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CanWEA Wind Energy Forum

New Trends in Uncertainty Analysis

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Presentation Overview

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2. Components
3. Aggregation of Uncertainty
4. Correlated Uncertainty
5. Time-Varying Uncertainty
6. Reality Check…
7. Minimizing Uncertainty
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Resource Assessment Uncertainty Intro

- Uncertainty in energy assessment is inevitable
- Uncertainty affects:
    - project feasibility
    - financial risk and returns
- Estimates of uncertainty typically used to define probabilities of exceedence for wind power project yields (P50, P70, P95…)
- The goal is to identify, quantify and minimize sources of uncertainty

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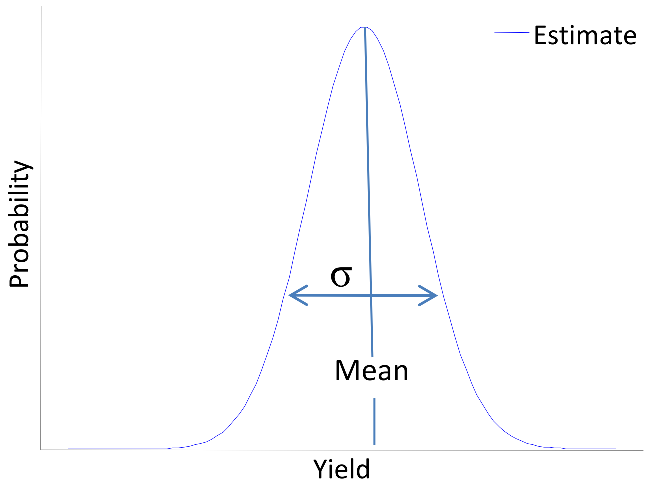
Resource Assessment Uncertainty Intro

- Uncertainty frequently defined as "standard uncertainty"
- Can be expressed as a standard deviation assuming a normal distribution
- Some sources report accuracy rather than uncertainty
- Accuracy reflects the maximum error while uncertainty is based on the distribution of errors



Resource Assessment Uncertainty Intro

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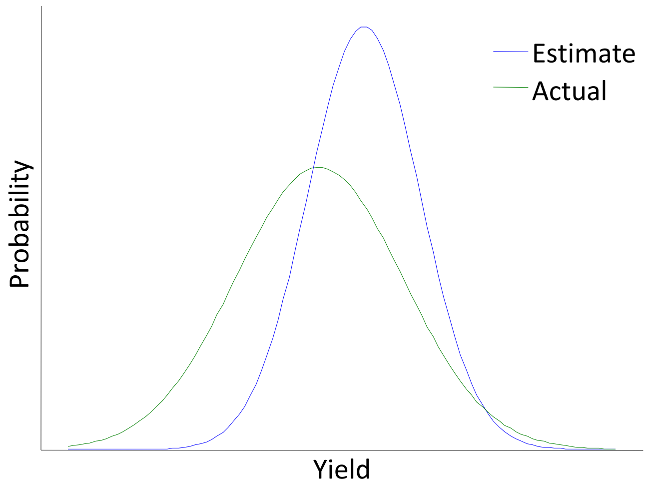
- Want to minimize the width and match distribution of estimate with actual (with some understood exceptions)



Contributions to Uncertainty

Wind Speed and Production:

- Anemometer
- Data Quality
- Shear Profile
- Tower Effects
- MCP
- Wind Variability
- Wind Flow Modelling

Losses:

- Power Curve
- Availability
- Wake
- Electrical
- Environmental
- Curtailment

Losses are like uncertainties with a negative bias…

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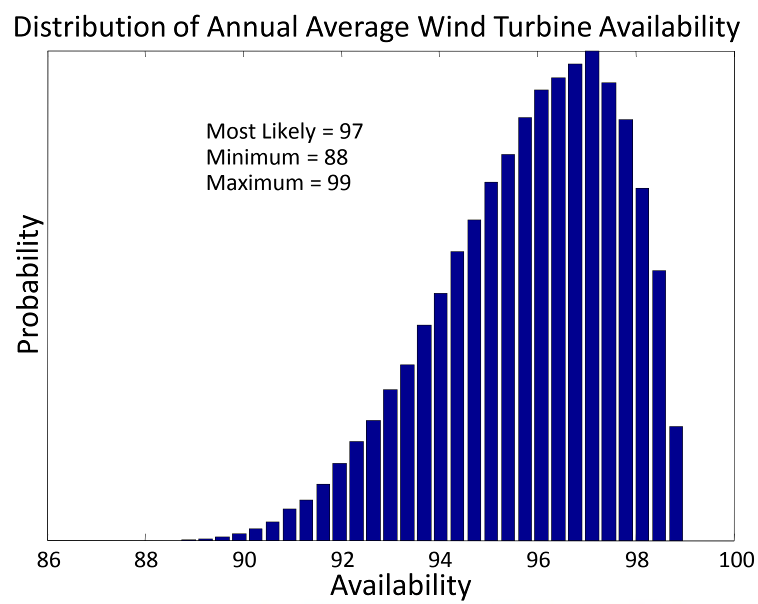
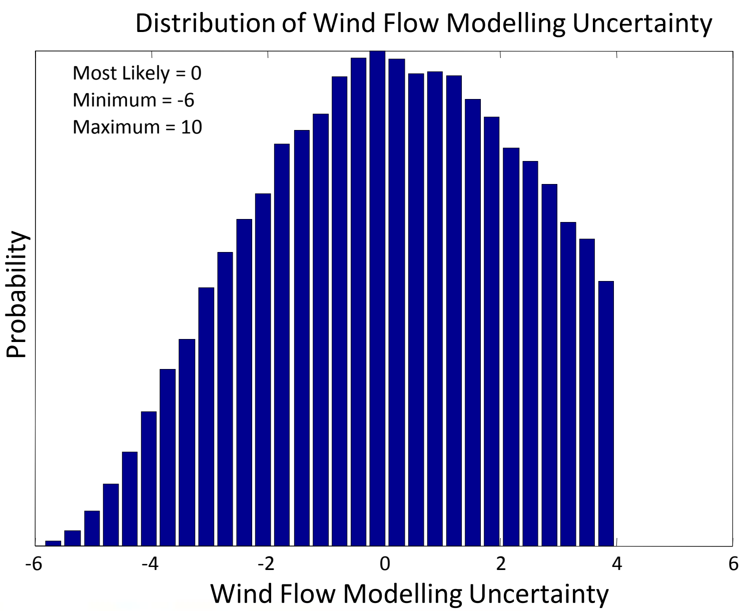
Aggregation of Uncertainty

- Normally distributed uncertainties may be combined by root-sum-squares; however, not all uncertainties are normally distributed…
- Important to identify sources of bias in resource assessment – whether due to met tower placement, sensor performance, availability etc.





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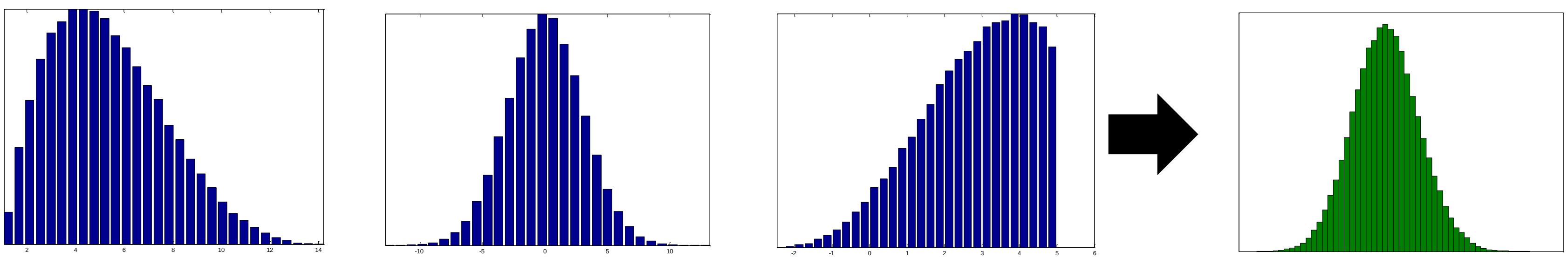
Aggregation of Uncertainty

