2014 nz wind energy CONFERENCE & EXHIBITION

# Using Remote Sensing to Reduce Energy Uncertainty

## Key findings from Parsons Brinckerhoff's research paper

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new zealand wind energy association

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# Agenda

1. Introduction to Parsons Brinckerhoff
2. Remote sensing – what is it?
3. Energy uncertainty – what are the causes?
4. The test case
5. Siting remote sensing devices – where do I put these things?
6. Data duration – how much data do I need?
7. Data rejection
8. Case study of combined uncertainty
9. Fiscal analysis – what is it worth $$$?



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# Introduction to Parsons Brinckerhoff

## Parsons Brinckerhoff

- Global engineering consulting firm
- Wholly owned subsidiary of Balfour Beatty plc.
- We employ over 14,000 staff worldwide
- 1,500 staff and 13 regional offices in Australia/NZ

## We have been advising on wind for over 20 years

- Pre-feasibility and feasibility
- Planning, environment and community consultation
- Detailed design
- Project and construction management
- Financial close out
- Operations and maintenance

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# Remote sensing – what is it?

## SODAR (sonic detection and ranging)

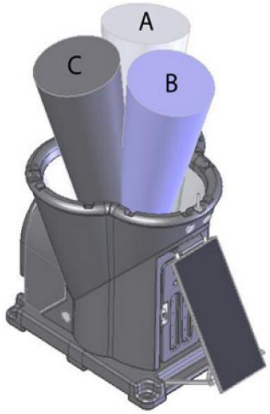


Image Source: Walls, E. 2010


Image Source: Fulcrum3D, 2013

- **Emits acoustic pulses**
- **Receives acoustic backscatter with Doppler shift**
- **Converts to signal to wind speed vectors at multiple heights**

## LIDAR (light detection and ranging)

Image Source: WindCube V2 Brochure

Image Source: CRES 2012

- **Emits light signals**
- **Receives backscattered light with Doppler shift**
- **Converts to signal to wind speed vectors at multiple heights**

**Similar concepts, different signal medium, different sensitivities.**

**Site validation is important, but not considered in this presentation**

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# Energy uncertainty – what are the causes?

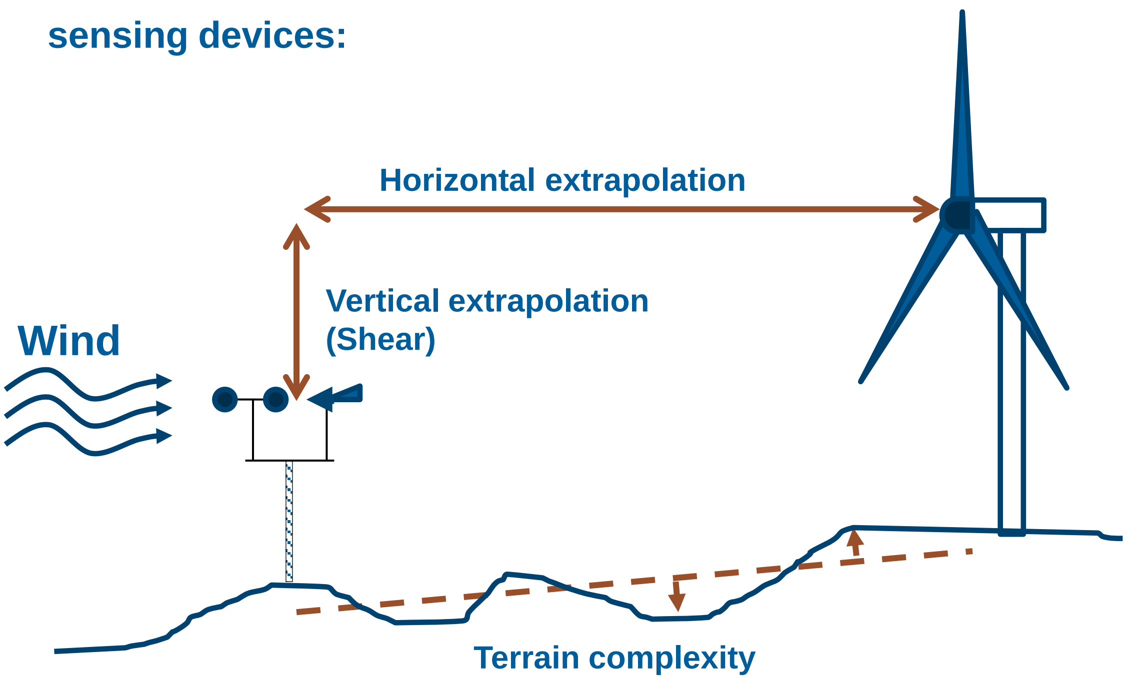
**Wind resource and energy prediction is a complicated process.**

