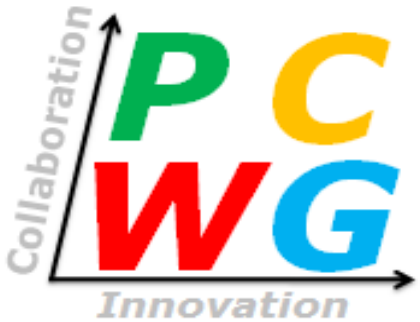
PCWG Roadmap 2018



PCWG Vision and Mission

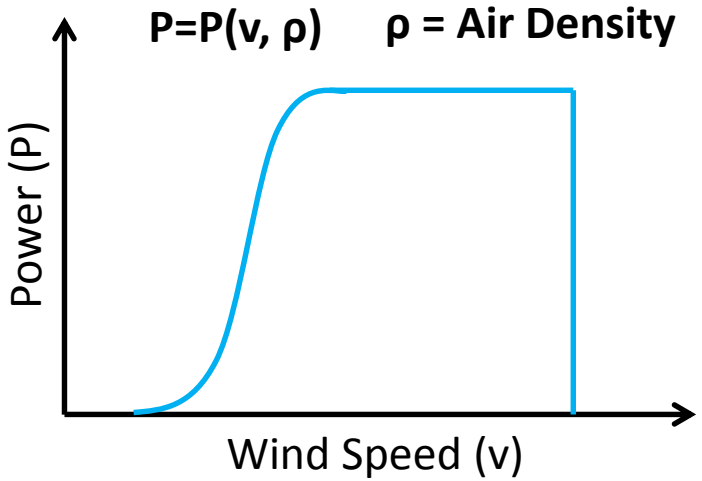
2018 Roadmap Update

We've Always Known that Real World Wind Turbine Performance is NOT as Simple as Power=P(v, ρ)!

Extract from C.J. Christensen et al: "Accuracy of power curve measurements", Risø-M-2632, 1986**...**

*"... The power curve is then seen as the relation between the **power P(v)** produced by this **undisturbed wind v**.*

*This definition is, however, of **very doubtful** value for a windmill in the natural wind. The main difficulty is that it assumes a **smooth laminar flow of high degree of homogeneity and symmetry**"*



The PCWG aims to build industry consensus on how best to predict real world turbine performance and look beyond P=P(v, ρ). www.pcwg.org.

Reflecting the Real World: Inner-Outer Range Decomposition

Categories of Turbine Performance Corrections

PCWG Activities

Inner Range Performance

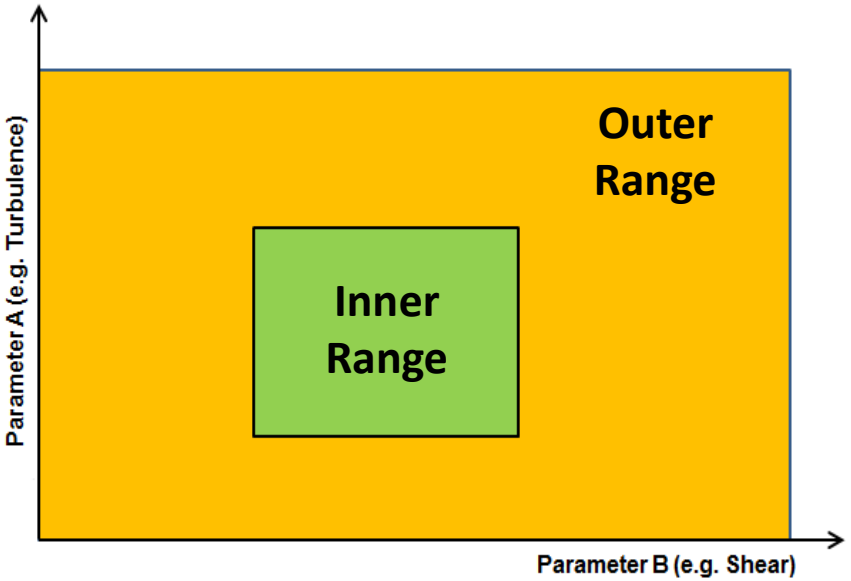
Adjustments to reflect the fact that even under warranted/ideal conditions performance may not be 100%

Outer Range Performance

Adjustments to reflect the fact that turbine performance may deviate from Inner Range behaviour in Outer Range Conditions e.g. Low/High TI, Low/High Shear etc.