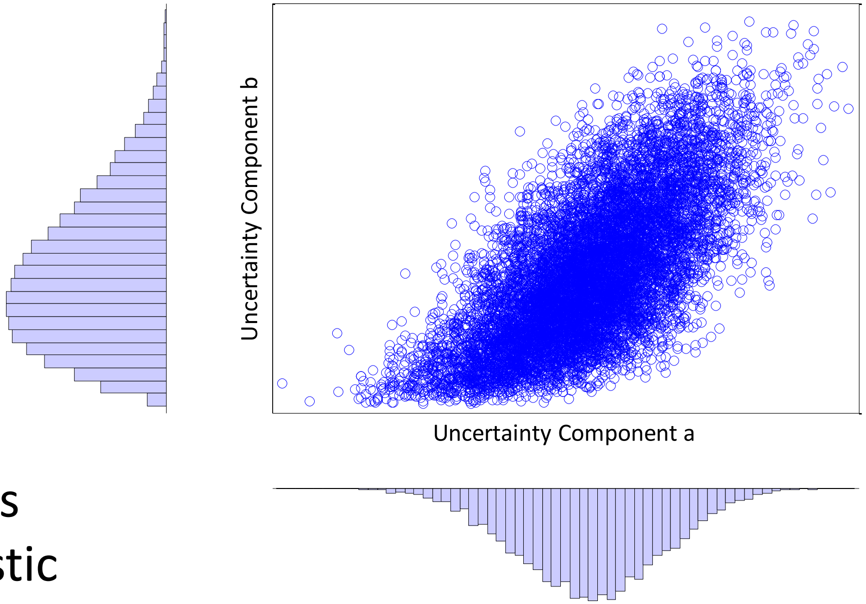
- Uncertainties may also be combined using a stochastic random sampling approach (such as Monte Carlo simulation)
- In the stochastic approach, many possible outcomes are randomly sampled for each uncertainty component - flexibility to choose shape of uncertainty distribution: normal, triangular, beta, truncated…
- These outcomes are then combined in order estimate uncertainty in yields



Correlated Uncertainty

- Generally, uncertainties are assumed to be independent; however, this is not always the case…
- For example, uncertainties in measured wind speeds (anemometer, tower shadow…) impact uncertainty in the shear profile estimate
- Correlations can lead to magnification of uncertainty
- Correlations between uncertainties can be defined as part of a stochastic approach

- Create multiple distributions linked by a specified correlation



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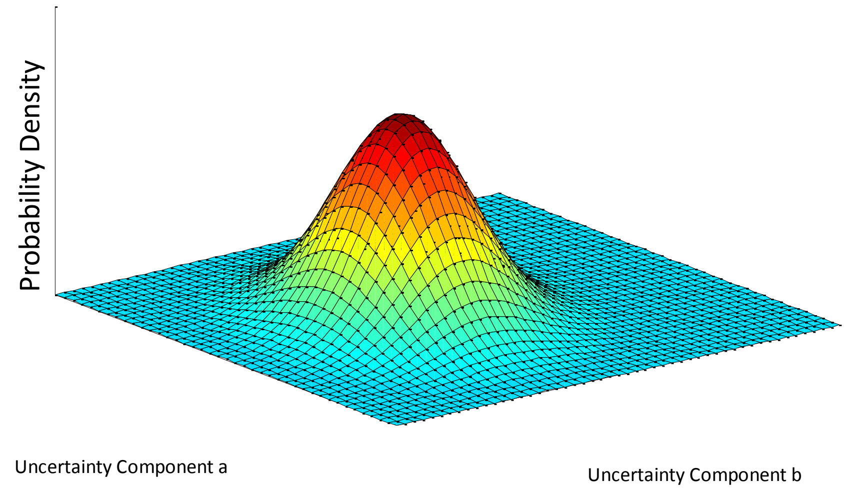
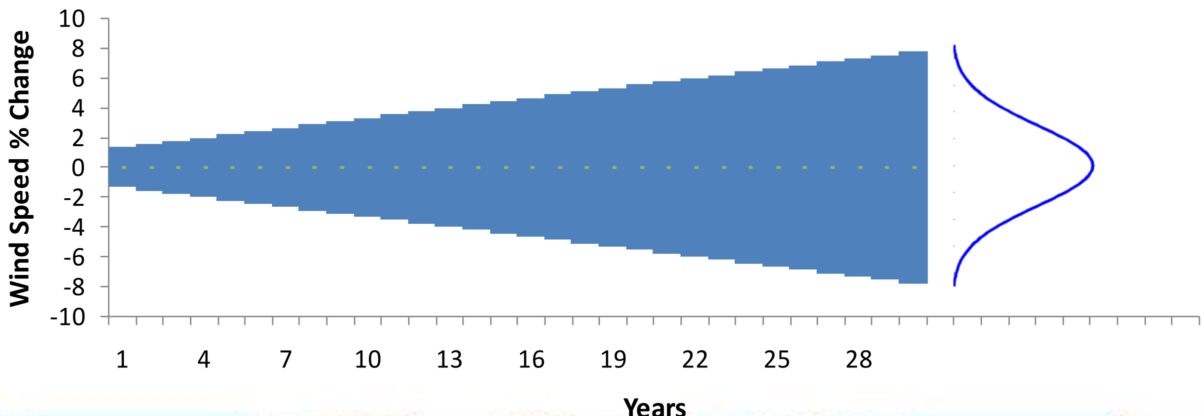