**There are many steps and each adds to uncertainty.**

**Two sources of uncertainty are considered today:**

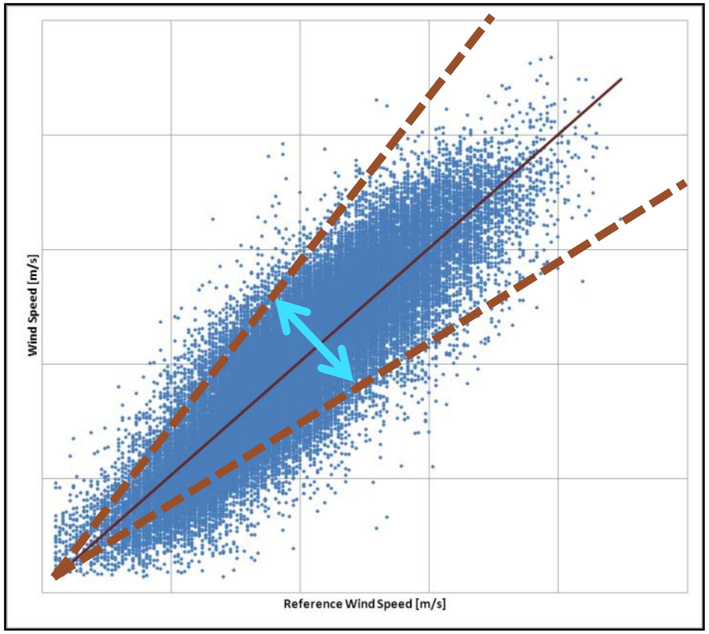
## Wind Flow Modelling Uncertainty

**Can be affected by siting of remote sensing devices:**




## Measure, Correlate, Predict (MCP) Uncertainties

**Can be affected by data duration and data rejection (among others)**



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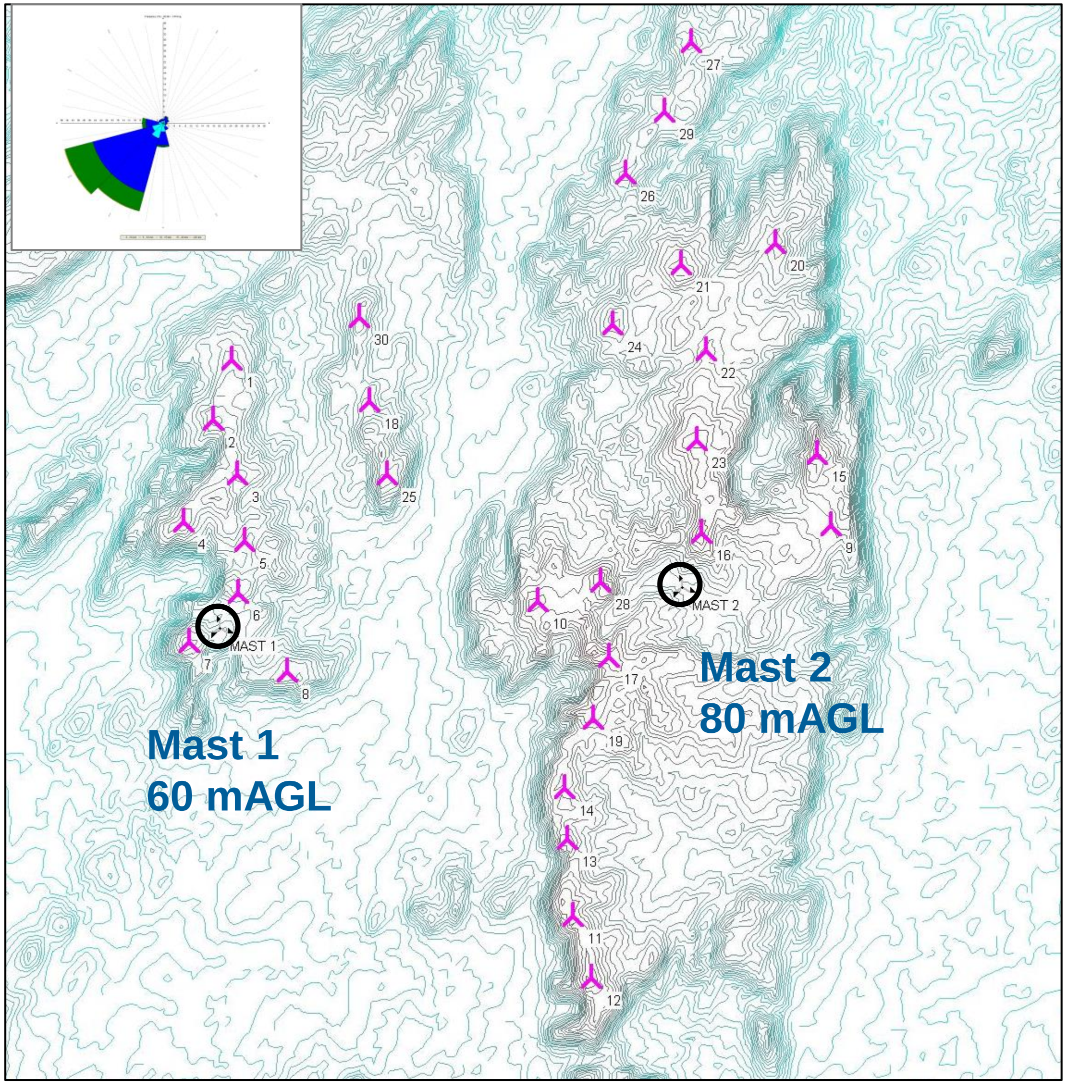
# Test case – a sample site to test uncertainty