+ Other Performance Corrections

Icing, Blade Degradation, Sub-optimal performance etc.



***Note**: The PCWG Inner-Outer Range Proposal is **Conceptual Decomposition**, and does infer specific parameter ranges.*

Reflecting the Real World: Average-Specific Decomposition

Categories of Turbine Performance Corrections

PCWG Activities

Average Performance

(Bulk) Adjustments to reflect the fact that on average (in all conditions) turbines may not meet their documented performance level

→ Remove Bias

Conditions Specific Performance

Adjustments to reflect the fact that turbine performance may deviate from average performance in 'non-average' Conditions e.g. Low/High TI, Low/High Shear etc.

→ Remove Uncertainty

Improve Project Design

→ Reduced:

- £/MWh
- $/MWh
- €/MWh

+ Other Performance Corrections

Icing, Blade Degradation, Sub-optimal performance etc.

Classification of PCWG Activities by Component

***Note**: whilst the two decompositions are subtly different, they are broadly compatible with respect to the roadmap e.g. actions to further 'Inner Range' understanding, will generally further 'Average Performance' understanding.*

The type of PCWG activates differs strongly depending on the problem component

Inner Range Performance

Average Performance

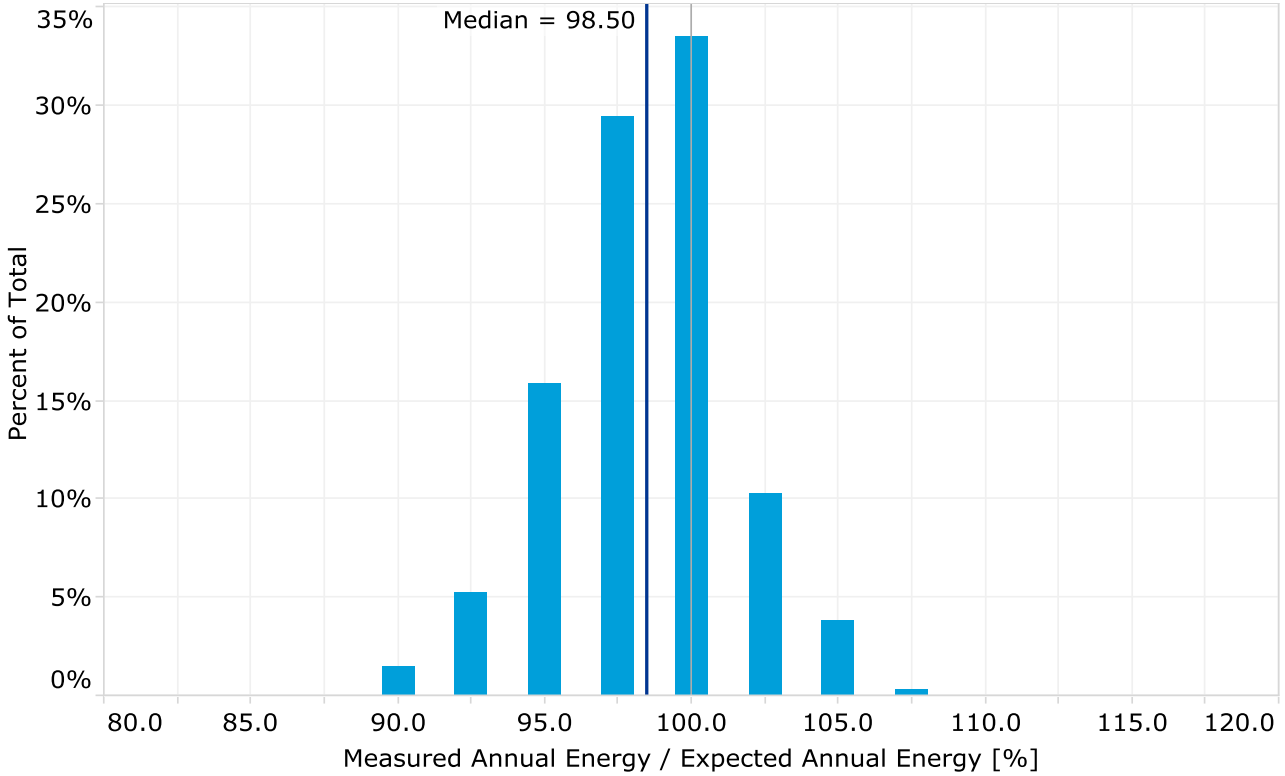
*The PCWG is seeking to define an **assessment framework** to define how to make best use of historic power performance tests when predicting future inner/average performance.*

