RENEWABLES ADVISORY

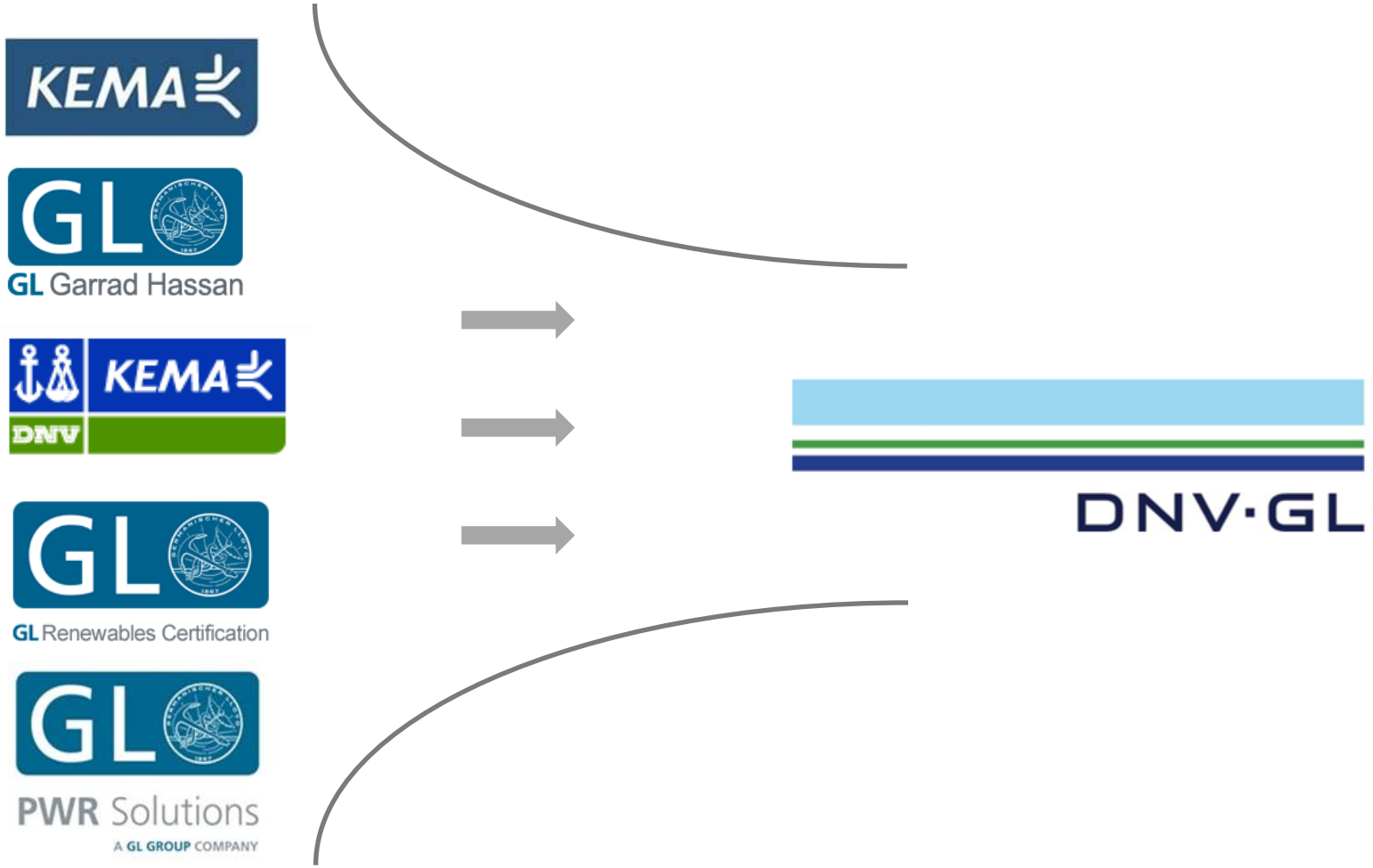
A study of turbine performance under cold weather driven stable atmospheric conditions in Scandinavia

Winterwind 2014 (Sundsvall, Sweden)

