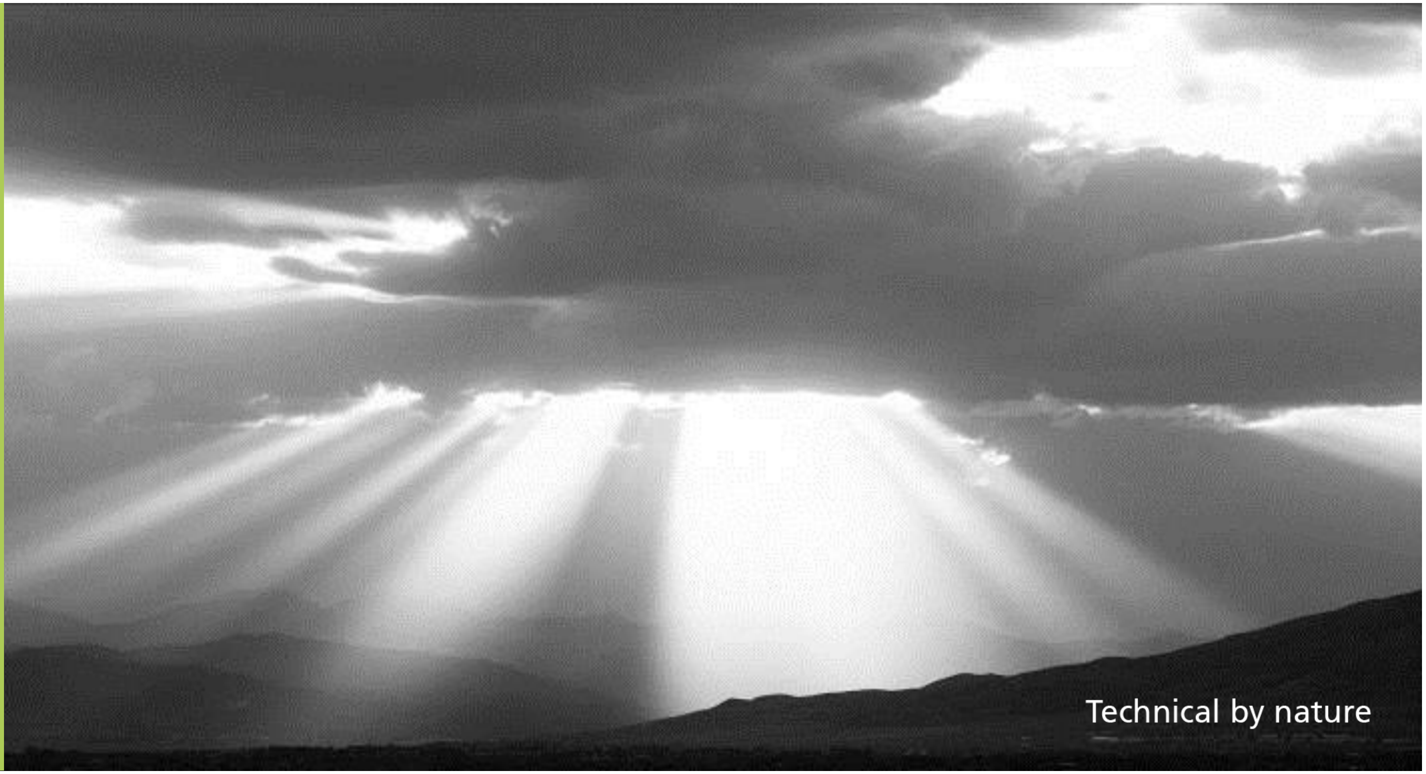
Renewable energy consultants

GL Garrad Hassan

One year on, A review of Working Group progress to date

4th December 2013, SSE Offices Glasgow – Andrew Tindal



Contents

Statement of the problem

Industry participation

Analytical methods

Proxy methods

