Resource Assessment Methods Incorporating Rotor Equivalent Wind Speed, Density and Turbulence on a Time Step Basis

Anna Marsh
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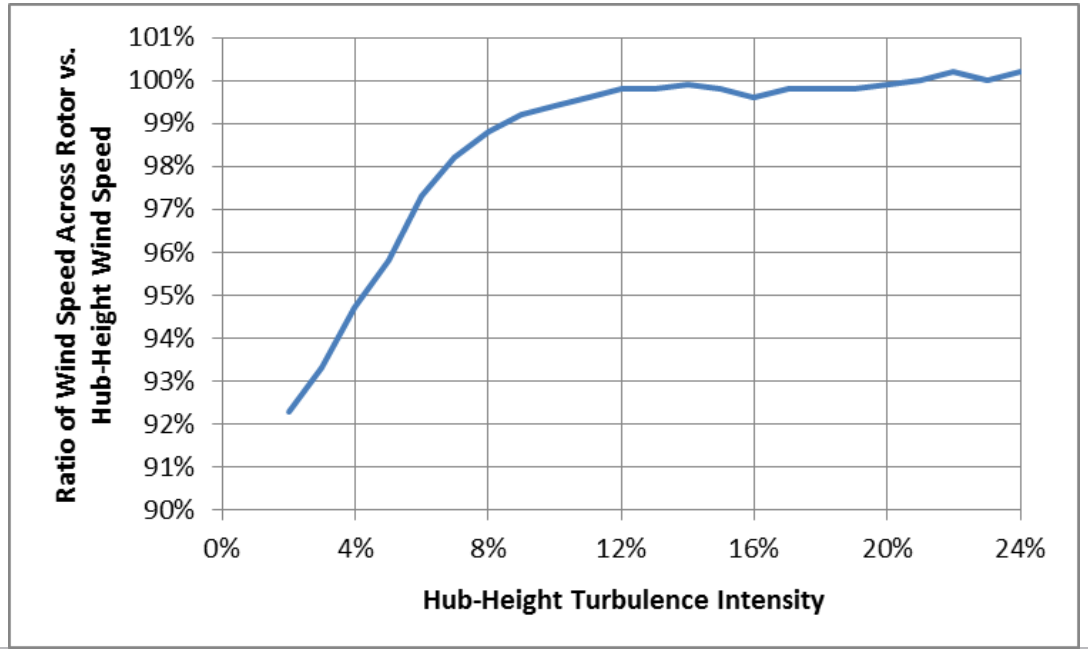
Key message

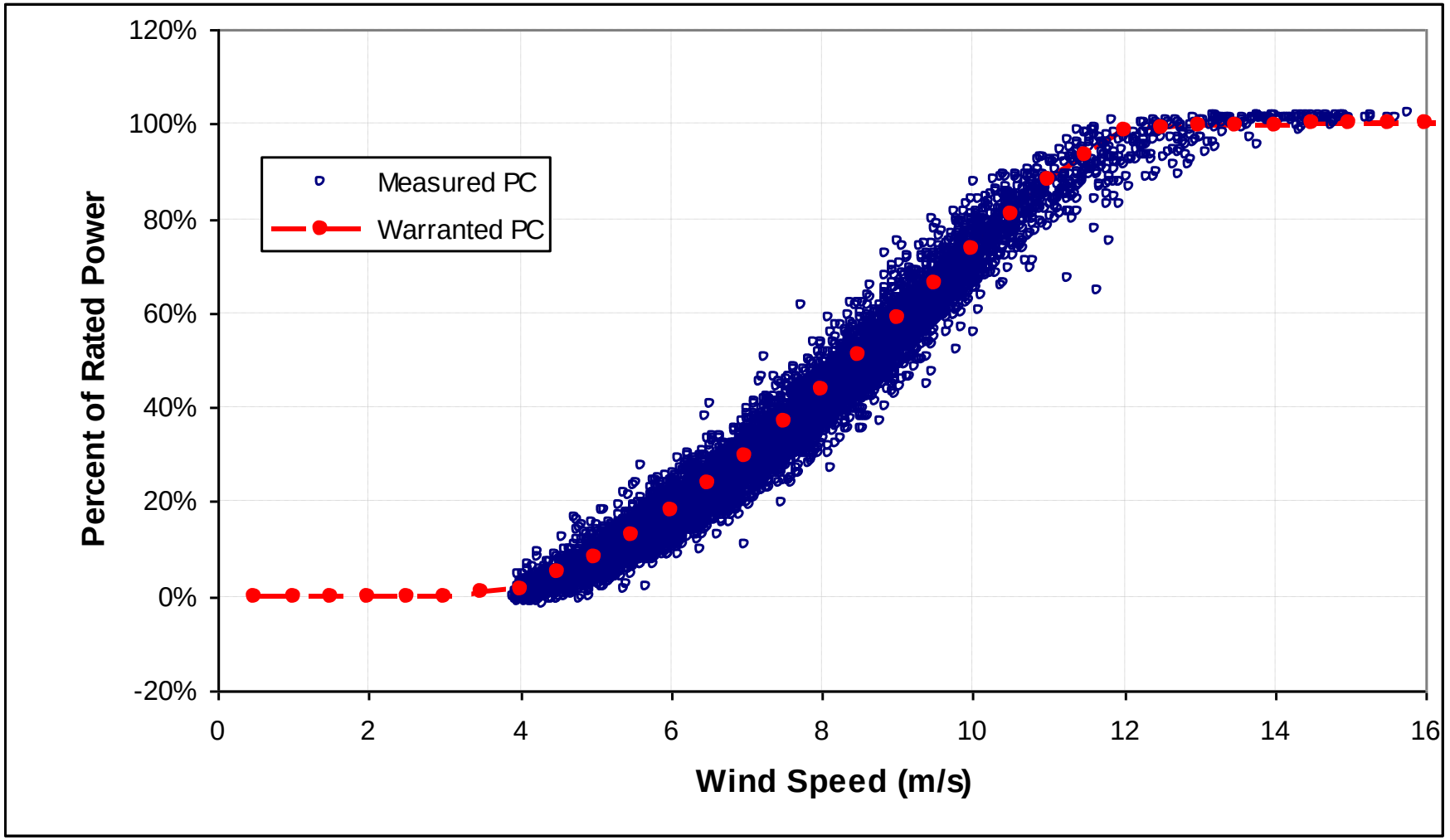
- Use of a Rotor Equivalent Wind Speed (REWS) makes a significant impact on AEP. It is recommended this is considered in energy assessment. Where data across the rotor is not available for each mast location or for each site a relationship to turbulence can be developed based on experience
- A time-series energy yield approach provides flexibility and allows the application of alternative power curves as provided from the turbine manufacturer or based on experience