Carla Ribeiro

12th February 2014

Who is DNV GL?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Content

- Theoretical model
- Review 2013 results
- Additional data results
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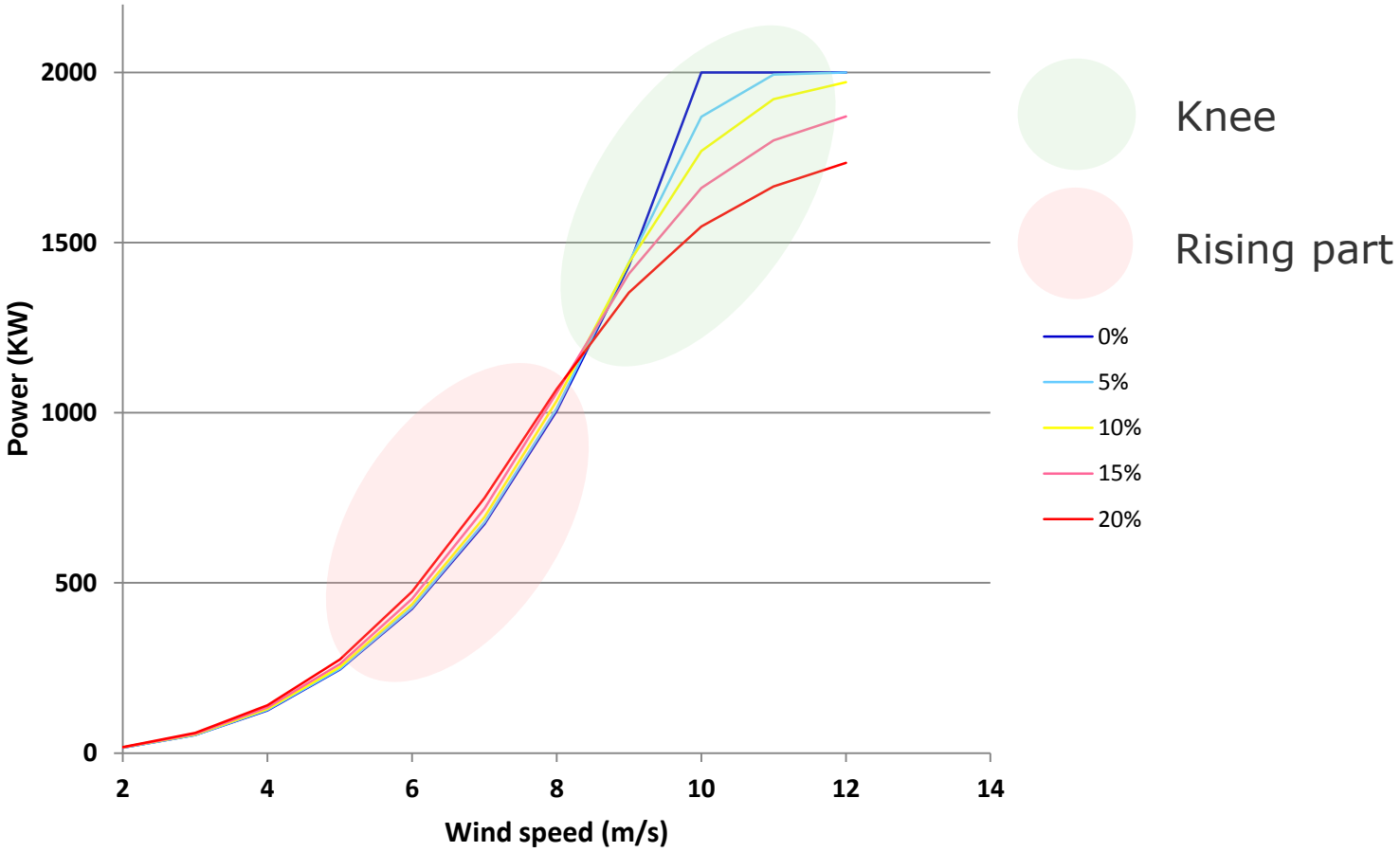
Theoretical model