## 30 x 3 MW WTGs with a hub height of 80 m

## 2 wind monitoring masts:

## Mast 1 60 mAGL

## Mast 2 80 mAGL

| Source of uncertainty | Energy uncertainty |
|---|---|
| Horizontal extrapolation using linear wind flow model | 7.7% |
| Vertical extrapolation from measurement height to hub height | 4.5% |
| Terrain complexity | 0.7% |
| **Combined wind flow model uncertainty** | **8.9%** |



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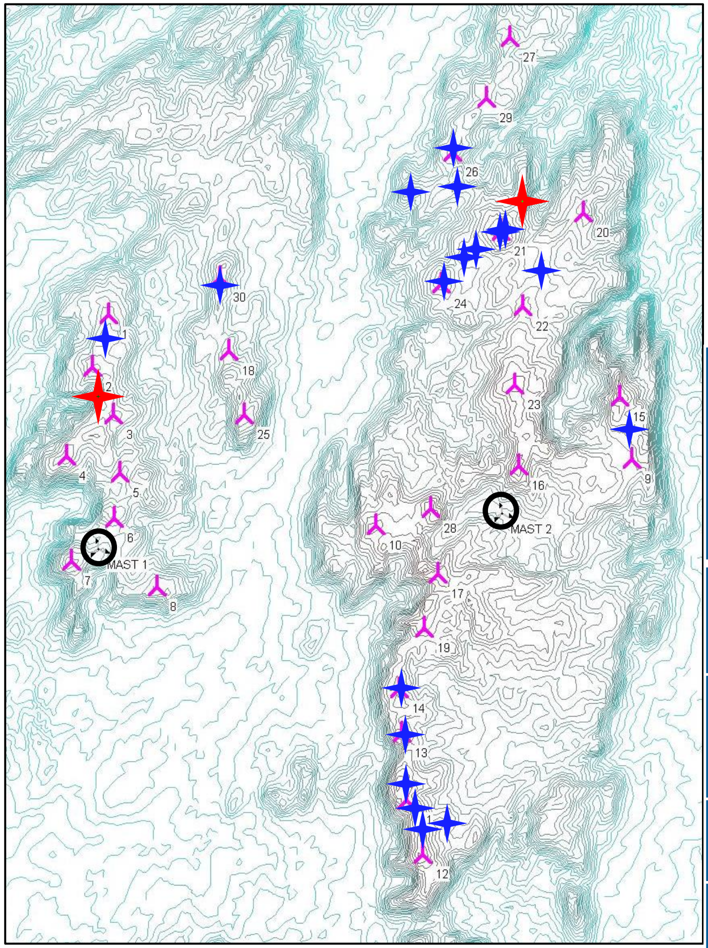
# Siting remote sensing devices – Test results