Time-Varying Uncertainty

- A stochastic uncertainty assessment also facilitates the incorporation of time-varying uncertainty
- Useful for estimating:
  - Impact of losses as a project ages
  - Increasing uncertainty in the strength of the wind resource due to changes in the climate

Wind Speed Uncertainty due to Climate Change



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Reality Check…

- In many ways, flexibility of the analysis exceeds our knowledge of the underlying uncertainty distributions… even the uncertainty is uncertain!
- Given the same assumptions, results from a stochastic approach to uncertainty propagation agree with simple RSS approach
- A stochastic approach requires more computational power, but that doesn't make it more difficult to understand or interpret – produces results in an intuitive and flexible format
- The ability to assess non-normally distributed, correlated, and time-varying uncertainty challenges our ability to assess the inputs
- It's better to estimate rather than ignore known sources of uncertainty
- Performing analyses multiple ways (different reference sites, different wind flow models…) can help to understand sources of uncertainty

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Minimizing Uncertainty

- Uncertainty analysis shouldn’t be restricted to a final step in the pre-construction yield assessment process
- Preliminary and interim uncertainty analyses can be very valuable for informing decisions about project spending:
  - Tower configuration and locations, remote sensing, wind flow modelling, monitoring duration…
- Consider how probability of exceedence results are going to be used:
  - Is the goal to quantify uncertainty in energy production or uncertainty in revenue?
- Account for everything, but don’t double count
- Take advantage of all potential inputs – relevant operational data?