Outer Range Performance

Conditions Specific Performance

*The PCWG is attempting to evaluate **quantitative methods** for predicting Outer/ Specific performance via the PCWG Intelligence Sharing Initiative (PCWG-Share-X)*

Reflecting the Real World: Inner Range / Average Performance

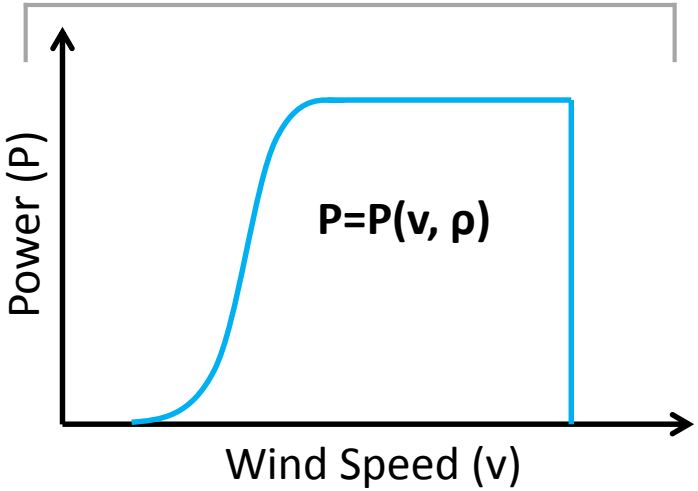


DNV·GL

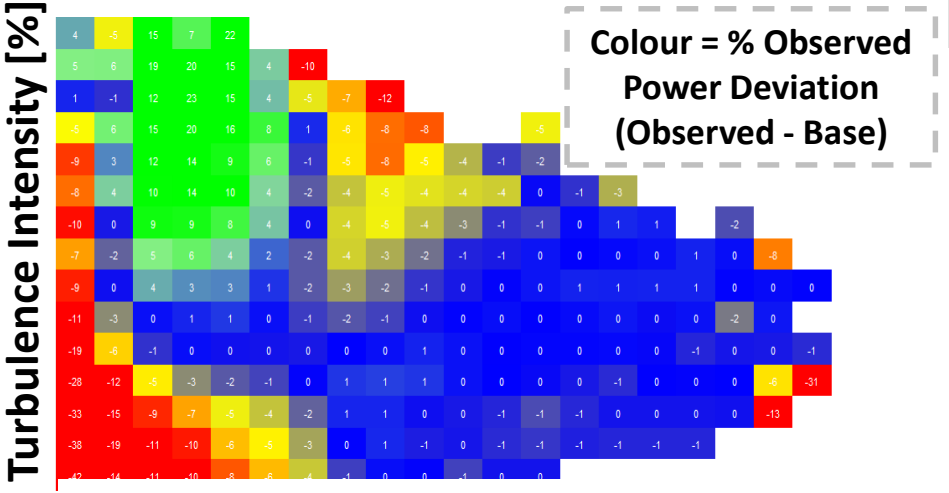
Extract from *'High Resolution Turbine-Specific Matrix'*, Carl Ostridge DNV GL, Colorado PCWG Meeting, 10 August 2016, download from www.pcwg.org.