## Two scenarios tested on the Sample Site, assuming two SODARs can be used on-site:




**Scenario 1 – Visual/Intuitive Selection:**

**Two SODAR locations chosen by 10 engineers (+)**

**Scenario 2 – Systematic Selection:**

**Two SODAR locations selected using PBs systematic uncertainty model (+)**

| Source of uncertainty | Sample site default energy uncertainty (no remote sensing) | Scenario 1: Visual intuitive energy uncertainty (average) | Scenario 2: Systematic model energy uncertainty |
|---|---|---|---|
| Horizontal extrapolation using linear wind flow model | 7.7% | **4.7%** | **4.6%** |
| Vertical extrapolation from measurement height to hub height | 4.5% | **3.6%** | **1.2%** |
| Terrain complexity | 0.7% | **0.7%** | **0.4%** |
| Combined wind flow model uncertainty | **8.9%** | **6.0%** | **4.8%** |



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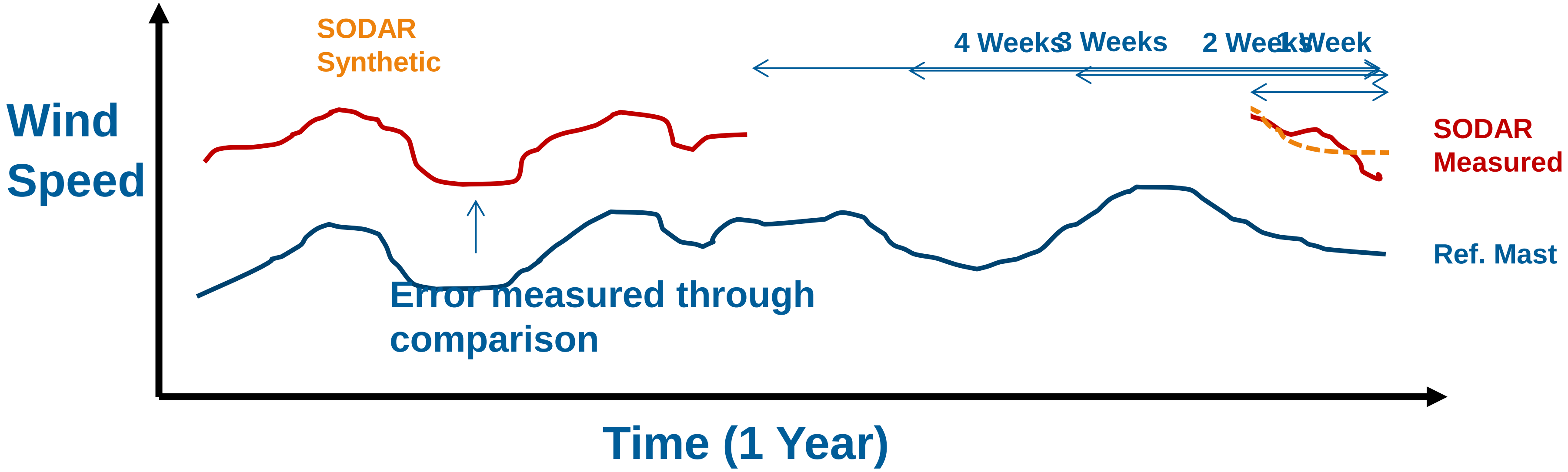
# Data duration – test method