Theoretical model

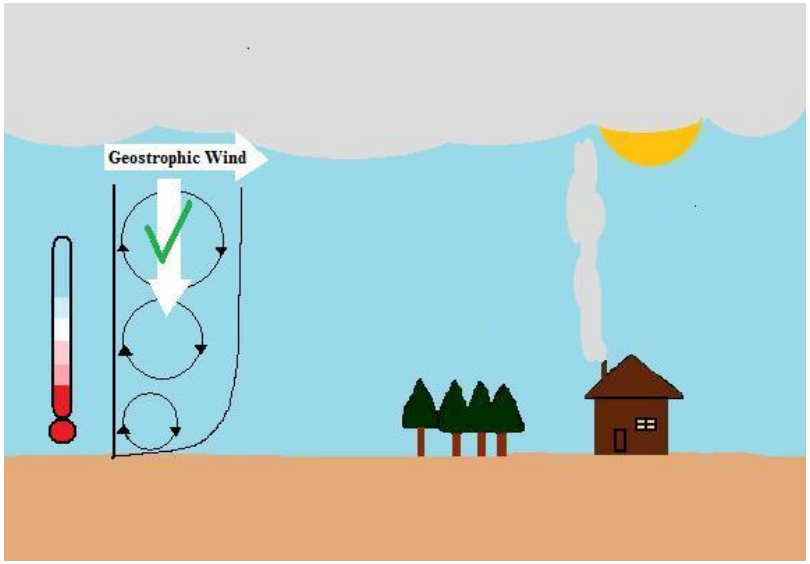
$$P = 1/2\rho(u)^3(1+3TI^2)ACp$$



Review 2013 results

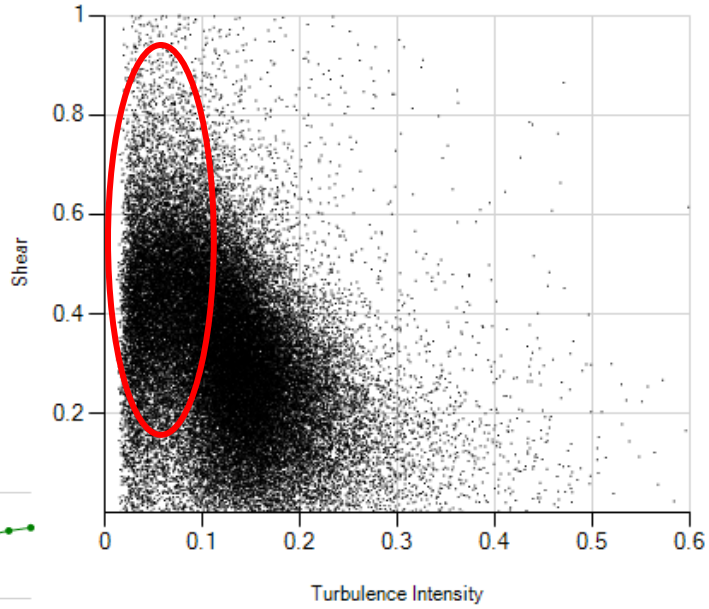
Radiative cooling driven stable atmospheric conditions

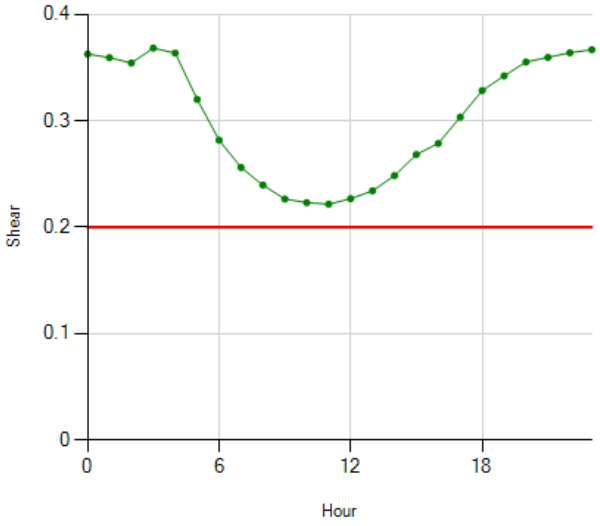
Unstable



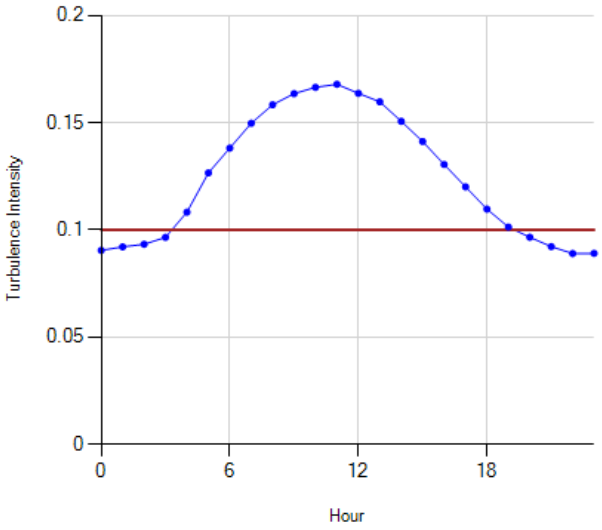
Stable

High frequency of stable atmosphere and wind conditions





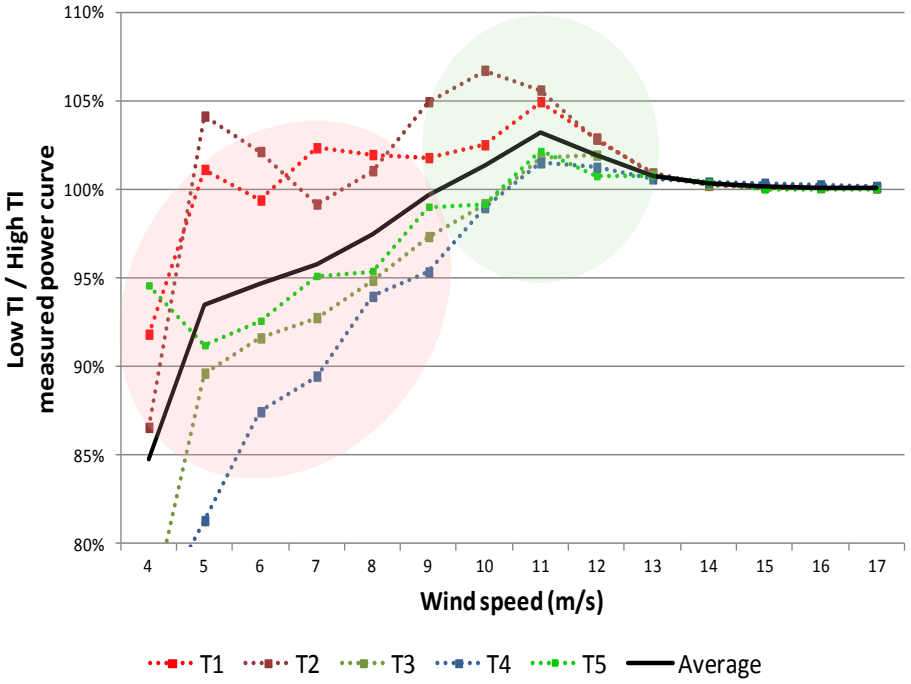
Low TI as a proxy for stable atmospheric conditions