Reflecting the Real World: Outer Range Performance

Inner Range Performance

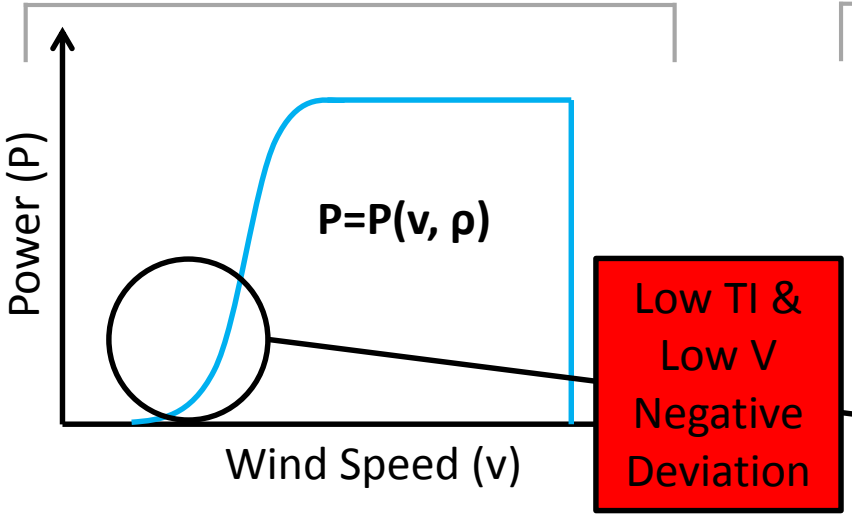


Outer Range Deviations (Observed – Base)



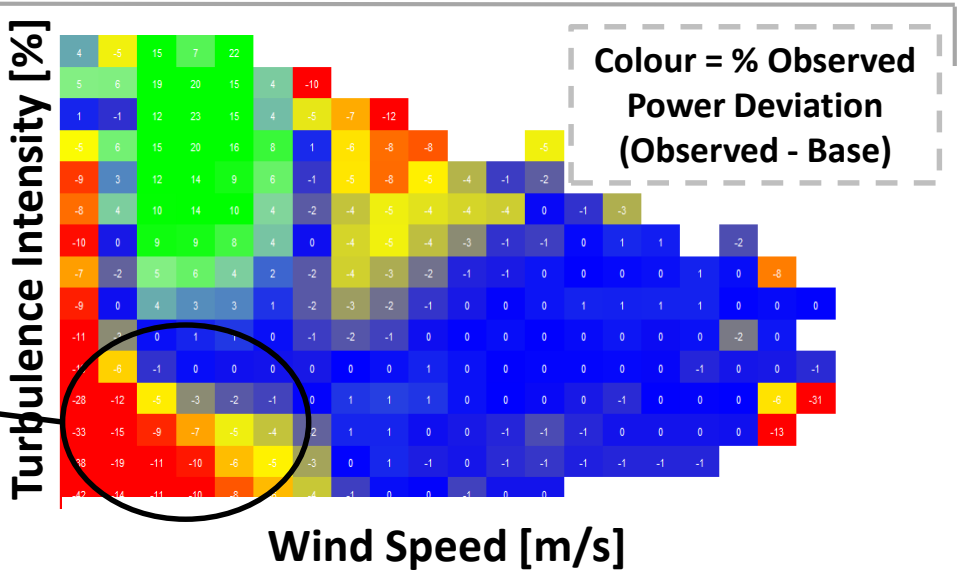
Reflecting the Real World: Outer Range Performance