**MCP was undertaken using SODAR data and reference mast data for the Sample Site**

**Using 9 shortened data durations (e.g 1 week, 2 weeks…16 weeks)**

**MCP is used to predict SODAR data for one year (synthetic)**

**Predicted data is compared to measured data for one year**



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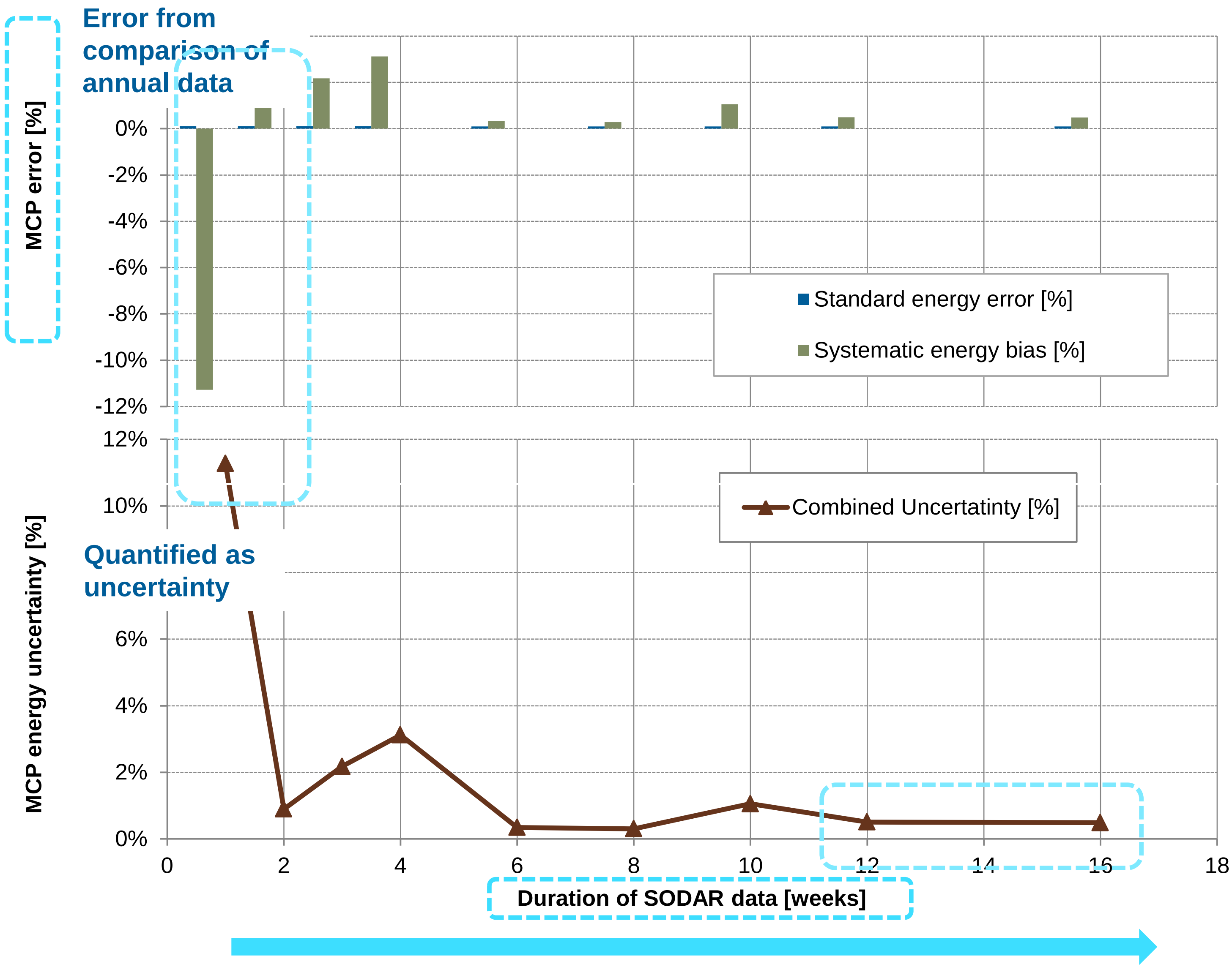
# Data duration – test results



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# Data rejection

**Remote sensing offers diagnostic metrics, such as:**

- **Signal to Noise Ratio**
- **Consistency**

**“*Quality Factor* ” used at the Sample Site**

**High *Quality Factor* means high quality data**

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# Data rejection – test method

MCP was undertaken using SODAR data and reference mast data for the Sample Site

SODAR data was filtered using seven different Quality Factor thresholds: 0%, 50%, 80%, 90%, 95%, 97% and 99%

Includes low quality data (0%, 50%)

Includes high quality data (95%, 97% and 99%)

MCP is used to predict SODAR data for one year (synthetic)