Rotor Equivalent Wind Speed

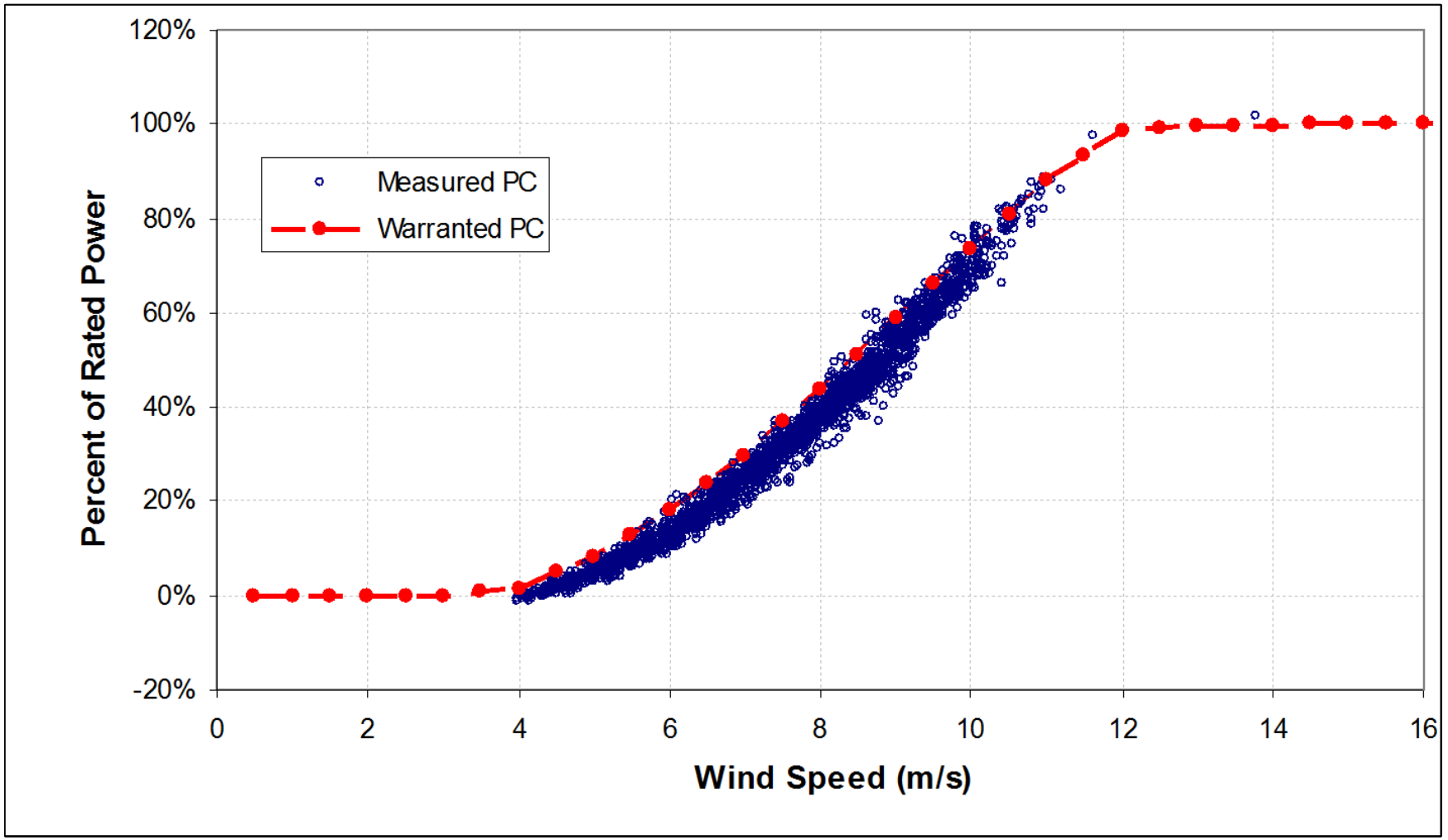
- Calculate REWS on a 10-minute basis – based on draft standard
- The use of remote sensing or tall met towers is required for characterising cross-rotor wind conditions
- Data suggests TI can be reliable proxy for identifying different cross rotor conditions
- Example of a relationship for a site in Mid-West USA:



Production – All Data

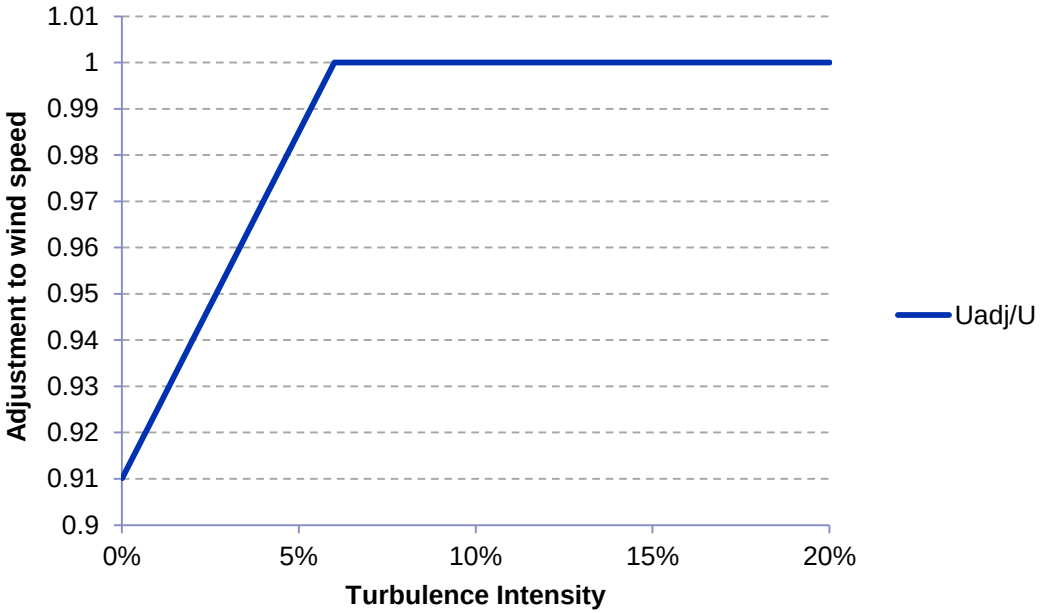


Production – TI Less than 6%



Making Adjustments – Using Empirical Model

- Empirical model based on measurements at many sites in North America
- Simple linear model
  - Reduce measured wind speed as hub-height TI decreases below threshold, TI_0
- Parameters depend on:
  - Hub height
  - Rotor diameter
  - Forestation



- Used for regions of the world where it has been shown to be applicable

Apply Based on Regional Experience

- 29 sodars and lidars across 13 US states
- 23 tall met. masts in North American and Brazil. All met towers were 80 m or taller (including one 140-m met tower)
- SCADA data and pre-construction meteorological data from six operating wind farms
- Power performance test data from approximately 45 test turbines across 16 wind projects
- Data sets ranged in length from 3 months to 24 months.
- Difference in AEP for test data set varies by site but averages 1.5% to 2% on wind speed and 2% to 3% on energy.

Time Series Resource Assessment

- Undertaken in MATLAB on a 10-minute basis

Rotor Equivalent Wind Speed (REWS)

Flow Modelling

Density Correction

Turbulence Correction

Wake Modelling

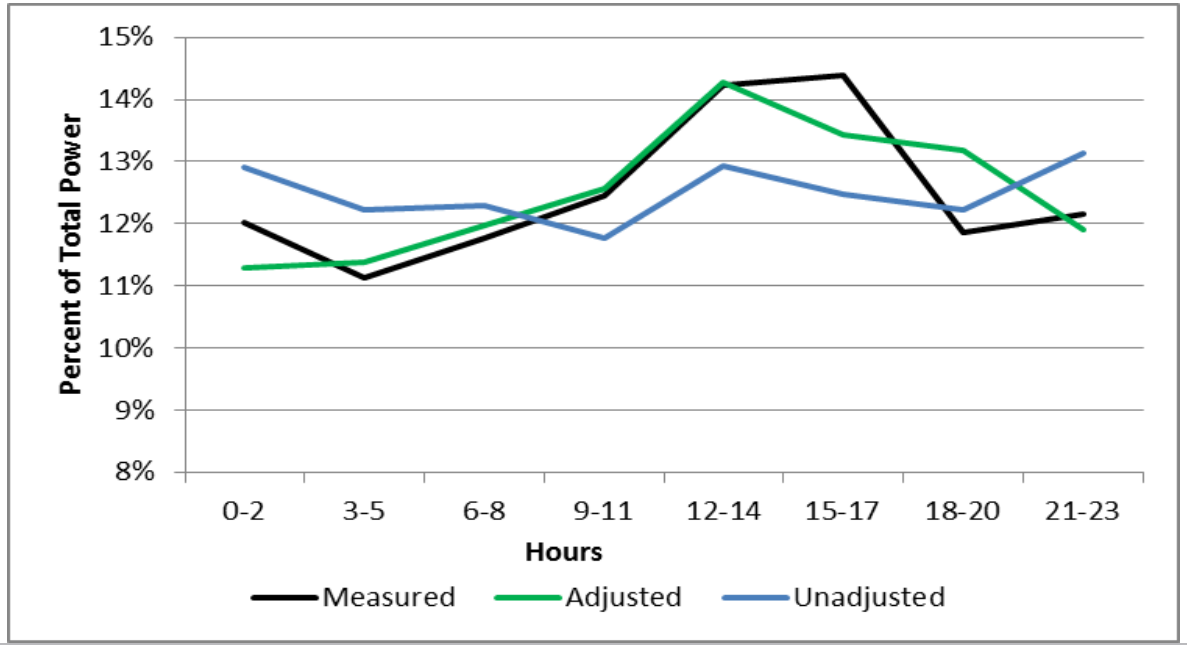
Curtailment

Flow Modelling and Density

- Flow Modelling – currently no flow modelling on a time-series basis – use look-up table to scale measured data (REWS) from an associated mast
- Density – corrected on a 10-minute basis using standard IEC correction. Compared to non-time-series approach ~0.1% difference on AEP. Where there is a distinct density profile e.g. cold climates can be ~0.5%
- Density and REWS result in significant difference on a diurnal basis:

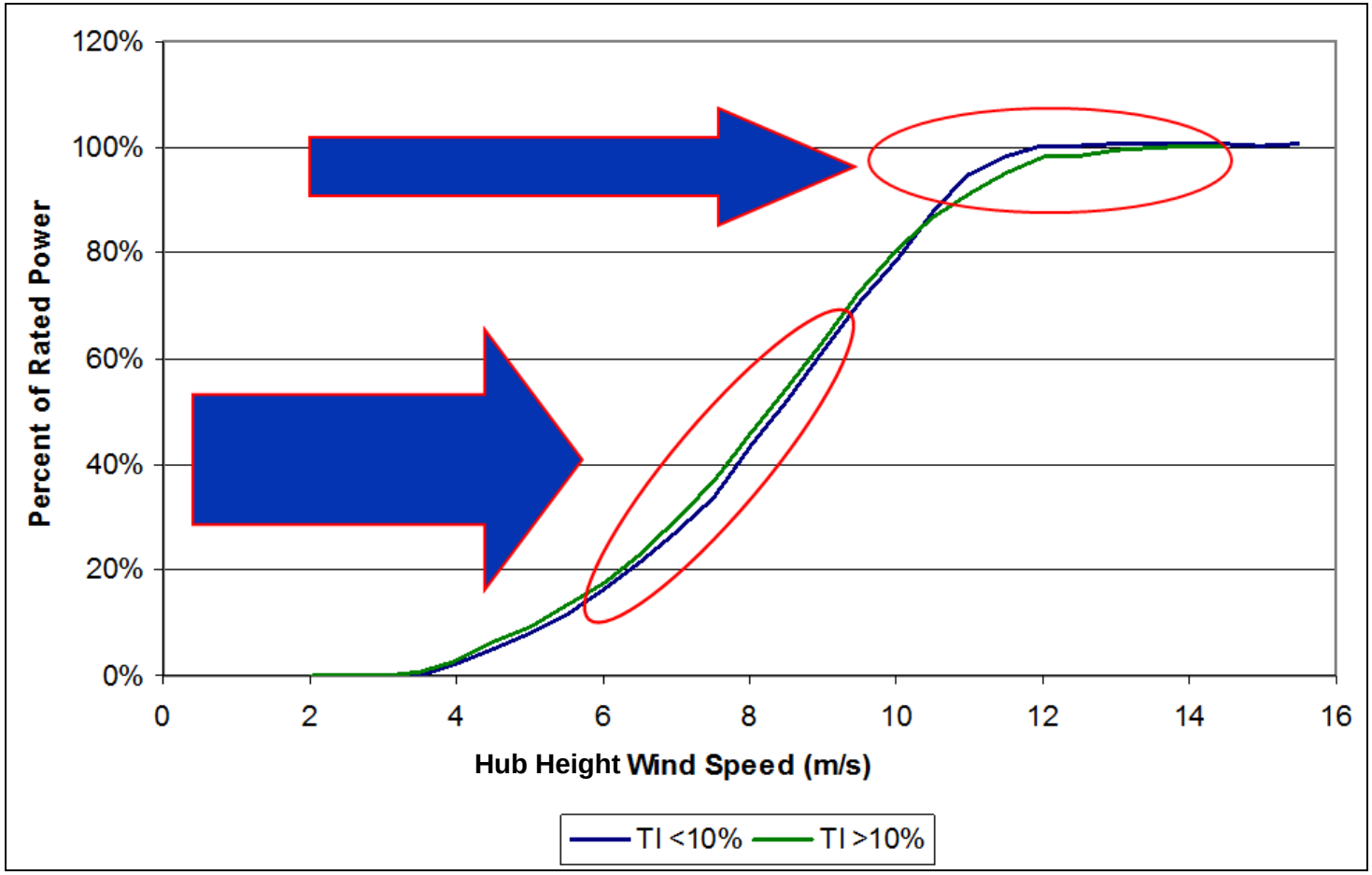
Excerpt from EWEA 2013 poster -

Benefits and Challenges in a Time Series Approach to Pre-Construction Energy Assessments