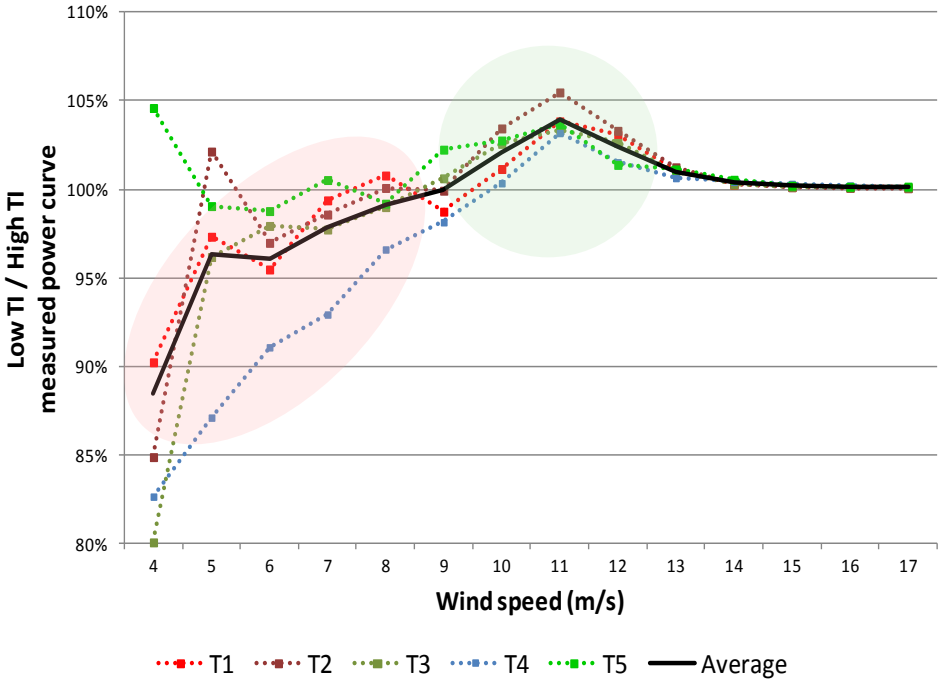
Performance of wind turbines under stable conditions in the Nordic Region – 2013 results