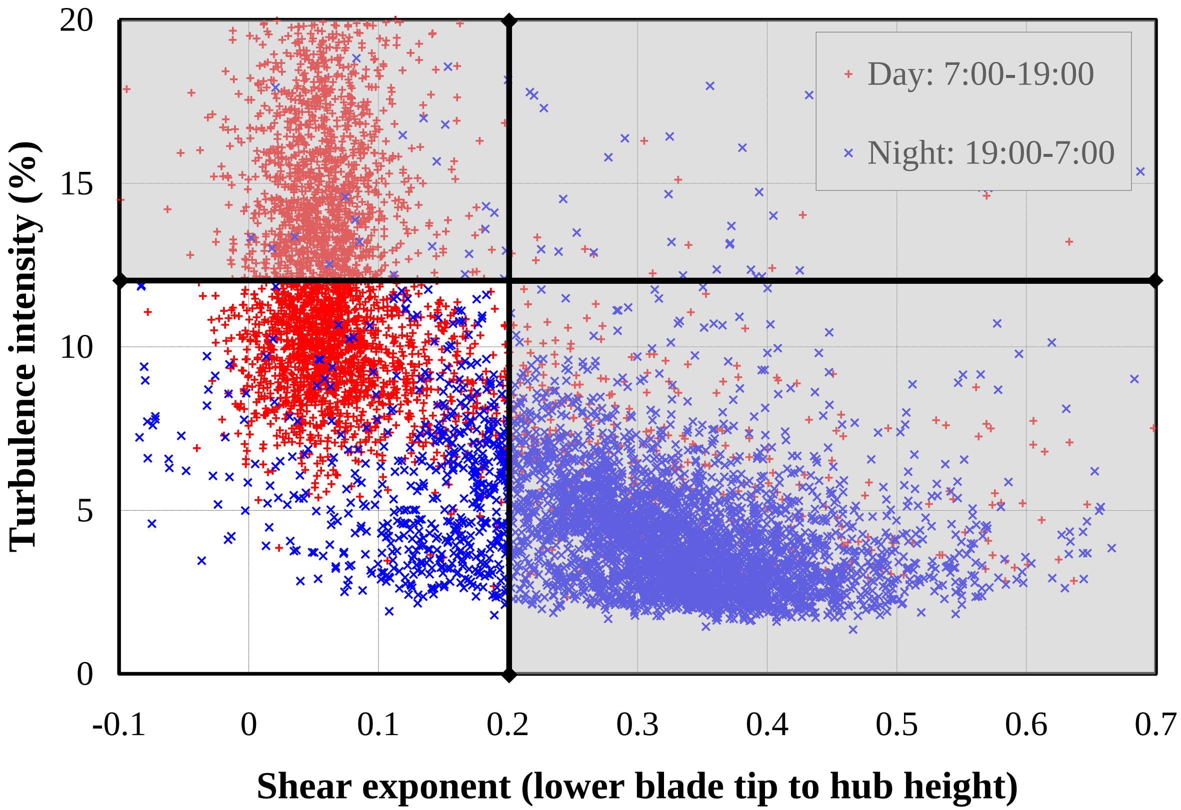
Inner and Outer range approach

Immediate next steps

What can we start to do differently?

Reminder of "Real World" site issues

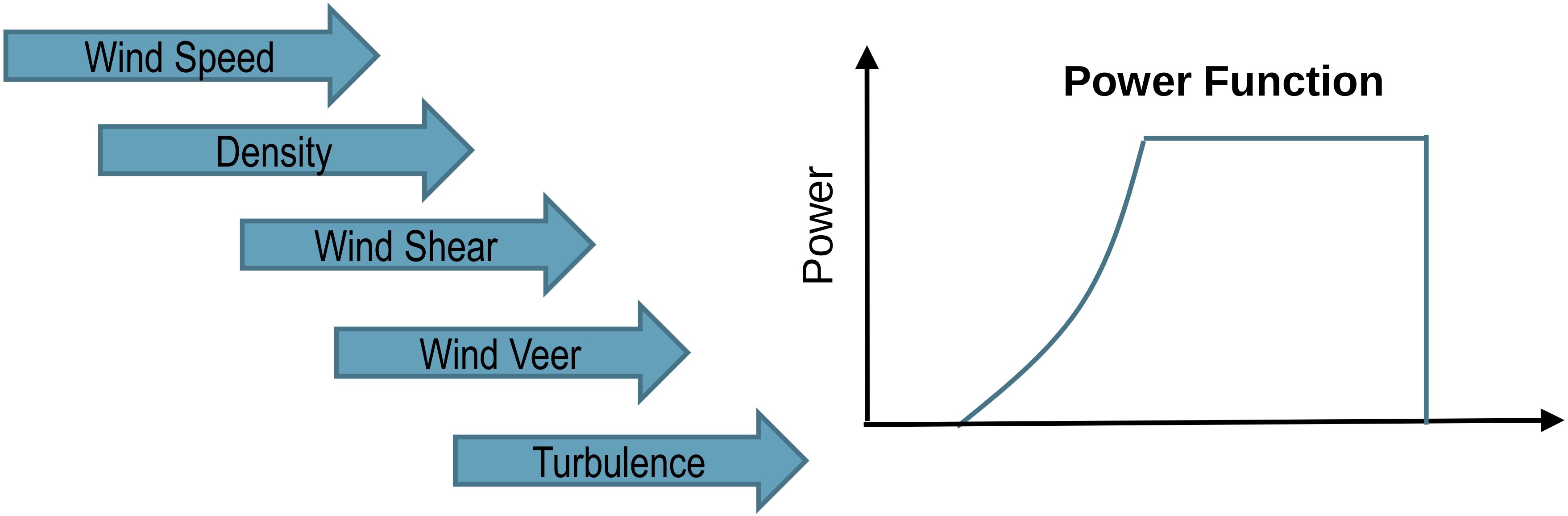
Application of example power curve screening filters for a US Midwest site. Data exclusions cover 73% of data.