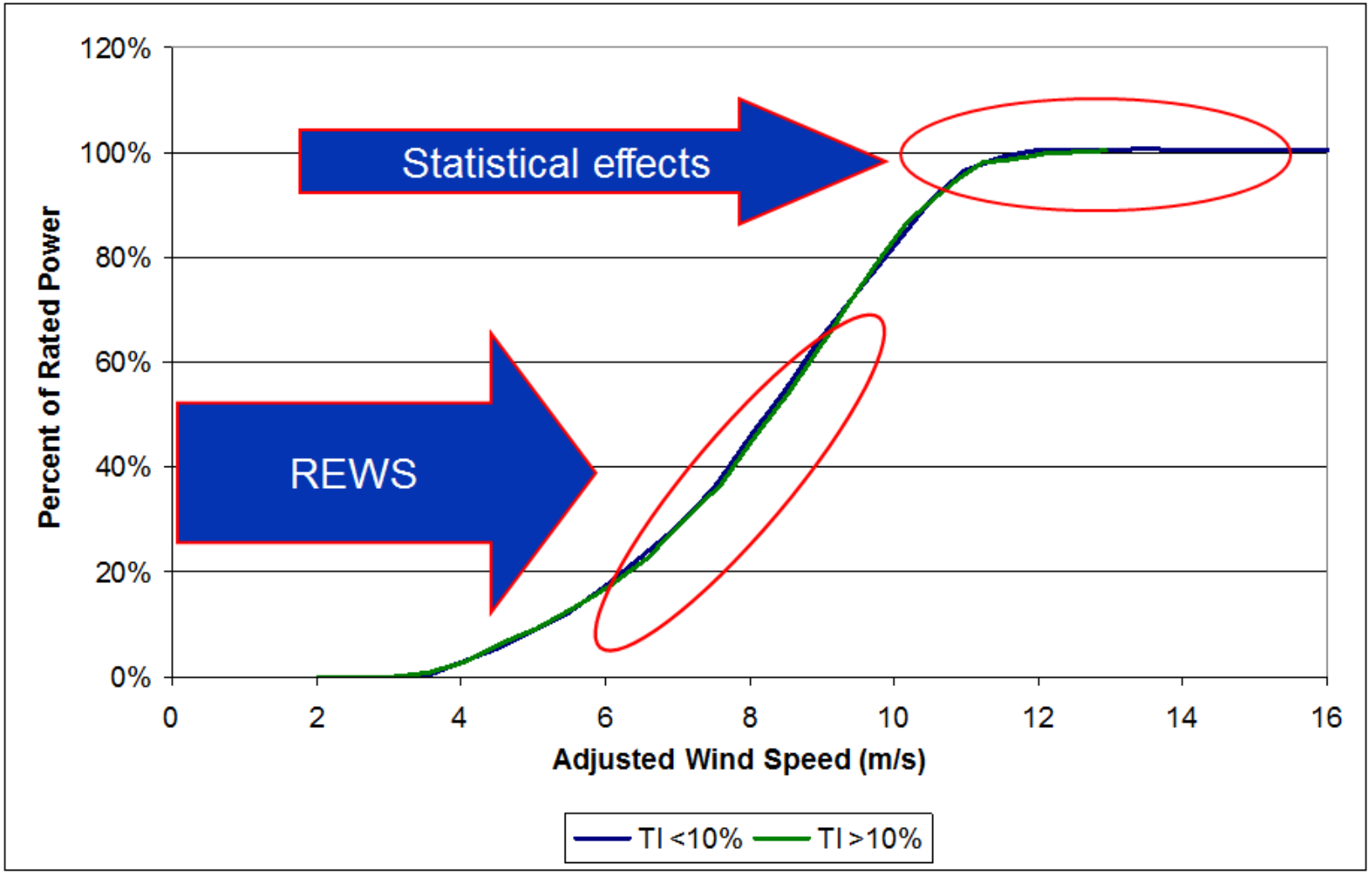


Turbulence – Statistical Correction

- Ti – Statistical correction – requires a 0% TI power curve or known TI power curve.