Predicted data is compared to measured data for one year

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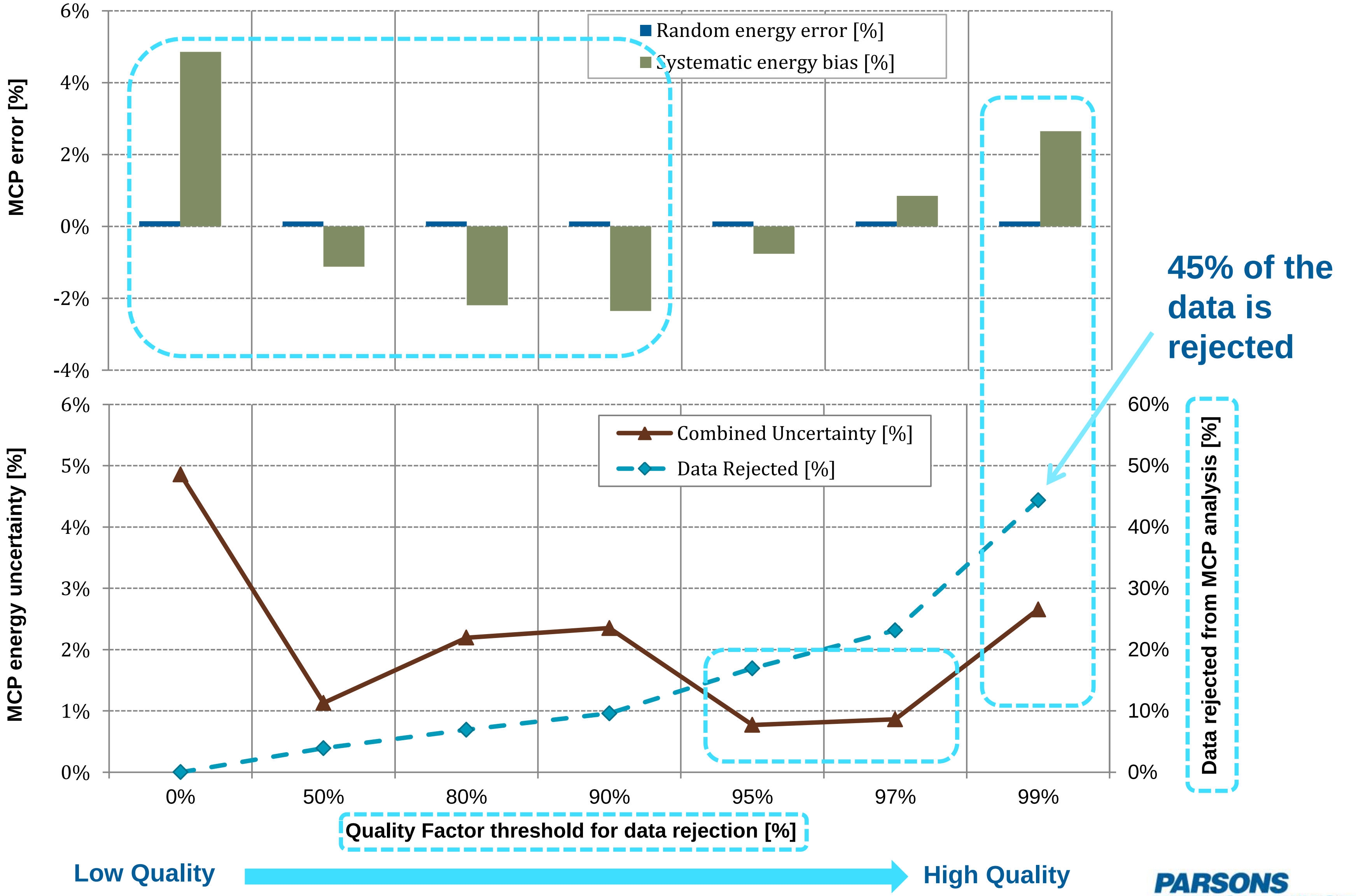
# Data rejection – test results



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# Case study – three scenarios for comparison

**Scenario 1:**

**Base case**

- **No Remote Sensing devices**
- **Only uses two masts**

**Scenario 2:**

**Inconsiderate approach**

- **Two SODARs**
- **Sited through intuitive approach**
- **Data duration of 4 weeks**
- **Data rejected using a Quality Factor of 90%**

**Scenario 3:**

**Considerate approach**

- **Two SODARs**
- **Sited through PBs Systematic model**
- **Data duration of 12 weeks**
- **Data rejected using a Quality Factor of 95%**



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# Case study – combined results