- Results for IEC Power Curve Measurements of 5 mast/turbine pairs in Sweden

Without different site calibration speedups



With different site calibration speedups



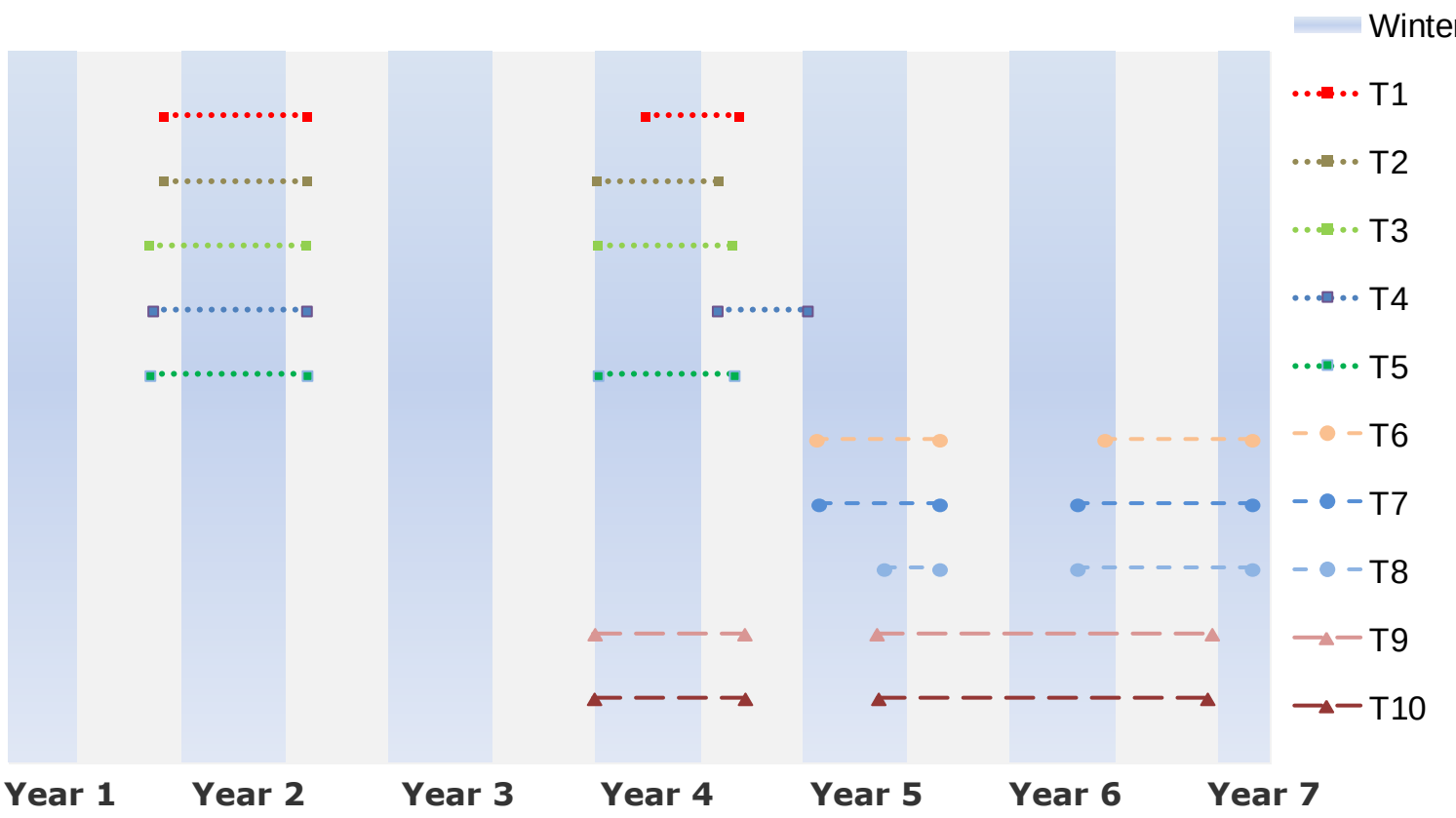
2013 results

- There is high frequency of stable and very stable atmospheric conditions in sites across the Nordic Region caused by radiative cooling
- Theory shows that low turbulence reduces turbine performance in rising part of the power curve
- Preliminary Nordic data supports this, however shows recovery in the "knee" of the power curve
- Site calibration speedups for stable and unstable conditions should be considered separately as suggested by the new draft of the IEC standard
- Need to gather more Power Curve Measurement data across the Nordic region

Additional data results

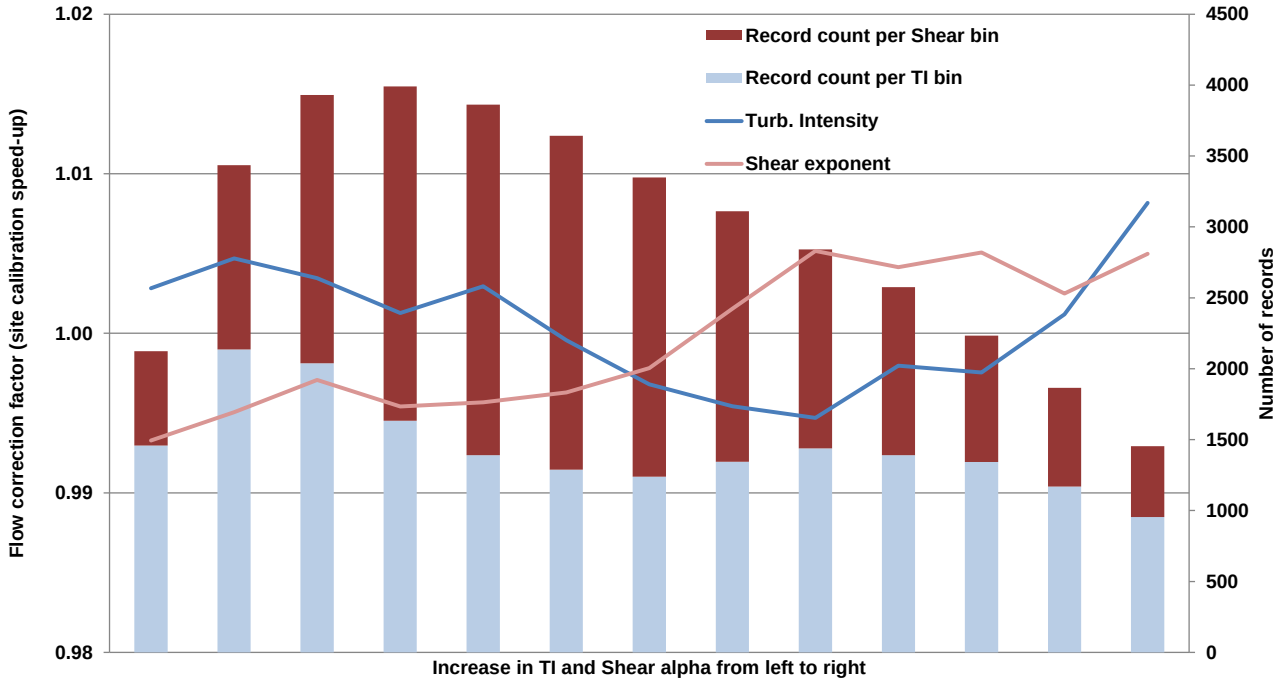
Available data

Results for IEC Power Curve Measurements of 10 mast/turbine pairs in 3 Swedish sites equipped with 3 different turbine types