Concluded we needed to review the industry approach to interpretation and application of power curves

The PCWG reached a consensus regarding a statement of the problem

- The power function of a wind turbine is dependent on **wind speed, density, vertical wind shear, vertical wind veer, turbulence intensity, directional variation and inflow angle.**



- From the above parameters; wind speed, density, vertical wind shear, vertical wind veer and turbulence intensity are thought to be of primary importance.

Power Curve Working Group has achieved good industry participation in 2013

The power curve working group (PCWG) is a balanced and broad industry group encompassing Developers, Consultants, Manufacturers and Academics/Researches.

RES
Vattenfall
Crown Estate
Dong
Iberdrola
SSE
RWE
EDF
EON

GLGH
DNV
Natural Power
AWS True Power
Sgurr
Wind Guard
Barlovento
Anemos-Jacob
IWES

Vestas
REPower
GE
Suzlon
Siemens

NREL
DTU
Lawrence
Livermore
National
Laboratory

Leosphere
Romowind

The group aims to examine ways of improving predictions of wind turbine energy yield in 'real world' conditions.

Openness is a key principal: Proceedings of all meetings publically available at:
http://www.ewea.org/events/workshops/resource-assessment-2013

Analytical methods - Rotor Equivalent Wind Speed

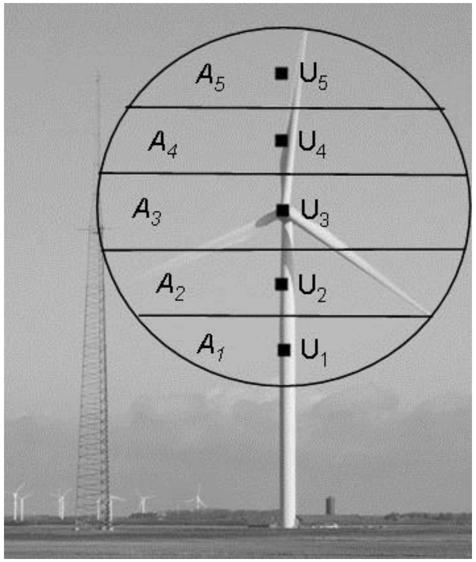
The working group has demonstrated that it can consistently apply the rotor equivalent wind speed method.

A consensus template has been produced to allow a standard methods to be applied in the future

Next step to validate model with real world power curve test data

Method adds most value when tip height wind measurements are available

Advanced flow modelling has an increasing role to play in better understanding the flow over the rotor disk



