# Power Performance Measurements Using Remote Sensing

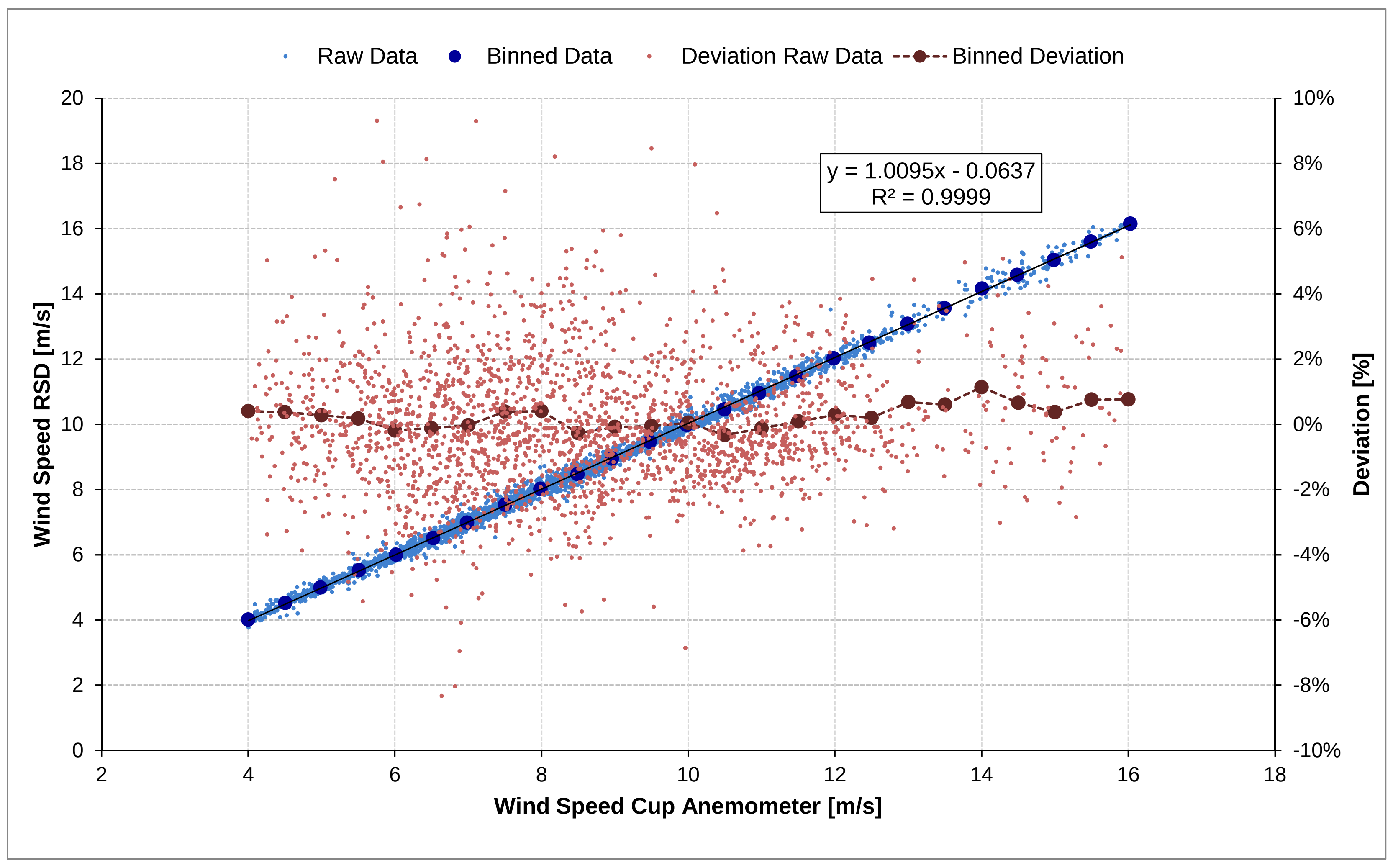
Luke Simmons (luke.simmons@dnvkema.com), Megan Quick (megan.quick@dnvkema.com)
Anna Marsh (anna.marsh@dnvkema.com) and Scott George (scott.george@dnvkema.com)