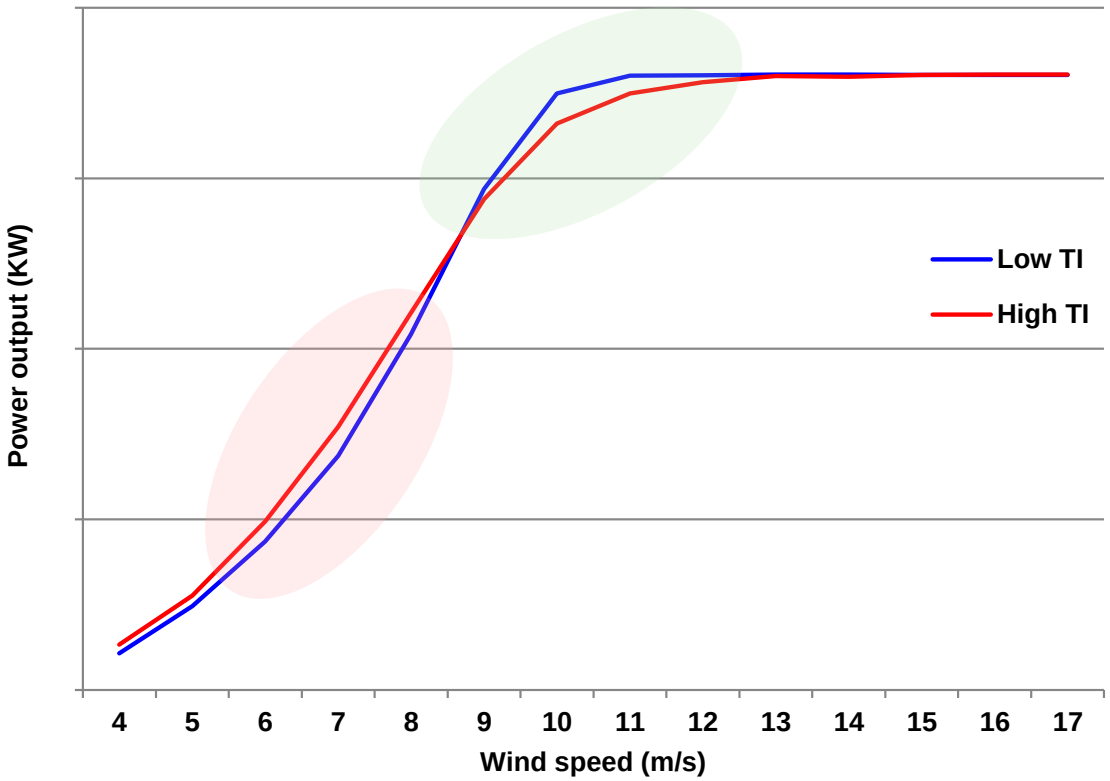


Selection of stability proxy

- Similarly to 2013 TI is seen as the better proxy for stable conditions.
- Low TI <10% (stable conditions)
- High TI >10% (unstable conditions)

