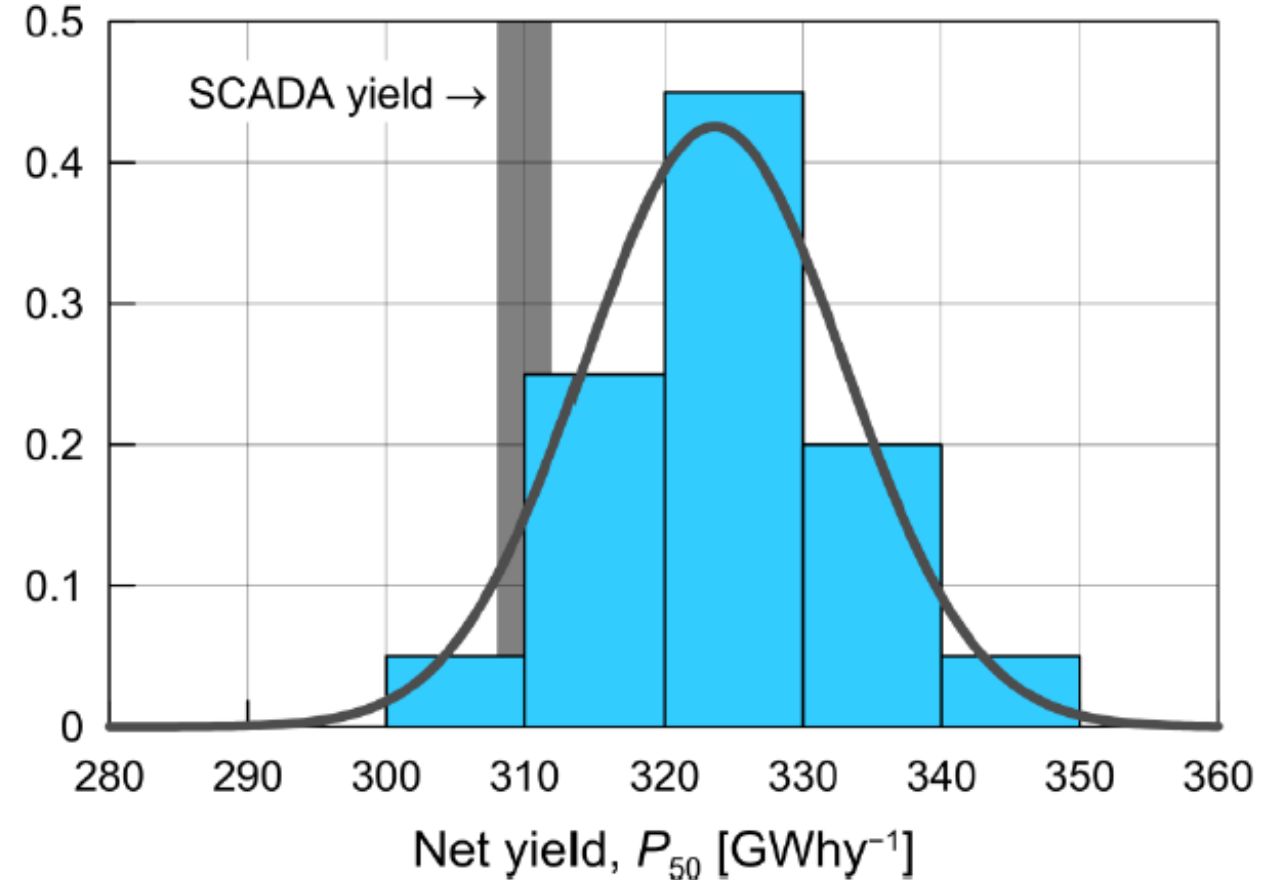
Comparison with previous CREYAPs

20-y net yield (P50)
CREYAP 2021 Walney 3 and 4