## Combined uncertainties for a 20 year period:

| Source of uncertainty | Scenario 1 Base case | Scenario 2 Inconsiderate approach | Scenario 3 Considerate approach |
|---|---|---|---|
| **Horizontal extrapolation** | 7.7% | 4.7% | 4.6% |
| **Vertical shear extrapolation** | 4.5% | 3.6% | 1.2% |
| **Terrain variation** | 0.7% | 0.7% | 0.4% |
| **MCP data duration** | - | 1.6% | 0.3% |
| **MCP data rejection** | - | 1.2% | 0.0% |
| **Other assumed uncertainties** | 10.2% | 10.2% | 10.2% |
| **Combined uncertainty** | **13.6%** | **12.0%** | **11.2%** |

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# Case study – probabilities of exceedance

## Assuming all three scenarios estimate:

- **P50 = 276 GWh and Capacity Factor = 35%**

| Probability of exceedance (for 20 year period) | Scenario 1 AEP [GWh] | Scenario 2 AEP [GWh] | Scenario 3 AEP [GWh] |
|---|---|---|---|
| **P50** | 276.0 | 276.0 | 276.0 |
| **P75** | 250.8 | 253.7 | 255.1 |
| **P90** | 228.1 | 233.7 | 236.2 |
| **P95** | 214.5 | 221.7 | 225.0 |
| **P99** | 189.0 | 199.2 | 203.8 |

**Lenders will use a probability of exceedance to calculate debt size**

**Let us assume they use P95**



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# Fiscal Quantities – What is it worth?

**Assuming: PPA = AUD$100/MWh and a Lender uses the P95 to evaluate loan**

**Simplified generation revenue model for the project life:**

***Generation Revenue = P95 x PPA x Number of Years***

| Years of generation | Scenario 1 Revenue | Scenario 2 Revenue | Scenario 3 Revenue |
|---|---|---|---|
| 1 Year | $21.5m | $22.2m | $22.5m |
| 10 Years | $214.5m | $221.7m | $225.0m |
| 20 Years | $429.0m | $443.4m | $449.9m |
| Revenue estimate increase from Scenario 1 | - | **$14.5m** | **$20.9m** |
| Revenue estimate increase from Scenario 2 | - | - | **$6.5m** |



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# Conclusions

- **Remote sensing can reduce uncertainty**
- **Applying knowledge further reduces uncertainty**
  - A considered approach (such as Parsons Brinckerhoff's systematic model) can further reduce uncertainty
  - Data duration can effect uncertainty. A possible duration criteria has been presented
  - Data rejection can effect uncertainty
- **A considered and knowledgeable approach can be valued in the millions of dollars $$**
- **Use Parsons Brinckerhoff, we'll save you millions!**

# Questions?

# Appendix – how long, how much?

**We need enough remote sensing data to reliably perform MCP. How much?**

**IEA:**

**“*a longer period might be required or measurement periods in different seasons may to necessary, to achieve sufficient representation of varying conditions in the data…*” [1]**

**IEC 61400-12-1 Annex C site calibration, per 10° sector:**

- **6 hours of data below 8 m/s per direction sector**
- **6 hours of data above 8 m/s per direction**
- **24 hours of data per direction sector [2]**

1. International Energy Agency, “DRAFT Recommended Practices for the Use of Sodar in Wind Energy Resource Assessment - Version 5,” IEA, Glasgow, 2011.
2. International Electrotechnical Commission, “IEC 61400-12-1 Power performance measurements of electricity producing wind turbines,” IEC, Geneva, 2005.