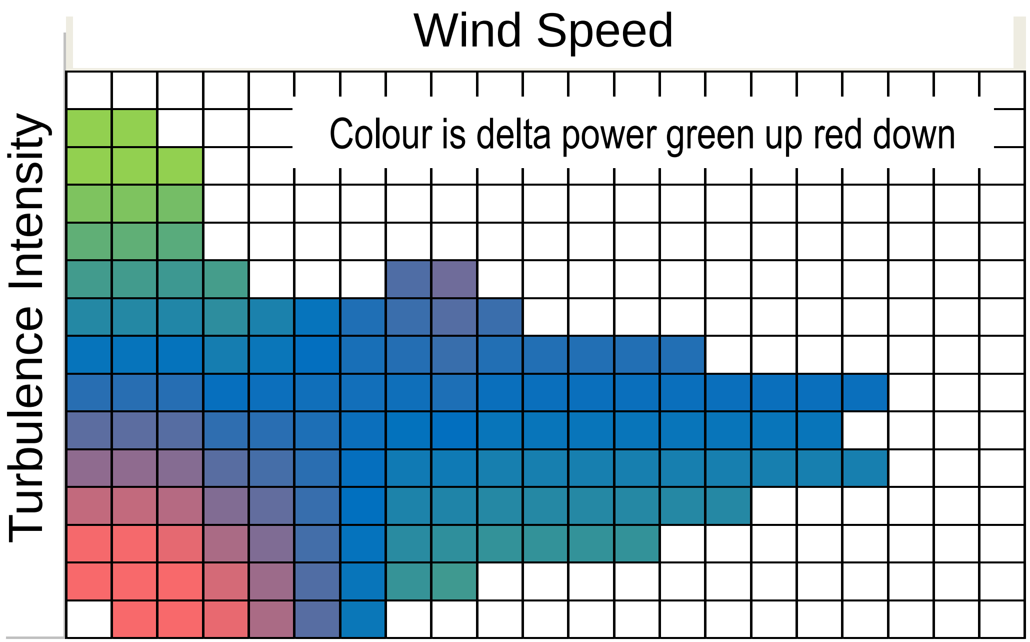
Analytical methods - Turbulence Adjustment

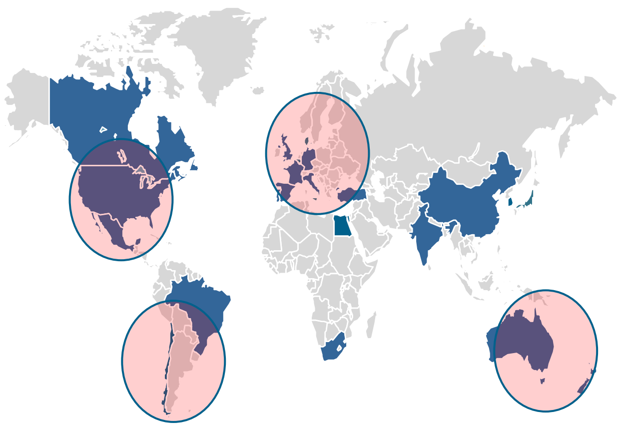
The working group has demonstrated that it can produce relatively similar results when applying turbulence adjustment methods but further work is required before a consensus method is defined.

Proxy methods – e.g. Turbulence and Wind Speed

If power deviation between a measured and a sales power curve are plotted as a function of wind speed and turbulence intensity a relatively consistent pattern is observed.

This information can be used to identify sites where early dialogue with turbine suppliers is merited and pragmatic corrections may be justified.





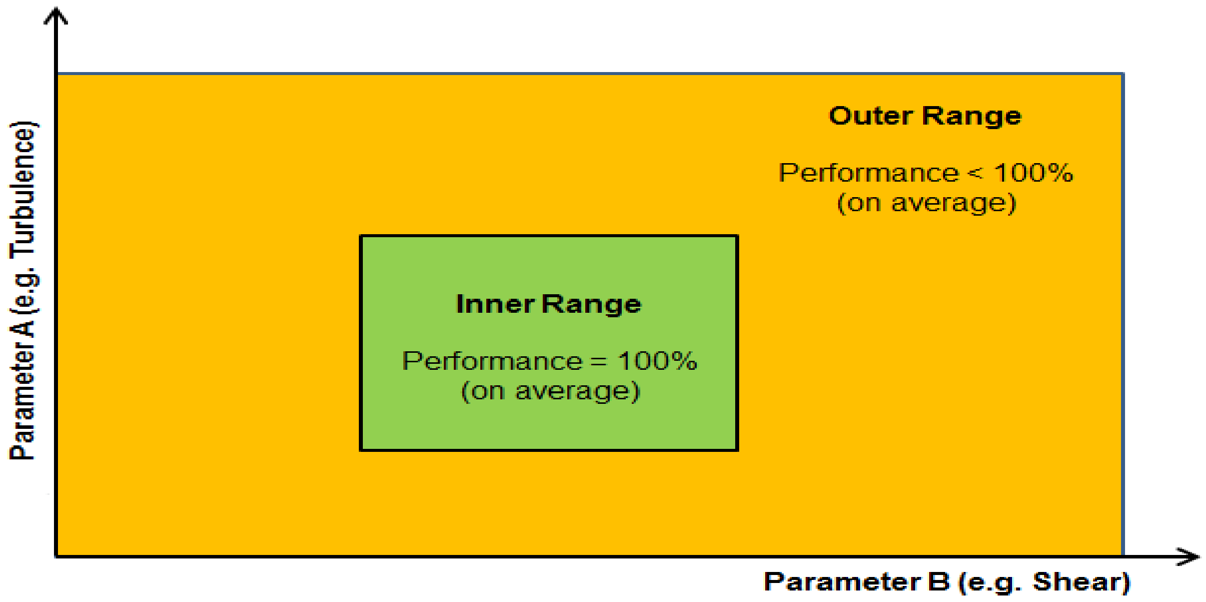
Similar patterns seen in different regions