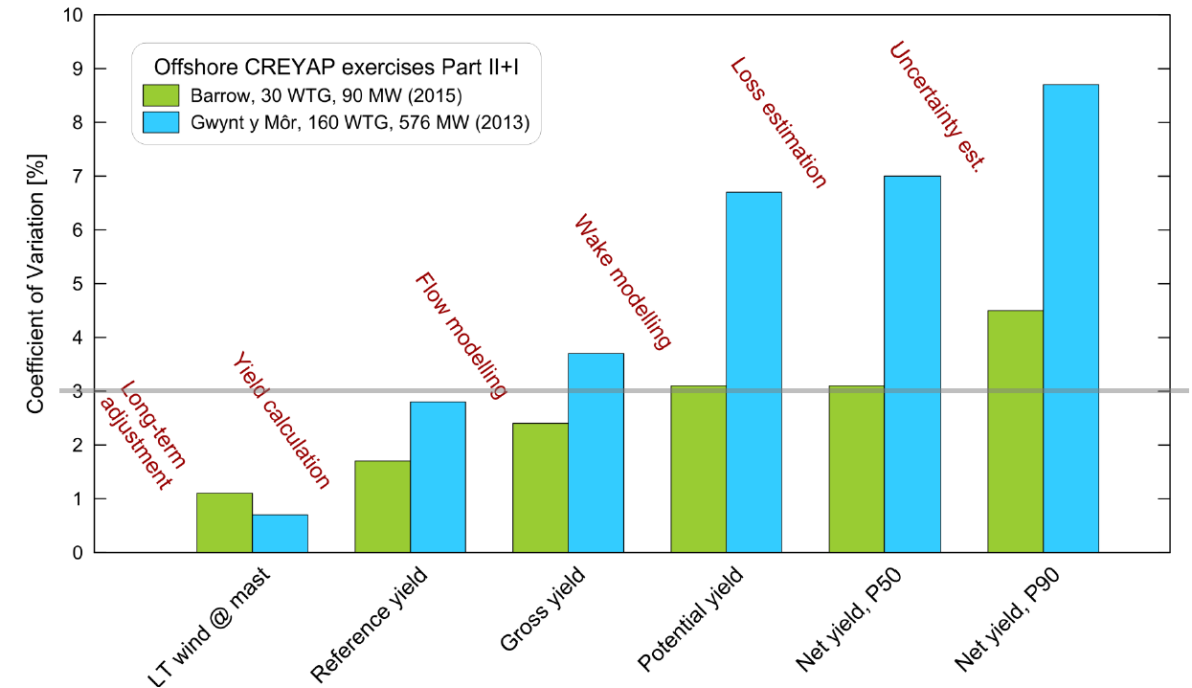
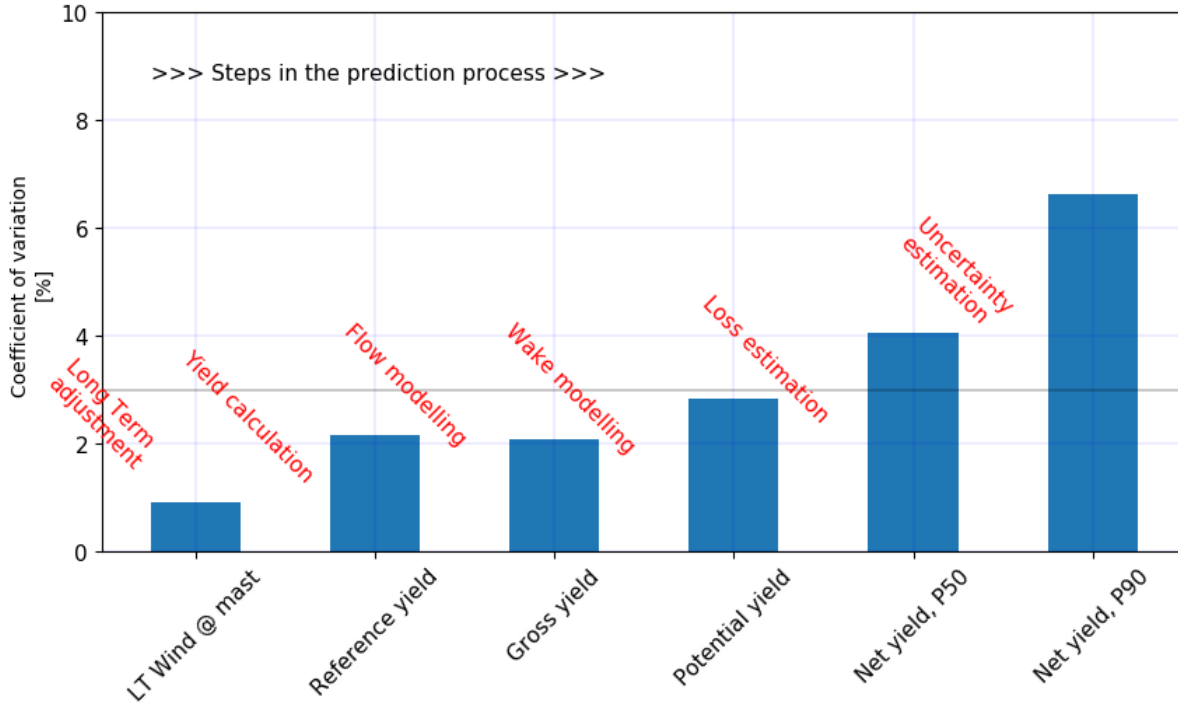
Coefficient of variance = 4.1 %
Mean estimate has -2.5 % bias