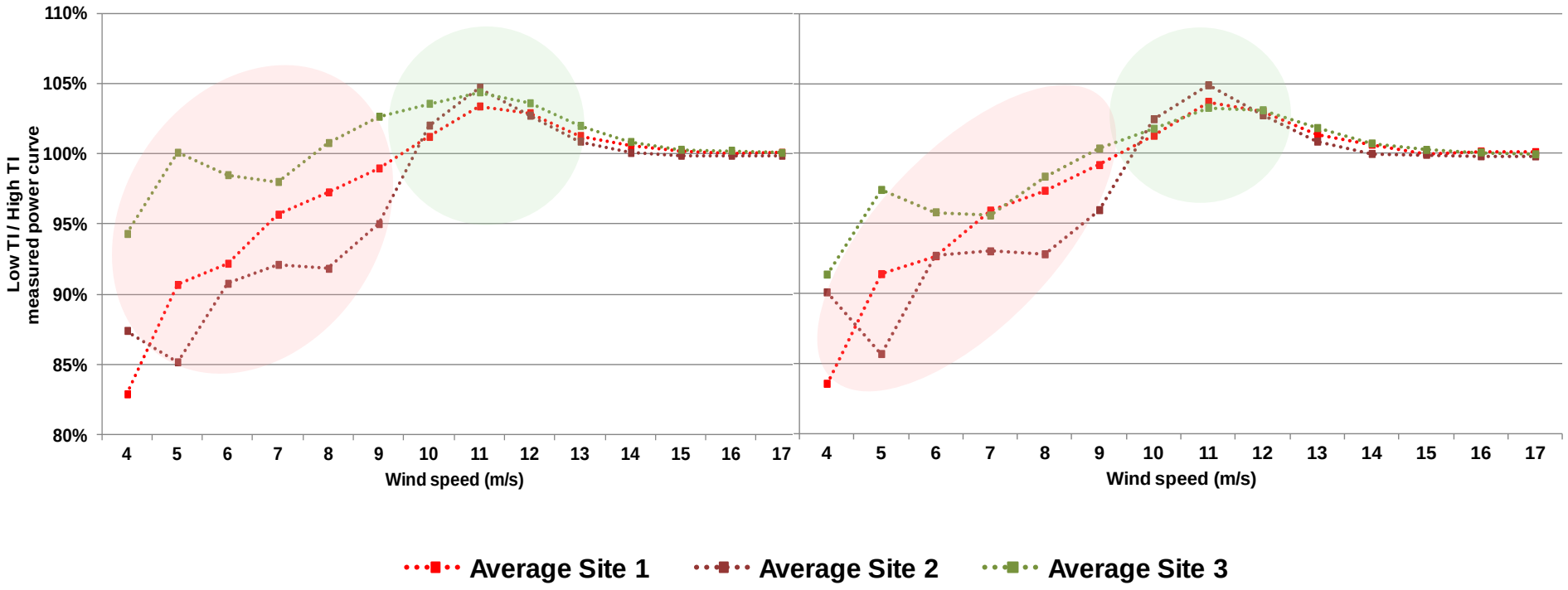


Measured power curve turbine T6

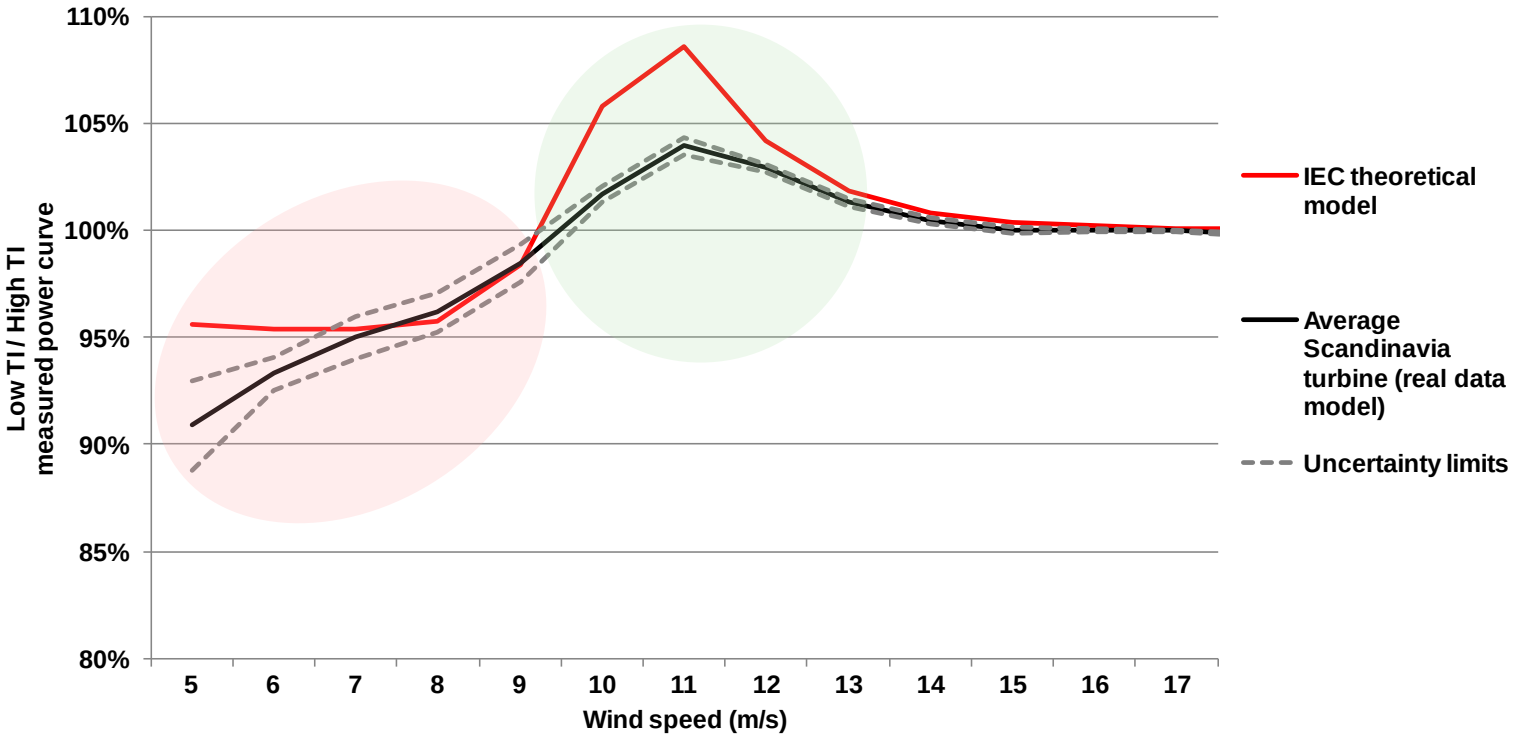


Performance of wind turbines under stable conditions in the Nordic Region – 2014 results