Inner / Outer Range

The working group plans to work towards publishing a statement on the benefits of the inner/outer range proposal

The inner and outer range power curve model is a tool which may be useful within warranty discussions.

.



Immediate next steps

Achieve consensus method for Turbulence Adjustment models

Validate Rotor Equivalent Wind Speed and Turbulence Adjustment methods using measured power curve data from a range of types of sites

Investigate next steps with proxy methods.

- Proxy methods can identify site conditions where there is a risk of deviations between modelled and actual performance and can inform site specific pragmatic adjustment methods – next step is to refine methods.

- These data sets may also be used refine and validate analytical methods.

What can we start to do differently?

Use Proxy methods to identify site conditions where there is a risk of deviations between modelled and actual performance.

Use findings from PCWG to engage in information exchange about sites at an early stage with turbine suppliers

For "at risk" sites consider making tip height wind speed measurements pre-construction and when power curve tests are being conducted

Experiment with applying industry consensus power curve adjustment methods where the data exist to do so but be aware of quality of current method validations

Use proxy characterisations to make adjustments to energy predictions

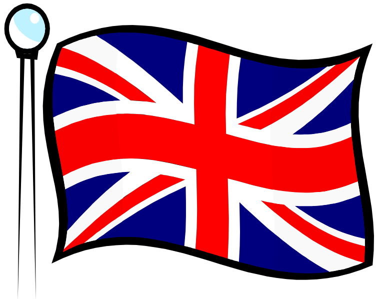
Consider the inner and outer range power curve model as a tool which may be useful within warranty discussions.

Questions?

Back up slides (if needed) for discussion session

London Meeting

4th December 2012
Key Outcomes Part 1

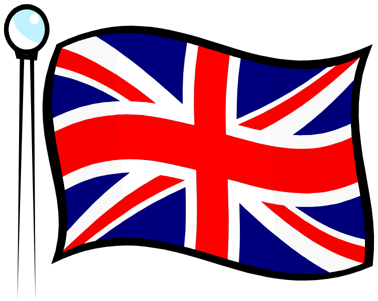


- The power function of a wind turbine is dependent on wind speed, density, vertical wind shear, vertical wind veer, turbulence intensity, directional variation and inflow angle.

- There is a need for greater clarity on the range of conditions for which power curves are representative. This will give a clear starting point for considering corrections for 'nonstandard' conditions.

- Corrections should be applied for 'non-standard' conditions which are different from those for which a power curve is representative. These corrections fall into two categories:
  - Type A: Adjustments made to reflect changes in the energy available for conversion across the rotor in a ten minute period due to 'non-standard conditions'.
  - Type B: Adjustments made to reflect changes in the conversion efficiency due to 'non-standard conditions'.

London Meeting



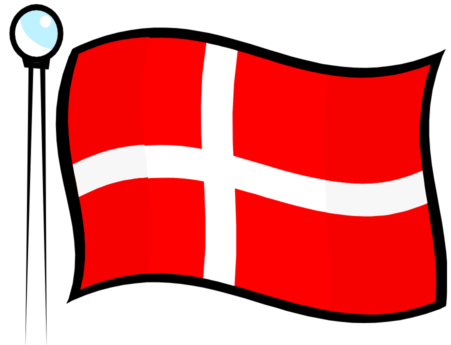
4th December 2012
Key Outcomes Part 2

- The corrections for wind shear, wind veer and turbulence intensity in the current working draft of the IEC Power Performance standard should be considered as candidate methods for incorporation into resource assessment methodologies (Type A corrections).

- Further collaboration between manufacturers, developers and consultants is required to improve communication of power function information and explore corrections for non-standard Conditions.