1-y net yield (P50)
CREYAP 2015 Barrow



Coefficient of variance = 3.0 %
Mean estimate has + 4.5 % bias

Comparison with previous offshore CREYAPs



Walney 3 and 4 (659 MW, 28 teams)

Barrow (90 MW, 22 teams)

Gwynt y Mor (576 MW, 38 teams)

- marked flow modelling step

- marked flow modelling step

- marked loss estimation step

-

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Summary

- We see a quite even spread of several methods across the different steps
- Flow modelling step did not increase the coefficient of variance
- Mean combined turbine interaction losses are 10 % (range 5 % – 16 %)
 - Internal wakes 8 % (range 5 % – 11 %)
 - External wakes 2 % (range 0 % – 11 %)
 - Blockage 1 % (range 0 % – 3 %)
- Ensemble methods for turbine interaction losses had small range of estimates
- Spread within a single modelling approach can be large

Summary

- Mean of the requested turbine performance losses is 2 % (range 0 % – 4 %)
- Good agreement of the mean of estimates for the directional dependency of the production
- Mean 20-y net yield (P50) (2754 GWh / year) has coefficient of variance = 4.1 %
- Mean estimated uncertainty is 8.7 %, coefficient of variance = 27 %
- Spread of the 20-y net yield (P50) is less than estimated uncertainty
- Actual production adjusted to 20-y is 2822 GWh / year
 - 2.5% higher than the mean 20-y net yield (P50)

Next steps

- Distributions of individually annotated results to participants
- Difficult to discern a distinct pattern of behaviour across methods choices
 - may required deeper different kind of analysis of the submitted data
 - may require a further questions to the participants



CREYAP references 2011-15

Land-based wind farms

- Mortensen, N. G., & Ejsing Jørgensen, H. (2011). [Comparison of resource and energy yield assessment procedures](#). EWEA Wind Resource Assessment Technology Workshop, Brussels, Belgium, 10-11 May.
- Mortensen, N. G., Ejsing Jørgensen, H., Anderson, M., & Hutton, K-A. (2012). [Comparison of resource and energy yield assessment procedures](#). EWEA 2012, Copenhagen, Denmark, 16-19 April.
- Mortensen, N. G., & Ejsing Jørgensen, H. (2013). [Comparative Resource and Energy Yield Assessment Procedures \(CREYAP\) Pt. II](#). EWEA Technology Workshop: Resource Assessment, Dublin, Ireland, 26 June.
- Anderson, M., & Mortensen, N. G. (2013). [Comparative Resource and Energy Yield Assessment Procedures \(CREYAP\) Pt. II](#). AWEA Wind Resource & Project Energy Assessment Seminar, Las Vegas, United States, 10-12 December.
- Mortensen, N. G., Ejsing Jørgensen, H. & Nielsen, M. (2014). [How well can the industry predict the wind resources? Overview of the results from EWEA CREYAP exercises](#). Danish Wind Industry Annual Event 2014, Herning, Denmark, 26-27 March.

Offshore wind farms

- Mortensen, N. G., Nielsen, M., & Ejsing Jørgensen, H. (2013). [First Offshore Comparative Resource and Energy Yield Assessment Procedures \(CREYAP\)](#). EWEA Offshore 2013, Frankfurt, Germany, 19-21 November.
- Mortensen, N. G., & Nielsen, M. (2015). [Offshore CREYAP Part 2 – preliminary results](#). EWEA Offshore Conference 2015, Copenhagen, Denmark, 10-12 March.
- Mortensen, N. G., & Nielsen, M. (2015). [Offshore CREYAP Part 2 – final results](#). EWEA Technology Workshop, Helsinki, Finland, 2-3 June.
- Mortensen, N. G., Nielsen, M., & Ejsing Jørgensen, H. (2015). [EWEA CREYAP benchmark exercises: summary for offshore wind farm cases](#). Wind Energy Denmark 2015, Herning, Denmark, 22-23 September.

Summary

- Mortensen, N. G., Nielsen, M., & Ejsing Jørgensen, H. (2015). [Comparison of Resource and Energy Yield Assessment Procedures 2011-2015: What have we learned and what needs to be done?](#) EWEA 2015, Paris, France, 17-20 November. [Presentation](#)