Without different site calibration speedups With different site calibration speedups



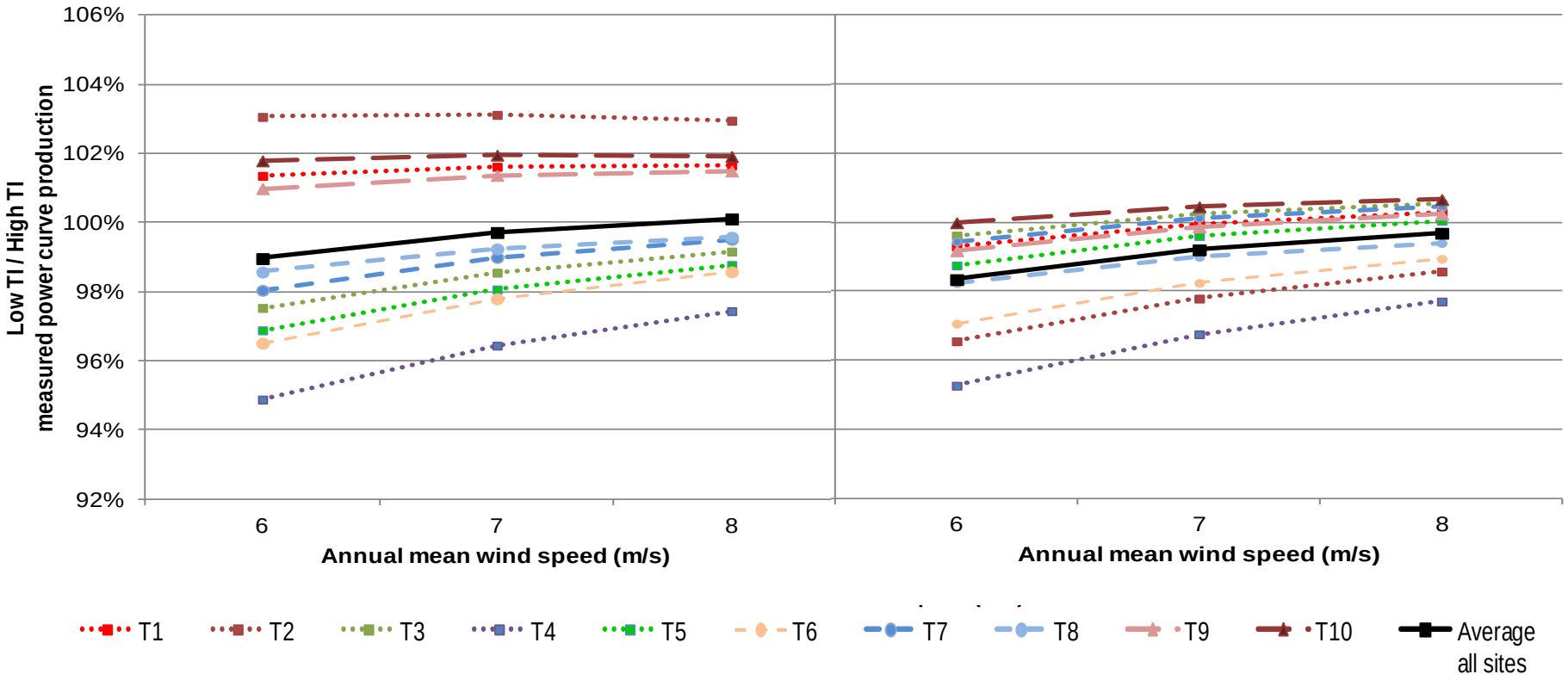
Performance of wind turbines under stable conditions in the Nordic Region – 2014 results



Performance of wind turbines under stable conditions in the Nordic Region – 2014 results

Without different site calibration speedups

With different site calibration speedups



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Conclusions

Conclusions

- On average results from the analyses of 10 PPM undertaken in Scandinavia confirm evidences of some underperformance of turbines under low turbulence. Low turbulence turbine underperformance is higher the lower the mean wind speed, and it's around 2% for sites with annual mean wind speed below 7 m/s.

- Site calibrations should be considered not only dependent on direction, but indeed also dependent on climatic conditions such as turbulence and shear, and when that is considered, differences in performance for different climatic conditions will attenuate on average.

Conclusions

- Turbulence and shear seem to impact site calibration in the same order of magnitude and are inversely correlated.

- Although the overall trend of the Scandinavian measured power curves is similar to the theoretical model, it does not show the same magnitude of variation. Nevertheless, based on the Scandinavian measurements, it is not expected a significant overall under or overperformance of the turbines for typical sites in this region, wind annual wind speeds around and above 7 m/s.

Thank you

Any questions?

With thanks to:

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SAFER, SMARTER, GREENER

In addition

Ratio of wind speeds measured at hub-height by two parallel first-class anemometers across a range of turbulence intensities (binned by wind speed)