Brande Meeting

12th March 2013
Key Outcomes Part 1:



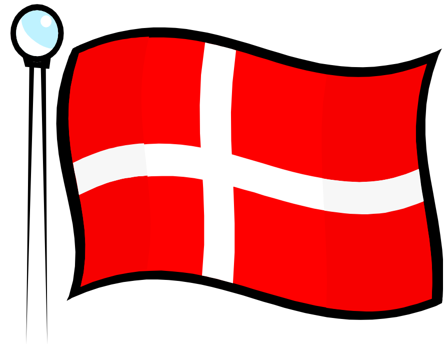
- The dependency of power output to five parameters (wind speed, density, wind shear, wind veer and turbulence intensity) should be made more explicit in power curve documentation.

- A proposal was made to improve stakeholder communication by supplying power curves with two ranges of conditions:

    - The ‘inner range’: the conditions for which a manufacturer believes a turbine will achieve its power curve (without correction).
    - The ‘outer range’: the conditions for which a manufacturer expects a turbine’s Performance will degrade below its power curve (and will require correction).

These ranges of conditions could be tied to the level of warranty e.g. X% warranty for the ‘inner range’ and Y% warranty for the ‘outer range’ where Y < X

Brande Meeting



12th March 2013
Key Outcomes Part 2:

- The use of rotor equivalent wind speed in wind resource assessment offers the opportunity to correct the wind speed input to the power curve so that it representative of the whole rotor. This approach is an effective way of dealing with the sensitivity of power output to wind shear.

- Tip-height measurements (using remote sensing devices e.g. LiDAR/SoDAR) have a big role to play in improving wind resource assessment. If such information is available it should not just be used in just the ‘traditional’ way (to verify mast measurement wind shear), instead it should form a core part of the resource assessment strategy.

- A round robin exercise will be conducted within the working group using a dataset including tip height measurements from a RES site in Sweden.

Hamburg Meeting

30th May 2013
Key Outcomes Part 1

- The 1st round robin demonstrated good agreement on the application of the equivalent wind speed concept, although further work is needed to align estimates. The turbulence normalised results showed a greater spread, but were nonetheless an encouraging start.

- The real world consideration of how best to combine a relatively short LiDAR dataset (containing gaps) with a longer met mast dataset warrants further investigation.

Hamburg Meeting

30th May 2013
Key Outcomes Part 2

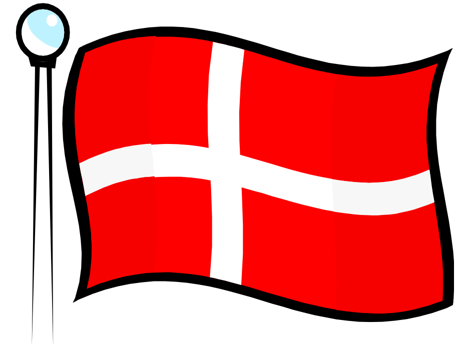
• The 1st round robin demonstrated that there is substantial merit in the inner/outer range proposal. There was broad agreement that this concept warrants further investigation through future round robin exercises and detailed consideration within individual organisations.

• There was a consensus from all manufacturers present that test site 'well-behaved' power curves are suitable for use with both hub wind speed and rotor equivalent wind speed.

• Additional round robin exercises will be organised to explore different datasets e.g. North American dataset, forest dataset etc.

Aarhus Meeting

19th September 2013
Key Outcomes Part 1



- The working group has demonstrated that it can consistently apply the rotor equivalent wind speed method.

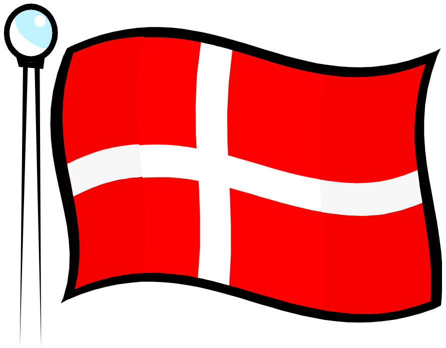
- Further work is required to build consensus on how to apply the turbulence renormalisation method.

- Both the time series and binned/frequency distribution approaches have been shown to give consistent results for both the equivalent wind speed and turbulence renormalisation methods.

- The rotor equivalent wind speed and turbulence renormalisation methods have been demonstrated to combine linearly and hence can be applied independently.

Aarhus Meeting

19th September 2013
Key Outcomes Part 2



- The working group plans to work towards publishing a consensus analysis of the round robin datasets.

- The working group plans to focus on validating the rotor equivalent wind speed and turbulence renormalisation methods. Securing appropriate validation datasets is critical.

- The working group plans to work towards publishing a statement on the benefits of the inner/outer range proposal.