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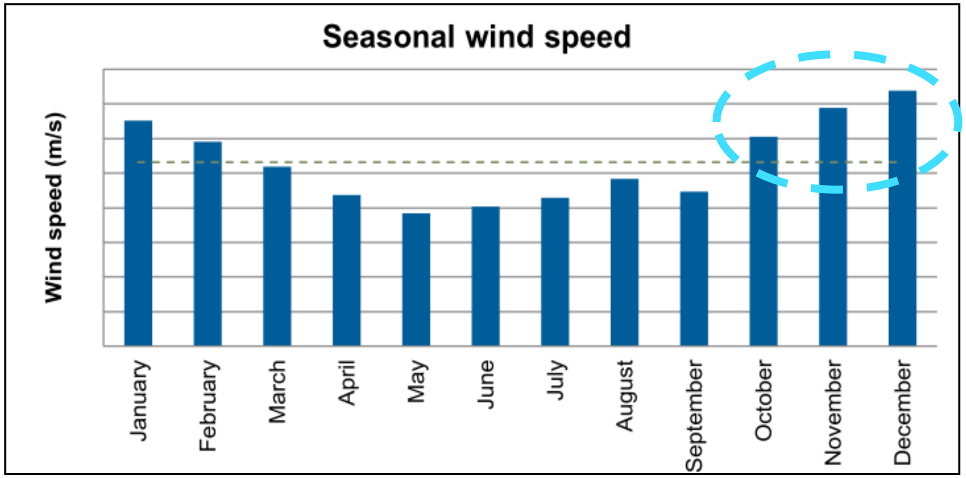
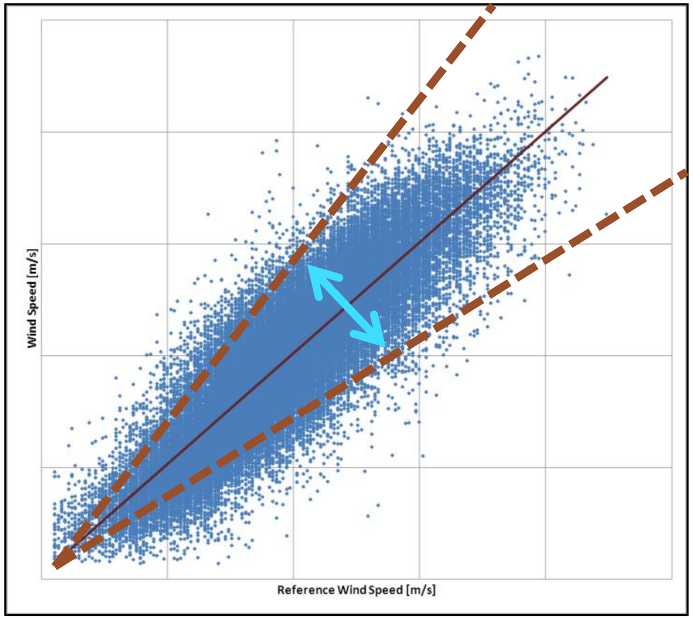
# Appendix – MCP uncertainties in more detail

## Wind speed and direction are seasonal




**Durations of data less than 1 year require supplementation.**

**Data can be supplemented through Measure, Correlate, Predict (MCP)**



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# Appendix – Duration test results

**MCP was undertaken using SODAR data and reference mast data for the Sample Site**

**Using 9 shortened data durations (e.g 1 week, 2 weeks…16 weeks)**

**Compared predicted data to one year of measured data**

| Shortened SODAR data duration [weeks of data] | 1 | 2 | 3 | 4 | 6 | 8 | 10 | 12 | 16 |
|---|---|---|---|---|---|---|---|---|---|
| Standard uncertainty [%] | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Systematic bias [%] | -11.3 | 0.9 | 2.2 | 3.1 | 0.3 | 0.3 | 1.0 | 0.5 | 0.5 |
| Combined uncertainty [%] | **11.3** | **0.9** | **2.2** | **3.1** | **0.3** | **0.3** | **1.1** | **0.5** | **0.5** |
| Bins complaint with IEC 61400-12-1 Annex C for direction sectors 190-300 deg. [%] | 25 | 47 | 53 | 64 | 75 | 75 | 81 | 83 | 86 |

# Appendix – Data rejection test results

**MCP was undertaken using SODAR data and reference mast data for the Sample Site**

**12 weeks of SODAR data was filtered using differing Quality Factor thresholds (e.g 0, 50, 80, 90, 95, 97 and 99% QF)**

**Compared predicted data to one year of measured data**

| Quality Factor threshold [%] | 0 | 50 | 80 | 90 | 95 | 97 | 99 |
|---|---|---|---|---|---|---|---|
| Data rejected [%] | 0 | 4 | 7 | 10 | 17 | 23 | 44 |
| Standard uncertainty [%] | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Systematic bias [%] | 4.9 | -1.1 | -2.2 | -2.3 | -0.8 | 0.9 | 2.7 |
| Combined uncertainty [%] | **4.9** | **1.1** | **2.2** | **2.4** | **0.8** | **0.9** | **2.7** |



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