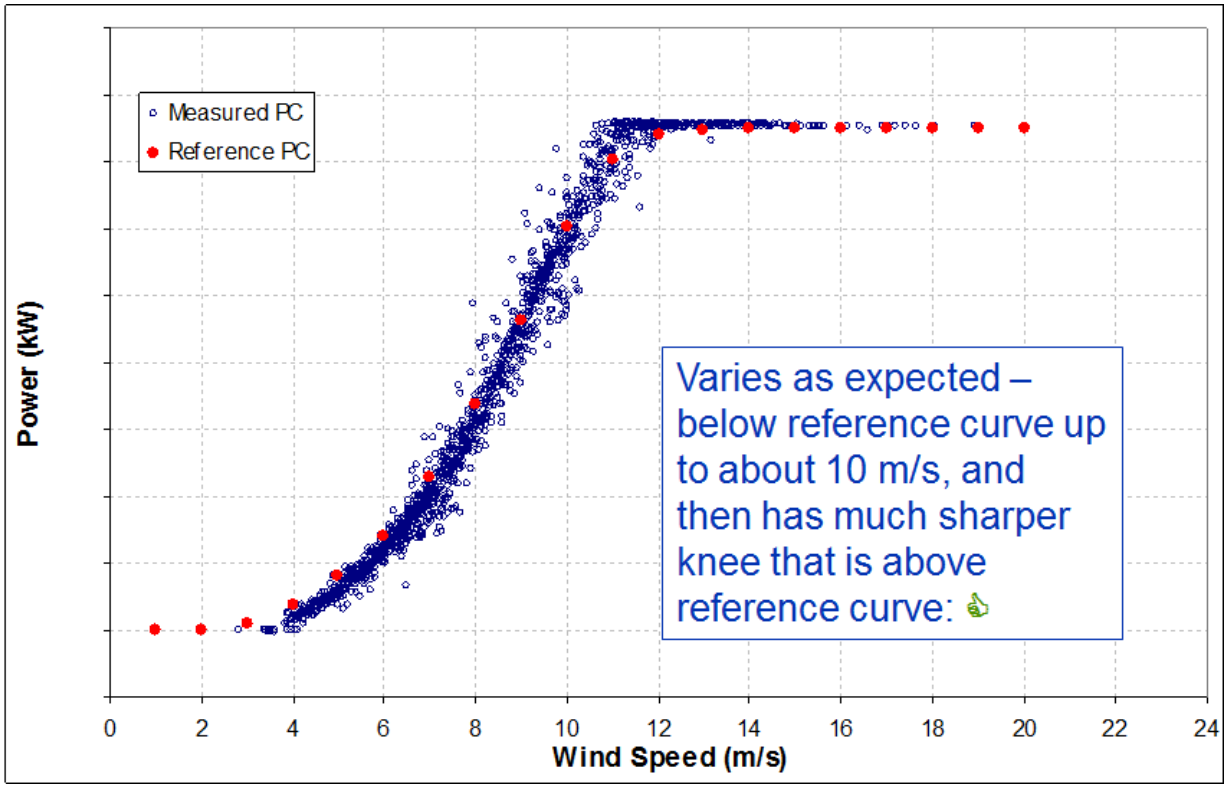


Power Curve with REWS and Statistical Correction

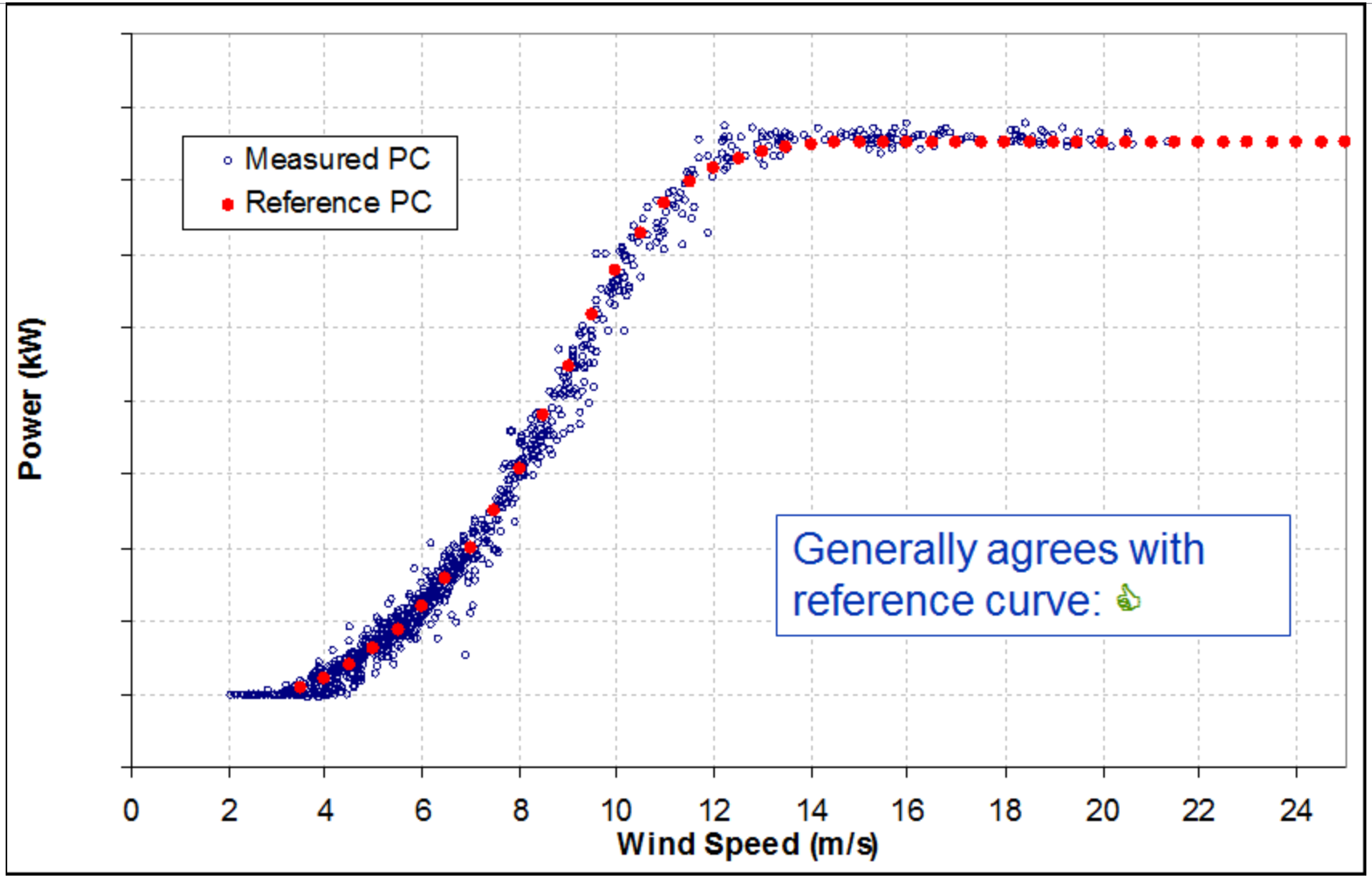


Turbulence – Other Effects

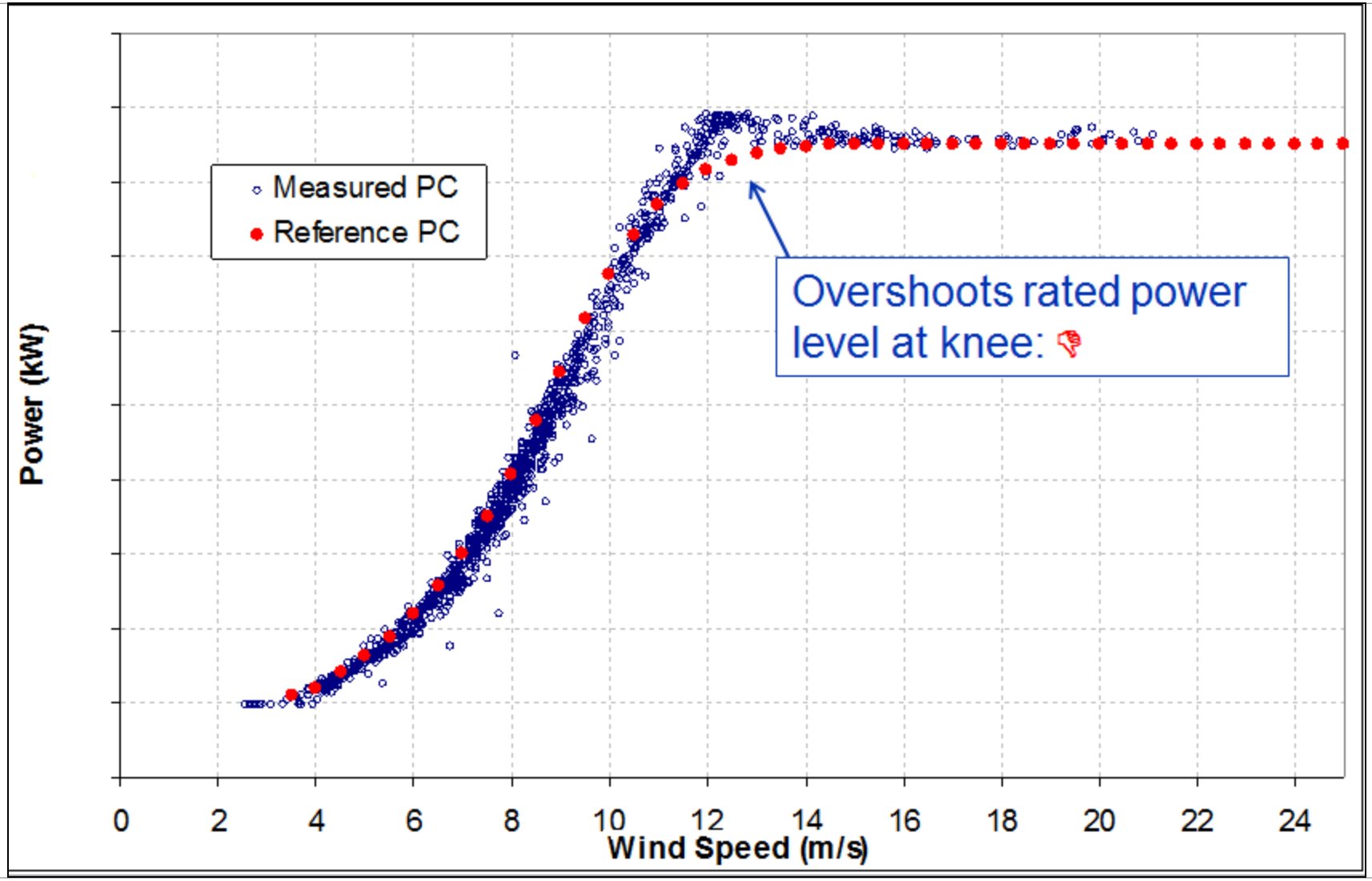
- TI – Other Effects - Turbine manufacturers do not supply a power curve for full range of turbulence. Some turbines do not follow a standard power curve e.g. pitch to stall before rated power or pitch to feather
- On a time-series basis could apply power curve based on experience
- Low turbulence:



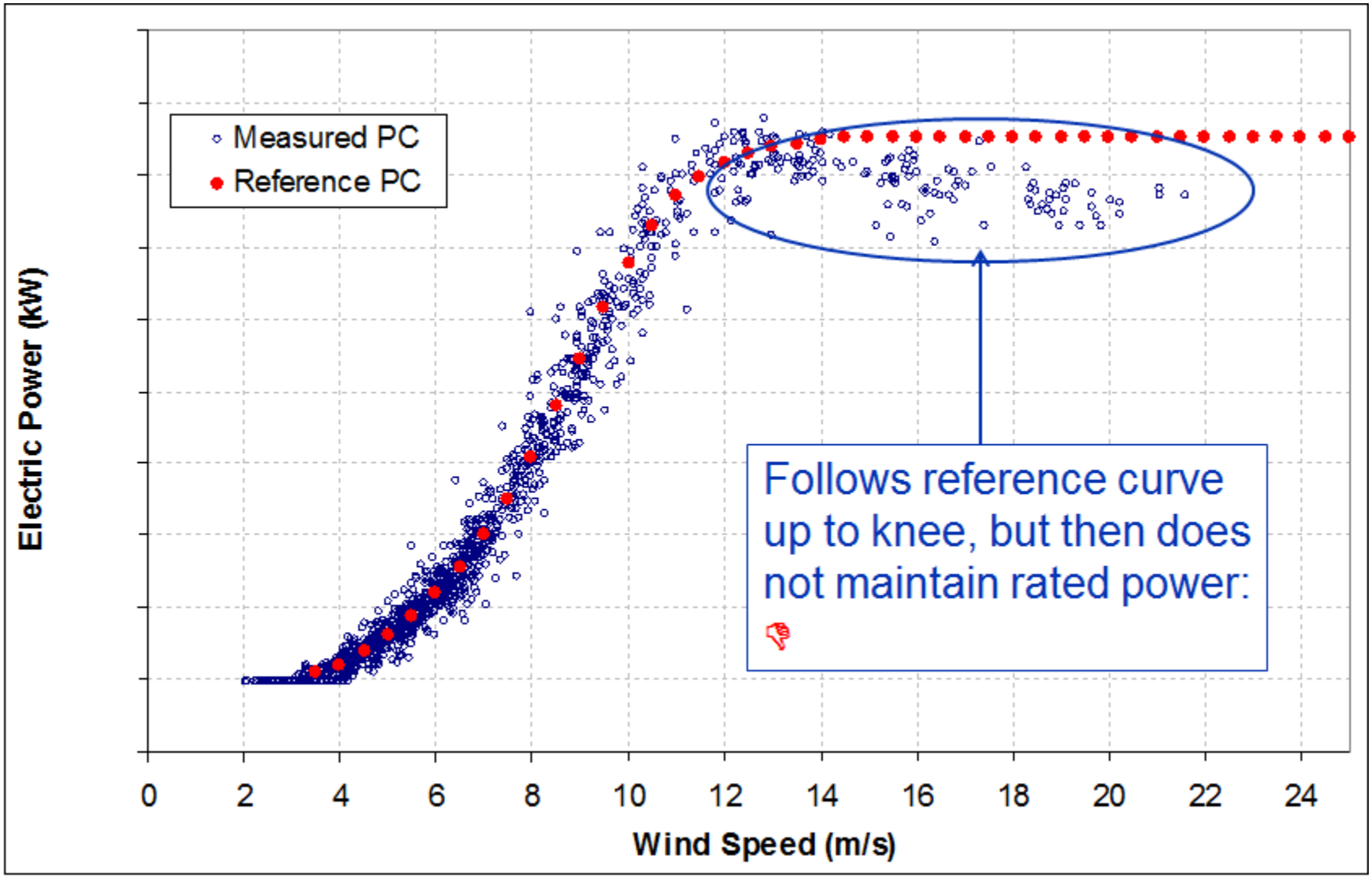
Type2 turbine, high turbulence



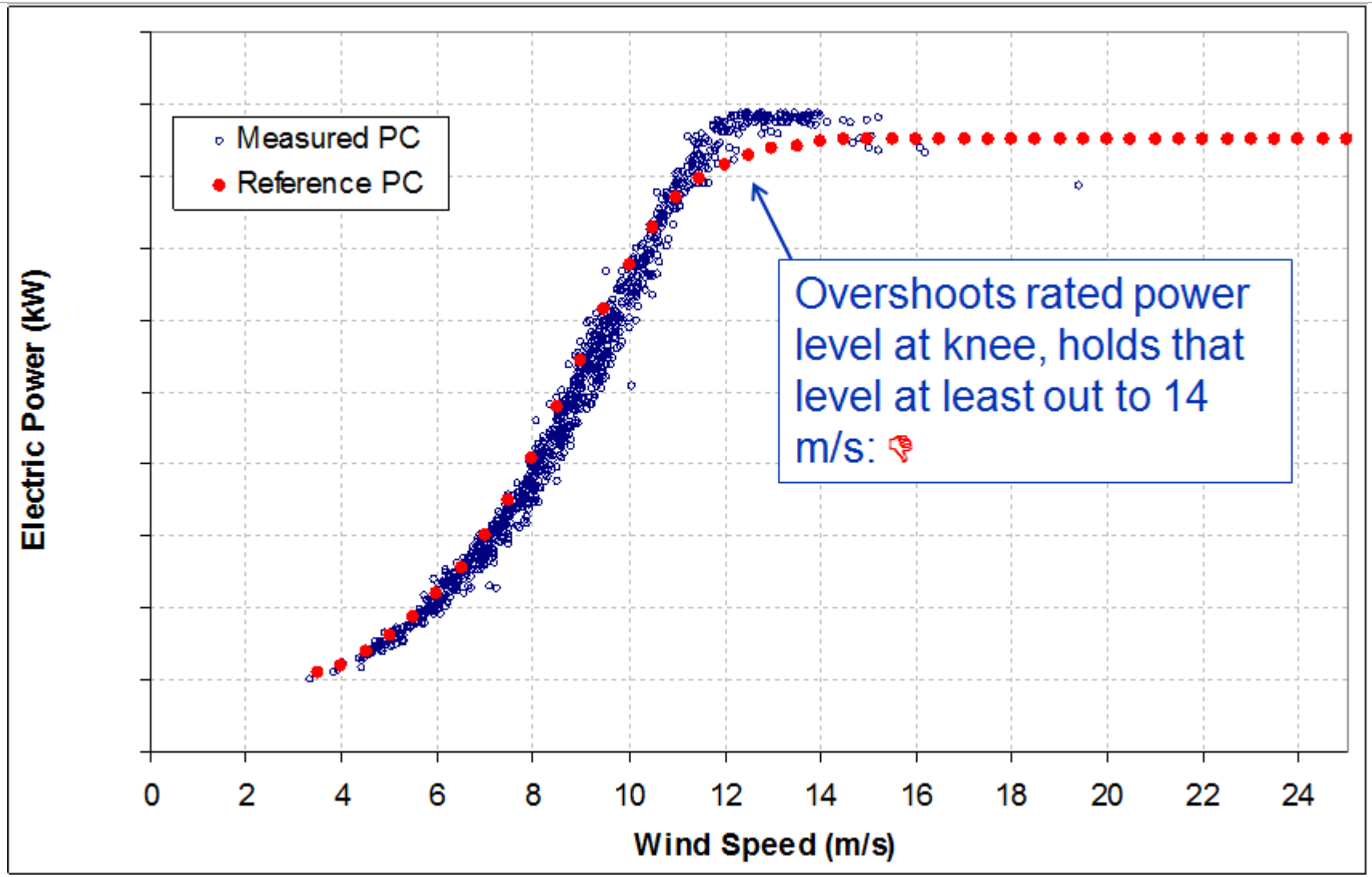
Type2 turbine, low turbulence



Type2 turbine #2, high turbulence



Type2 turbine #2, low turbulence



Reasons for Time-series Approach

- Accounting for turbine performance was not the main driver towards developing a time-series approach. These were the main drivers:
  - Turbine Boosts
  - De-rating
  - High wind hysteresis
  - More sophisticated wake modelling and wake model studies looking at TI
  - Diurnal profiling for time-of-day electric price

- Can incorporate, noise mitigation, curtailments and off-take limit
- Particularly relevant with a time-of-day electricity pricing scheme

Conclusions

- Use of REWS in annual energy prediction leads, on average, to significant impacts across the 42 measurement points reviewed. It is recommended REWS is reviewed and accounted for at all sites
- This approach can be undertaken by correcting wind speed and using standard tools
- When looking at density variation impacts on the power curve on a 10-minute basis relative to an annual average density the impacts are generally small but can be up to 0.5%
- A statistical TI correction can be made but a 0% (or defined) TI power curve is required for accuracy
- Some turbine models do not follow a standard power curve. The use of a time-series energy assessment allows flexibility for this to be captured
- Other very useful applications for a time-series approach

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