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Minimizing Uncertainty

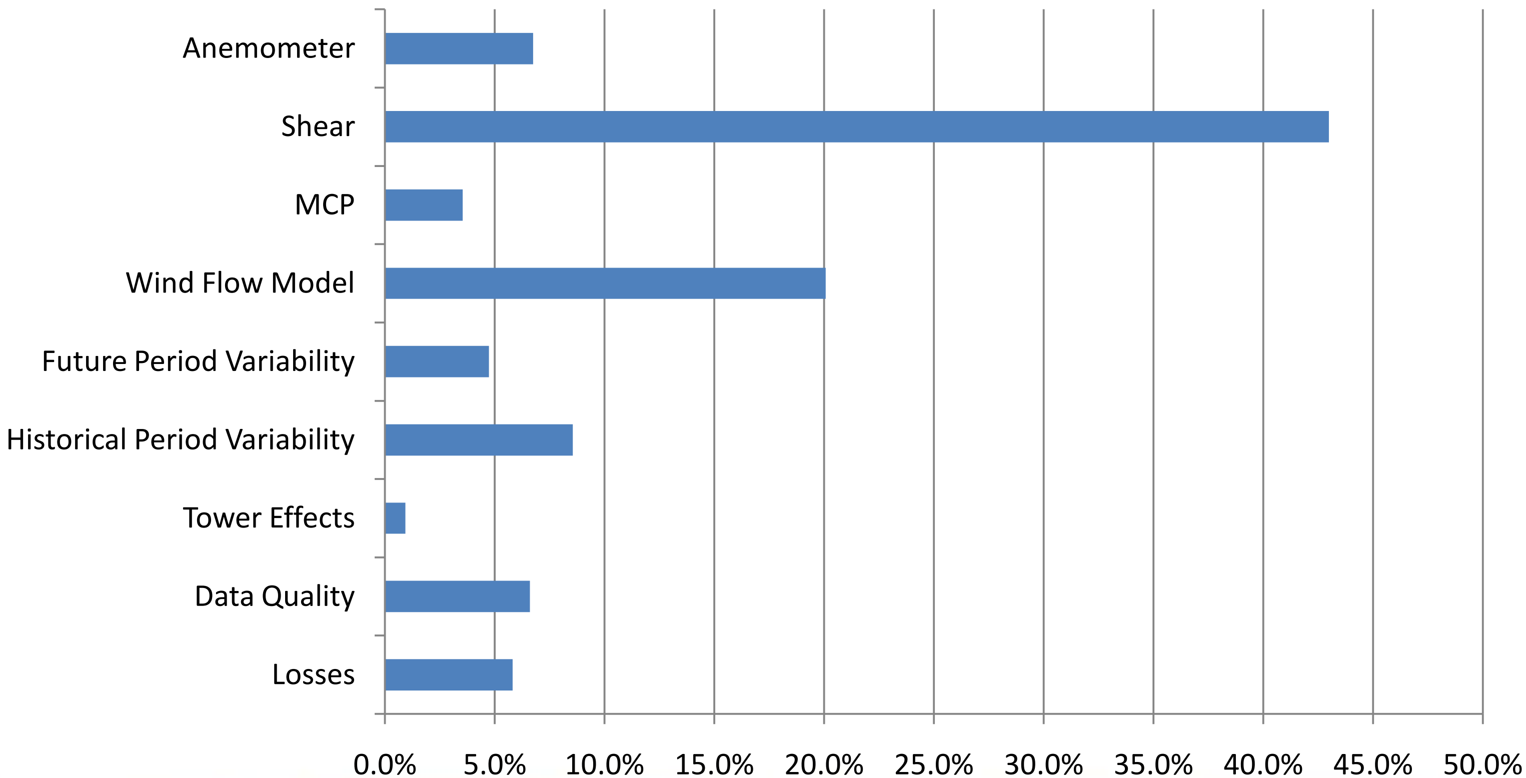
Simplified Example - Sources of Uncertainty

Source	Standard Uncertainty
Anemometer	0.1 m/s
Shear	0.25 m/s
MCP	1.0% of wind speed
Wind Flow Model	5.0% production
Future Period Variability	1.1% wind speed
Historical Period Variability	1.5% wind speed
Tower Effects	0.5% wind speed
Data Quality	0.1 m/s
Losses	2.7% production