## Re-defining Wind Speed

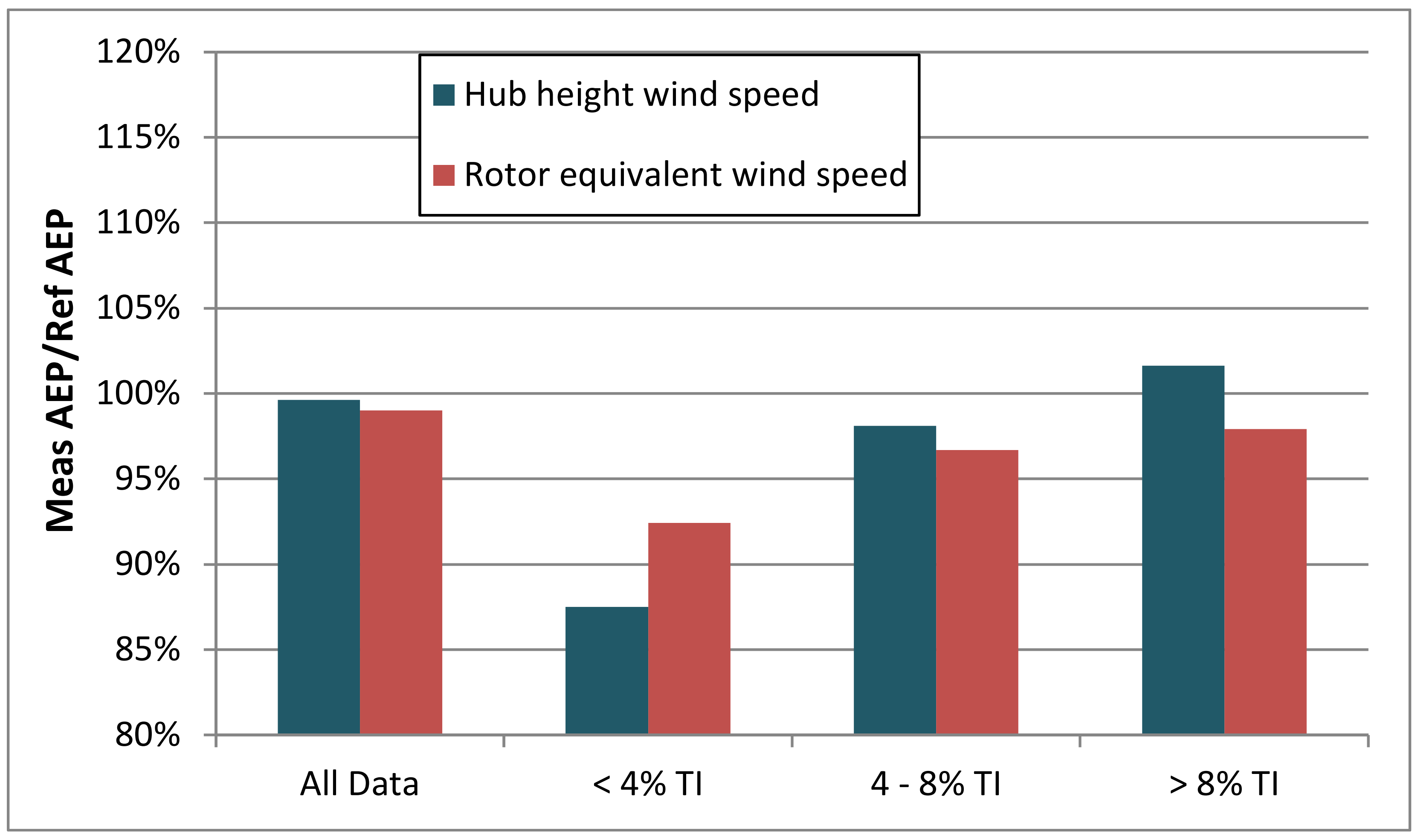
Many studies have demonstrated that the use of a single hub-height wind speed measurement does not accurately represent the available energy across a large turbine rotor under varying inflow conditions. In response, the Committee Draft for Vote of the International Electrotechnical Commission standard 61400-12-1 Ed. 2 (CDV 12-1 Ed. 2) provides several definitions for wind speed to account for new measurement technology and larger rotor diameters. A rotor equivalent wind speed (REWS) has been introduced which requires measurement of horizontal wind speed at a minimum of three points across the rotor height. This study presents a comparison of REWS power curves with hub-height wind speed (HHWS) power curves as described in CDV 12-1 Ed. 2. The impact of using these two methods under different turbulence intensities (TI) is presented in terms of annual energy production (AEP). Other considerations for implementation of the REWS defined in CDV 12-1 Ed. 2 are discussed including costs and logistics of utilizing remote sensing devices (RSD) for power performance measurements.