Inner Range Performance



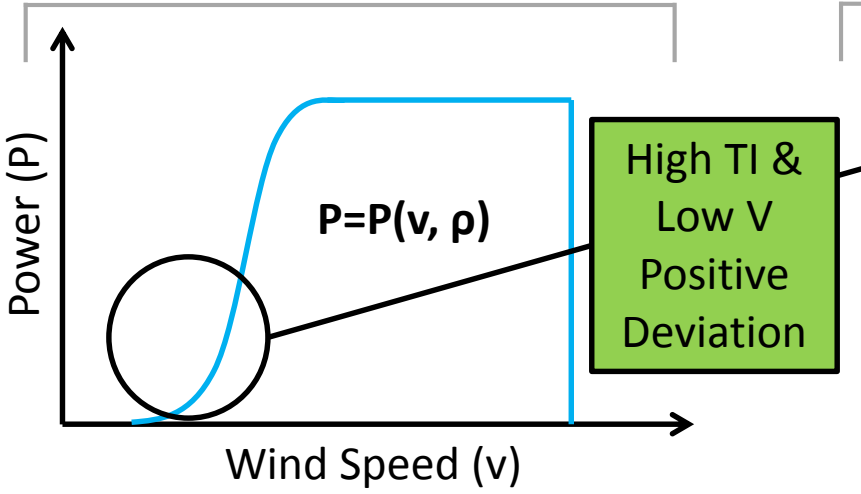
Low TI & Low V Negative Deviation

Outer Range Deviations (Observed – Base)



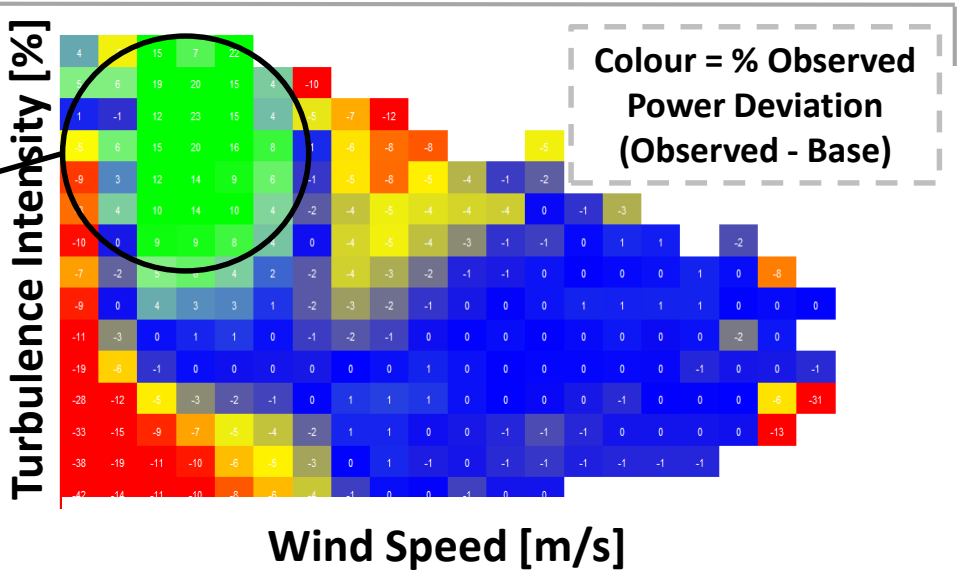
Reflecting the Real World: Outer Range Performance