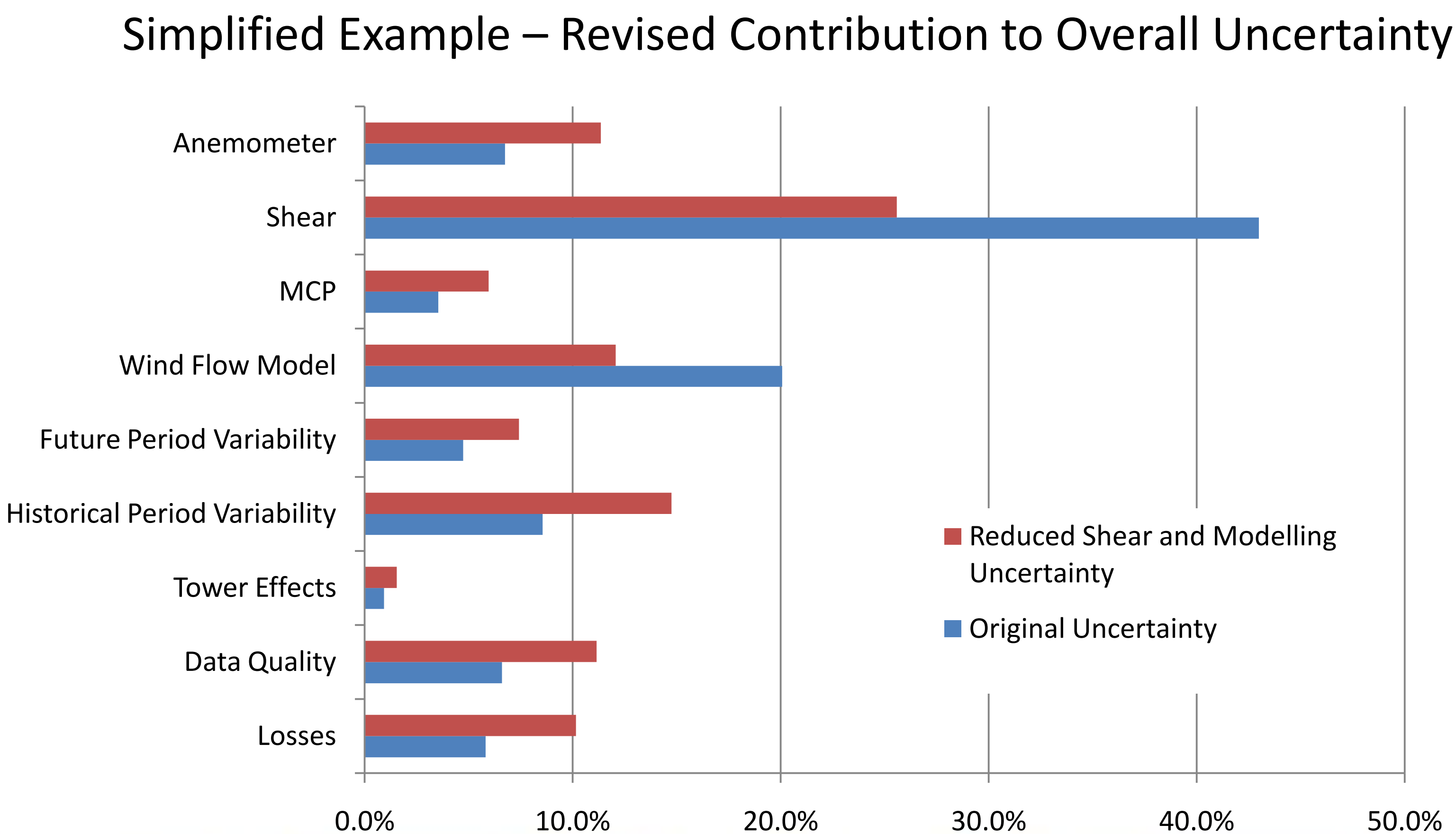
- Somewhat difficult to assess impact in this format
- In a stochastic approach, the correlation of inputs to overall uncertainty can be used to assess individual contributions

Minimizing Uncertainty

Simplified Example – Contribution to Overall Uncertainty



Minimizing Uncertainty



Minimizing Uncertainty

- Focus effort on minimizing largest contributors to overall uncertainty
- More information doesn’t necessarily mean that yield estimates will go up – at least not at the P50 level
- However, reduced uncertainty can increase the P90, P95, P99…
- Example: Case 1 has high shear and modelling uncertainty; Case 2 assumes additional on-site monitoring which resulted in lowered yield expectation but also decreased uncertainty
- Despite decreased P50, increased P95 may result in more viable project
- Consider a target DSCR of 1.0x at P95, a 3% increase in expected production is significant

Case 1

Probabilities of Exceedence (Percentage of Case 1 P50 Net Yield)	**Confidence level (%)**				
	50	70	90	95	99
1-Yr Average Production	100%	91%	78%	72%	61%
10-Yr Average Production	100%	94%	85%	81%	73%
20-Yr Average Production	100%	94%	86%	82%	74%

Case 2: Reduced Yield and Uncertainty

Probabilities of Exceedence (Percentage of Case 1 P50 Net Yield)	**Confidence level (%)**				
	50	70	90	95	99
1-Yr Average Production	98%	90%	79%	73%	63%
10-Yr Average Production	98%	94%	87%	84%	78%
20-Yr Average Production	98%	94%	88%	85%	80%

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Concluding Remarks

- Uncertainty in wind resource assessment is unavoidable
- Tools and techniques are facilitating more comprehensive uncertainty analyses
- Industry's understanding of wind resource assessment uncertainty is evolving (non-normal, biased, correlated, time-varying…) – expect greater scrutiny
- Positive for the industry because it helps inform/incent good project development practices – reduced uncertainty improves project viability
- Need for continued evaluation and integration of operational experience
- Probability of exceedence results are valuable, but so is the process – include this at intermediate stages in development process

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