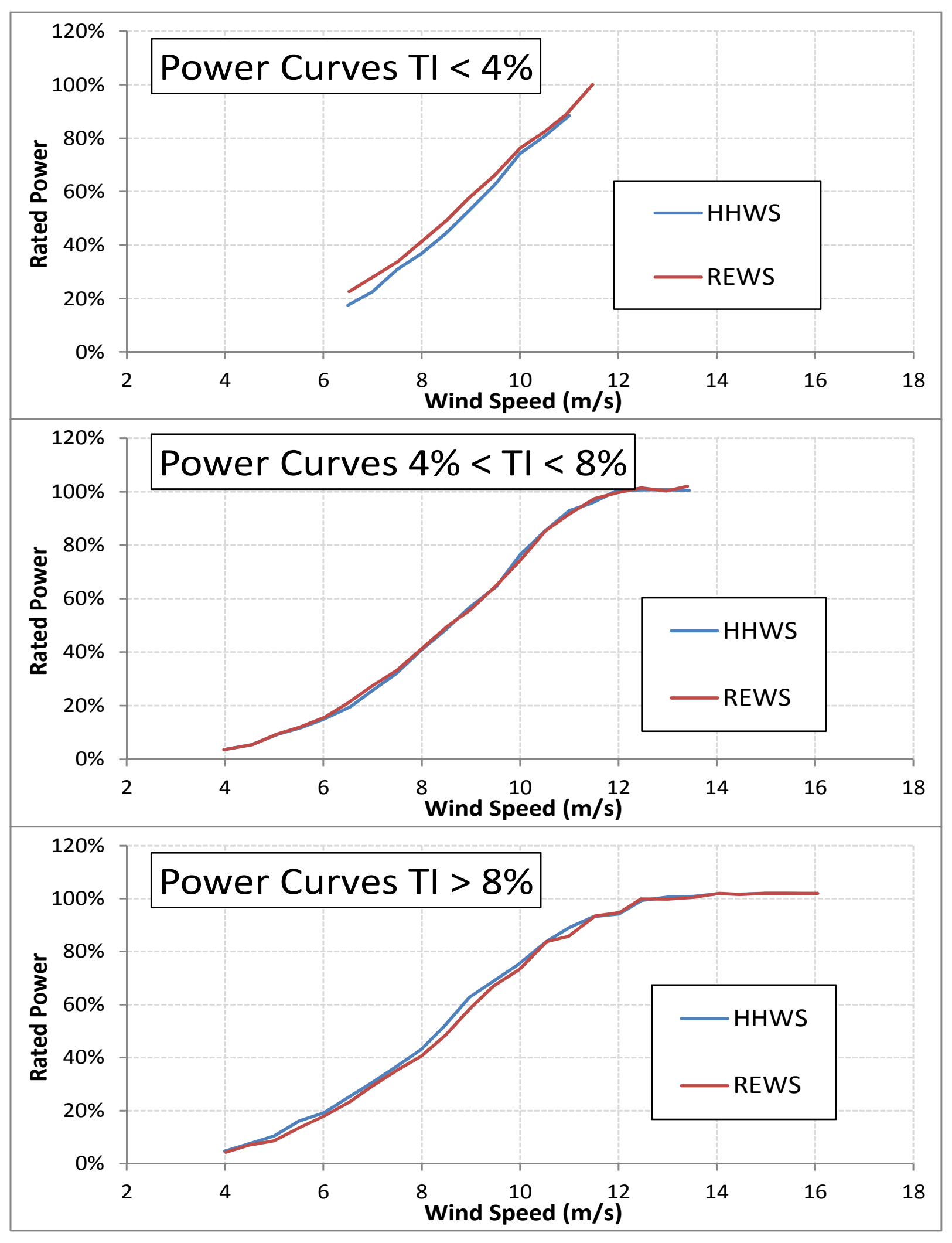
## Methods and Site Description

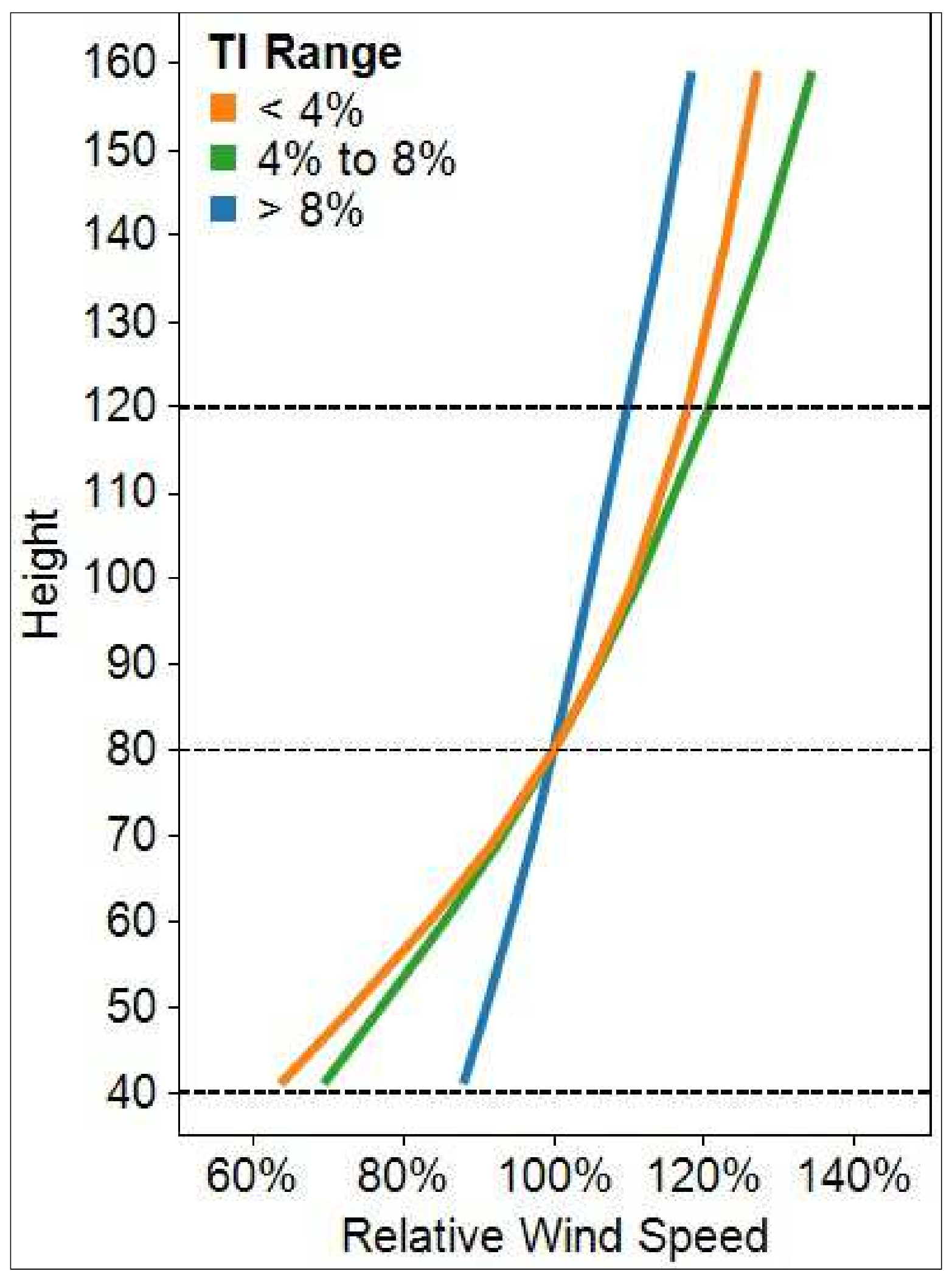
Four months of measurements were collected from a "typical" Midwestern U.S. wind project, from August through November 2012. The test turbine had a hub height of 80 m, rotor diameter of <100 m, and was part of a previous power performance measurement campaign. The turbine was located in flat terrain where site calibration was not necessary. An existing free-standing hub-height met mast was located two rotor diameters upwind of the test turbine. The met mast was equipped with a goalpost anemometer mounting system that meets the requirements of IEC 61400-12-1 Ed.1. Anemometers were also installed at the mid-blade and lower-blade tip heights. The hub-height anemometers used to measure the HHWS were Windsensor P2546A OPR anemometers calibrated by Svend Ole Hansen in March 2012. A Leosphere Windcube V2 Lidar was located approximately one rotor diameter upwind of the met mast. A verification of the Lidar, or RSD, was performed following Annex L of CDV 12-1 Ed. 2. Partial results of the verification are shown in the below figure. The RSD was used to calculate the REWS using nine measurement heights across the rotor. Both the HHWS and REWS were adjusted to the same reference density and binned in accordance with CDV IEC 12-1 Ed. 2. The power curves were then used to calculate the Measured AEP for comparison to a Reference AEP for the complete wind speed bins. The reference AEP was calculated from a power curve that was assumed to be based on HHWS. Measurement uncertainties were reported for both methods following CDV 12-1 Ed. 2. The data were then binned by TI in 4% bins for comparing AEP results under different conditions. Shear profiles were also reported using the Lidar for the same TI bins. These profiles help support the differences reported in AEP for different TI bins. Turbulence normalization per CDV 12-1 Ed. 2 was not applied to the power curves.