Inner Range Performance



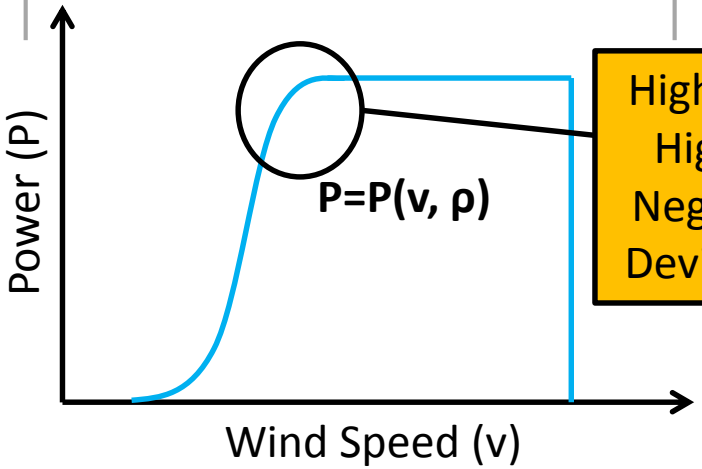
High TI & Low V Positive Deviation

Outer Range Deviations (Observed – Base)



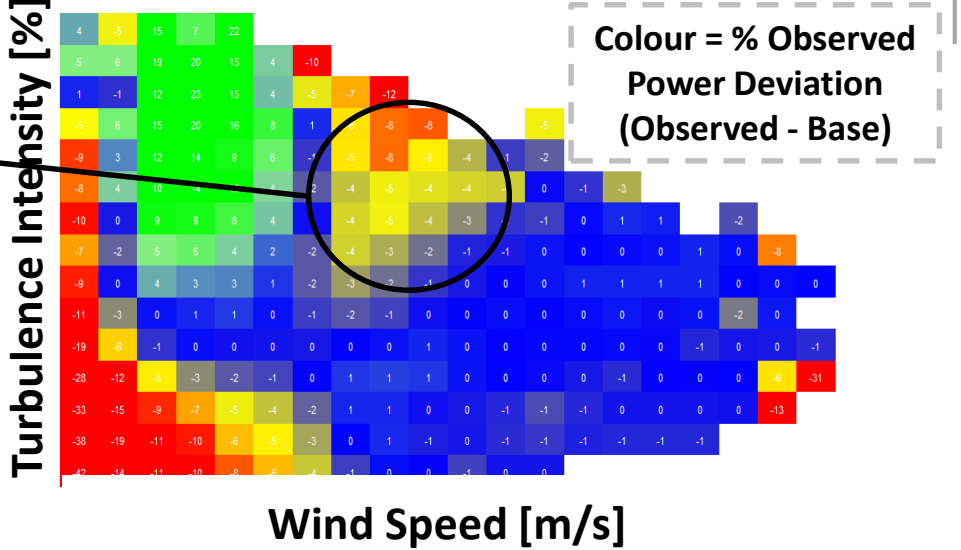
Reflecting the Real World: Outer Range Performance

Inner Range Performance



High TI & High V Negative Deviation

Outer Range Deviations (Observed – Base)



PCWG Vision and Mission

2018 Roadmap Update

PCWG 2018 Roadmap

NOW

1. Inner/Average Performance

Define best **practice guidelines** for stakeholder data exchange and analysis to establish inner/average performance

2. Outer/Specific Performance

Objectively **determine/refine the best methods for modelling outer/specific performance** using the PCWG-Share-X Platform

3. Enabling Activities

Publically available worked Examples
PCWG Analysis Tool Development

End of 2018

OUTCOME

Evidence Pathway for Inner/Average Performance
→ **Reduced Investor Risk**

50% reduction in outer/specific modelling uncertainty, contribute to IEC 61400-15
→ **Reduced Investor Risk**

