

Reducing Uncertainty of Wind Power Energy Estimates



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Presentation for RDF Advisory Board

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Reducing Uncertainty of Wind Power Energy Estimates

- Energy generation affects economics
- Reducing uncertainty reduces risks
- Used pre- and post-construction data from operating wind farms to identify methods to reduce uncertainty

Participating Projects



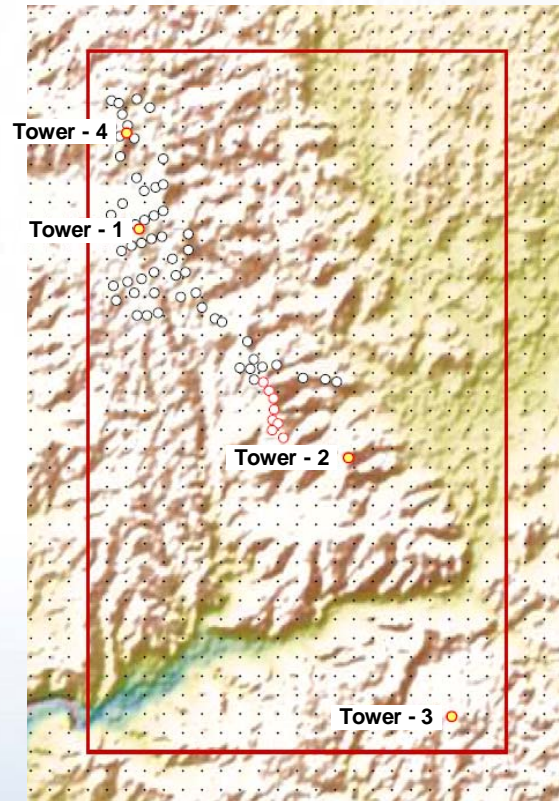
Energy Estimates

- Energy estimates need:
 - Wind speeds at each turbine
 - Average wind speeds over time
- Typically wind measured with met towers



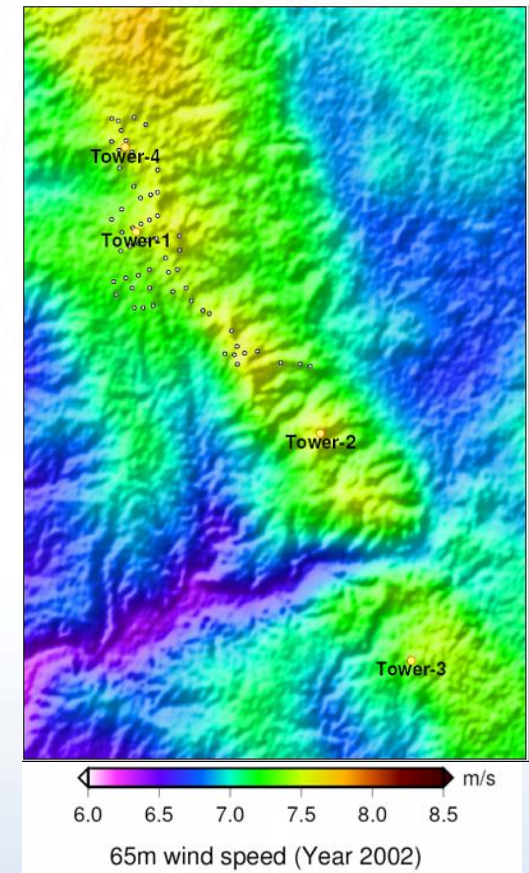
Improving Estimates of Wind Speeds at each Turbine- I

- How many met towers per project?
- How estimate wind speeds between towers?
 - Use nearby tower data?
 - Interpolate between towers?



Improving Estimates of Wind Speeds at each Turbine- II

- How estimate wind speeds between towers?
 - Use tower data and computer models?
 - Use weather models?