## Results







### Pros of REWS Method

- More accurate measurement of available energy and turbine performance. Hub-height measurement can over- or under-predict performance during differing inflow conditions. This effect will increase with increasing turbine rotor diameters.
- Remote sensing devices are highly mobile and re-usable which should result in long-term cost savings and the ability to quickly expand or modify power performance measurement campaigns.
- Installation and commissioning are very simple.
- REWS has reduced measurement uncertainty following CDV 12-1 Ed. 2 compared to HHWS method. For this study the difference was ~1.5% relative to AEP.

### Cons of REWS Method

- A met mast is still required that is at least the height of the lower blade tip.
- Power supply requirements are larger than for a typical met mast system which can complicate remote or temporary installations.
- Initial costs for a complete system (RSD, short met mast, and power supply) are higher than for a typical reference met mast installation.
- Analysis and reporting procedures are more complex.
- An RSD cannot currently be used to measure the REWS in complex terrain and met masts taller than hub height incur significant incremental costs.

## Conclusions

- REWS method corrects for available energy across the turbine rotor under differing TI conditions following the associated shear profiles.
- REWS method using an RSD is cost effective when it is used for multiple measurement campaigns.
- REWS method using an RSD adds value when:
  - Non-typical inflow conditions represent a large enough portion of the test data set that using HHWS significantly biases the overall AEP result (e.g., low AEP for low TI site).
  - Reducing uncertainty per CDV 12-1 Ed. 2 is desired.
  - Turbine rotor diameters are >100 m and understanding the inflow conditions across the rotor is desired.
- For flat sites, the REWS method improves flexibility for project owners looking to test multiple turbines and better understand turbine performance

AWEA WINDPOWER Conference & Exhibition, May 5-8, 2013