The **right tools & industry understanding** to deliver items 1 & 2

PCWG 2018 Roadmap

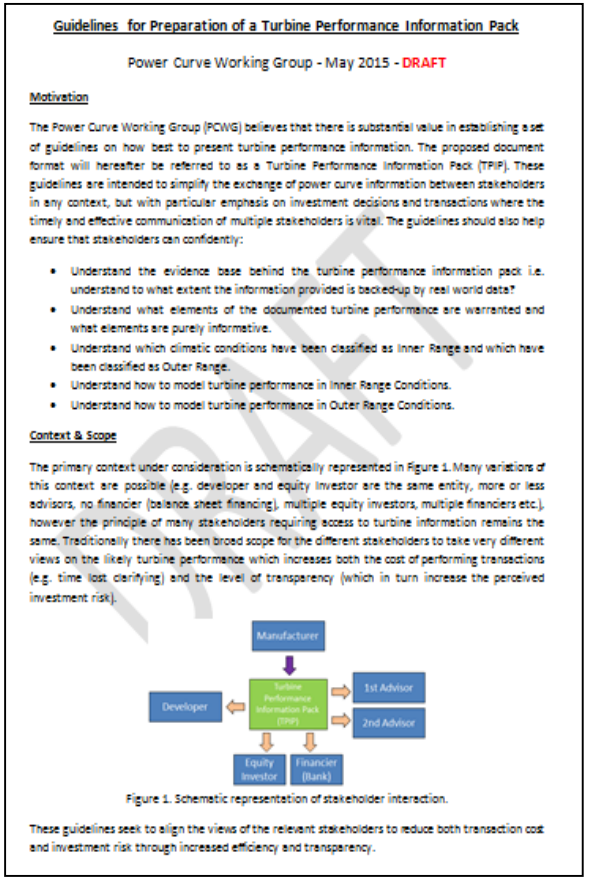
Roadmap Page 2/4

1. Inner/Average Performance

- Define best **practice guidelines** for stakeholder data exchange and analysis to establish inner/average performance (**based on real world industry practice**)

2018 - Timeline

Aug	Draft Guidelines Document (based on a overhaul of existing DRAFT 'guidelines for preparation of a turbine information pack' document).
Sep	Feedback
Oct	Updated Draft Document
Nov	Final Feedback
Dec	Publication on PCWG Website



Guidelines for Preparation of a Turbine Performance Information Pack

Power Curve Working Group - May 2015 - DRAFT

Motivation

The Power Curve Working Group (PCWG) believes that there is substantial value in establishing a set of guidelines on how best to present turbine performance information. The proposed document format will hereafter be referred to as a Turbine Performance Information Pack (TPIP). These guidelines are intended to simplify the exchange of power curve information between stakeholders in any context, but with particular emphasis on investment decisions and transactions where the timely and effective communication of multiple stakeholders is vital. The guidelines should also help ensure that stakeholders can confidently:

- Understand the evidence base behind the turbine performance information pack i.e. understand to what extent the information provided is backed-up by real world data?
- Understand what elements of the documented turbine performance are warranted and what elements are purely informative.
- Understand which climatic conditions have been classified as Inner Range and which have been classified as Outer Range.
- Understand how to model turbine performance in Inner Range Conditions.
- Understand how to model turbine performance in Outer Range Conditions.

Context & Scope

The primary context under consideration is schematically represented in Figure 1. Many variations of this context are possible (e.g. developer and equity investor are the same entity, more or less advisors, no financier (balance sheet financing), multiple equity investors, multiple financiers etc.), however the principle of many stakeholders requiring access to turbine information remains the same. Traditionally there has been broad scope for the different stakeholders to take very different views on the likely turbine performance which increases both the cost of performing transactions (e.g. time lost clarifying) and the level of transparency (which in turn increase the perceived investment risk).

Figure 1. Schematic representation of stakeholder interaction.

These guidelines seek to align the views of the relevant stakeholders to reduce both transaction cost and investment risk through increased efficiency and transparency.