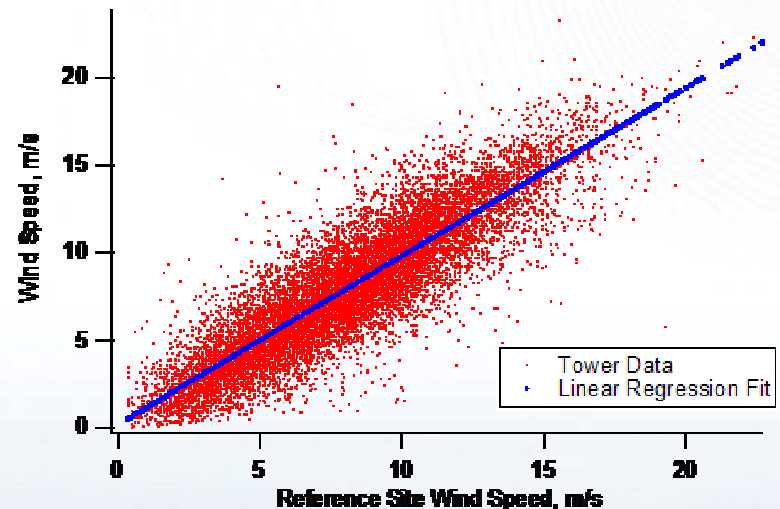
Determining Long-Term Wind Speeds

- Typically, 1-2 years of measured data are compared with nearby long-term data:
 - Other met towers
 - Airport data
 - Weather balloon data
 - Archived upper-level weather data



Improving Estimates of Average Wind Speeds over Time

- Which reference data sets give the best results?
- Which methods give the best results?



What We Did

- Quality controlled and analyzed data from five projects
 - Data from multiple towers per project
 - Wind turbine generation data
 - Reference site data
- Tested multiple methods on data from each project
 - Methods to estimate wind speeds between towers
 - 234 different cases
 - Methods to compare site to reference data
 - 256 different cases

Turbine Wind Speed Results

- More met towers better
- Flow models and weather models no better than extrapolating between towers

Uncertainty of Site-Wide Wind Speed Extrapolation Models				
Method	One Tower	Two Towers	Three Towers	Four Towers
Nearest Tower Results	10.2%	8.4%	6.3%	3.2%
Distance Weighted Results	10.2%	7.8%	6.4%	5.2%
WindSim	9.9%	7.0%	6.4%	6.2%
WAsP	13.8%	8.5%	7.3%	3.8%

- Results depend on terrain

Wind Speed Estimation Uncertainty at Each Site						
	Method	Open Ridge	Mountain Side	Rolling Hills	Upper Prairie	Eastern Mountain
		3 Towers	3 Towers	3 Towers	2 Towers	2 Towers
Analytical Models	One Tower	6%	11%	3%	5%	16%
	Nearest Tower	6%	10%	2%	3%	14%
	Distance Weighted	5%	8%	2%	3%	12%
Numerical Models	WindSim	2%	8%	8%	6%	13%
	WAsP	2%	8%	7%	5%	16%
	NWP			9%	4%	

Long-Term Wind Speed Results

- Reference data sets:
 - Tower data best
 - Balloon, airport data acceptable
- Methods
 - Two methods with lower uncertainties identified

Long-Term Extrapolation Uncertainties	
Met towers	1%
ASOS	2%
Reanalysis data	11%
Balloon data	3%
MOS-corrected NWP	3%

Long-Term Extrapolation Methods		
Wind Speed MCP Method	Acceptability	
	Mean Wind Speed	Wind Speed Distribution
Linear Regression	Yes	No
Variance MCP	Yes	Yes
Ratio MCP	No	No
JPD MCP	Yes	Yes
Wind Direction MCP Method	Overall Acceptability	
Direction Linear Regression	No	
2-D Linear Regression	No	
Difference MCP	No	
JDP MCP	Yes	

Value to Xcel Rate Payers

- Xcel - #1 wind power provider in US (1/1/2008)
- Xcel projects in low complexity terrain similar to three of the sites studied
- Research provides information with which to reduce uncertainty of energy estimates
- Ultimately reduces project finance risk and costs

GEC a DNV company

- Global Energy Concepts (GEC) was acquired by Det Norske Veritas (DNV) effective June 2008.
- DNV is a global provider of services for managing risk, helping customers to safely and responsibly improve their business performance. DNV is an independent foundation with presence in more than 100 countries.

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