Measuring Progress

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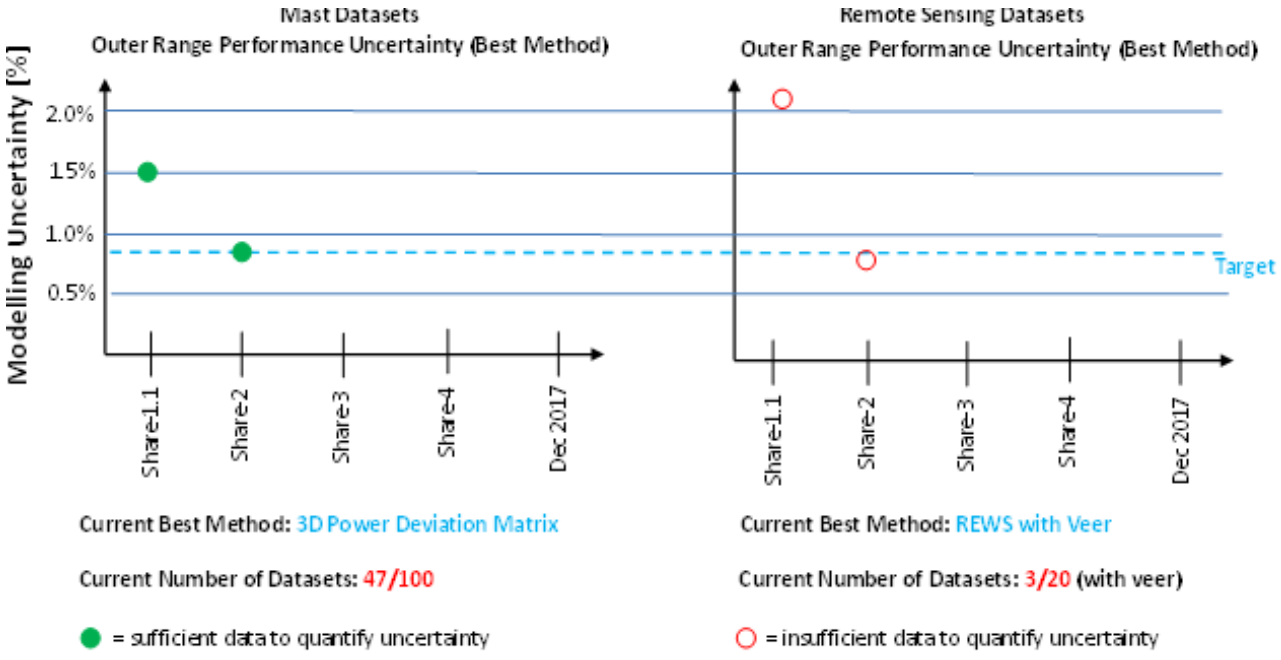
2. Outer/Specific Performance



2018 - Timeline

Feb	PCWG-Share-3
Jun	PCWG-Share-4
Sep	Provide input to IEC 61400-15

PCWG 2018 Roadmap

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3. Enabling Activities

- **Publically Available Worked Examples**
  - Further Worked Examples to support PCWG-Share-X and ensure numeric integrity.
  - Avoid further work examples & round robins not directly related to PCWG-Share-X (focus and bandwidth)

- **PCWG Analysis Tool Development**
  - Implementation of New Methods
  - Improved Testing and worked examples
  - Improved Beta Testing (Beta Testing Sub Group) – Led by Paul Housley (SSE)
  - Improved Documentation (Beta Testing Sub Group) - Available for PCWG-Share-3

- **Machine Learning**
  - Sub-group meetings and discussions
  - Creation of Machine Learning Web Service for PCWG-Share-4

- **Publish Summary of PCWG Activities & Outcomes (on PCWG Website)**

Summary

1. **Focus activities of group:**
   - **Don’t try and do too much.**
   - **Focus on delivering tangible input to IEC 61400-15 (by Q3)**

2. **PCWG-Share-X**
   - **Leverage PCWG-Share-X to achieve 1)**
   - **Implement lessons learnt and ensure tool is comprehensively numerically and usability tested prior to start each sharing iteration (don’t rush!)**

3. **Best practice guidelines**
   - **Distil best of current industry practice**