

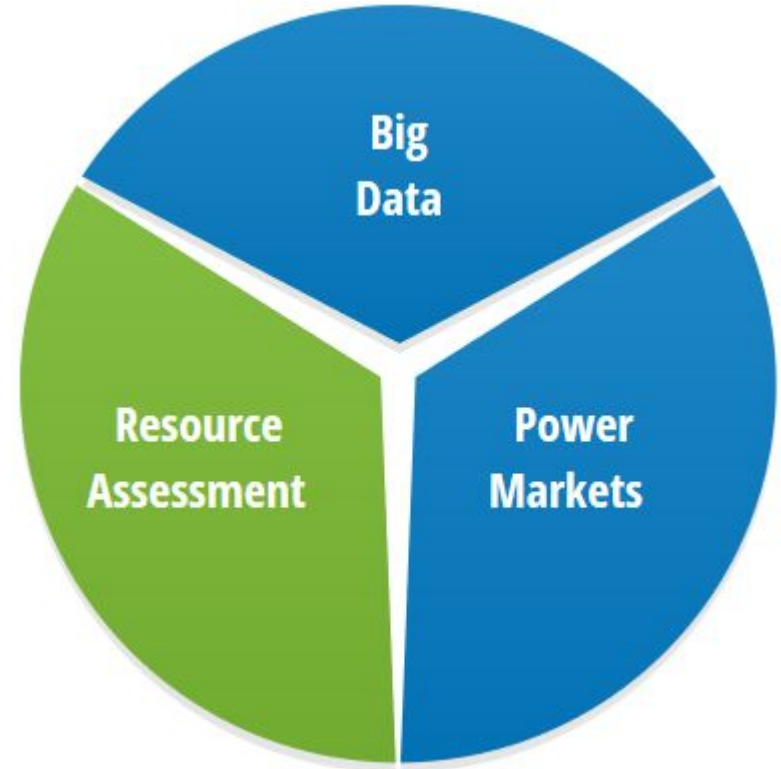
Industry Needs for Wind Flow and Wake Modeling

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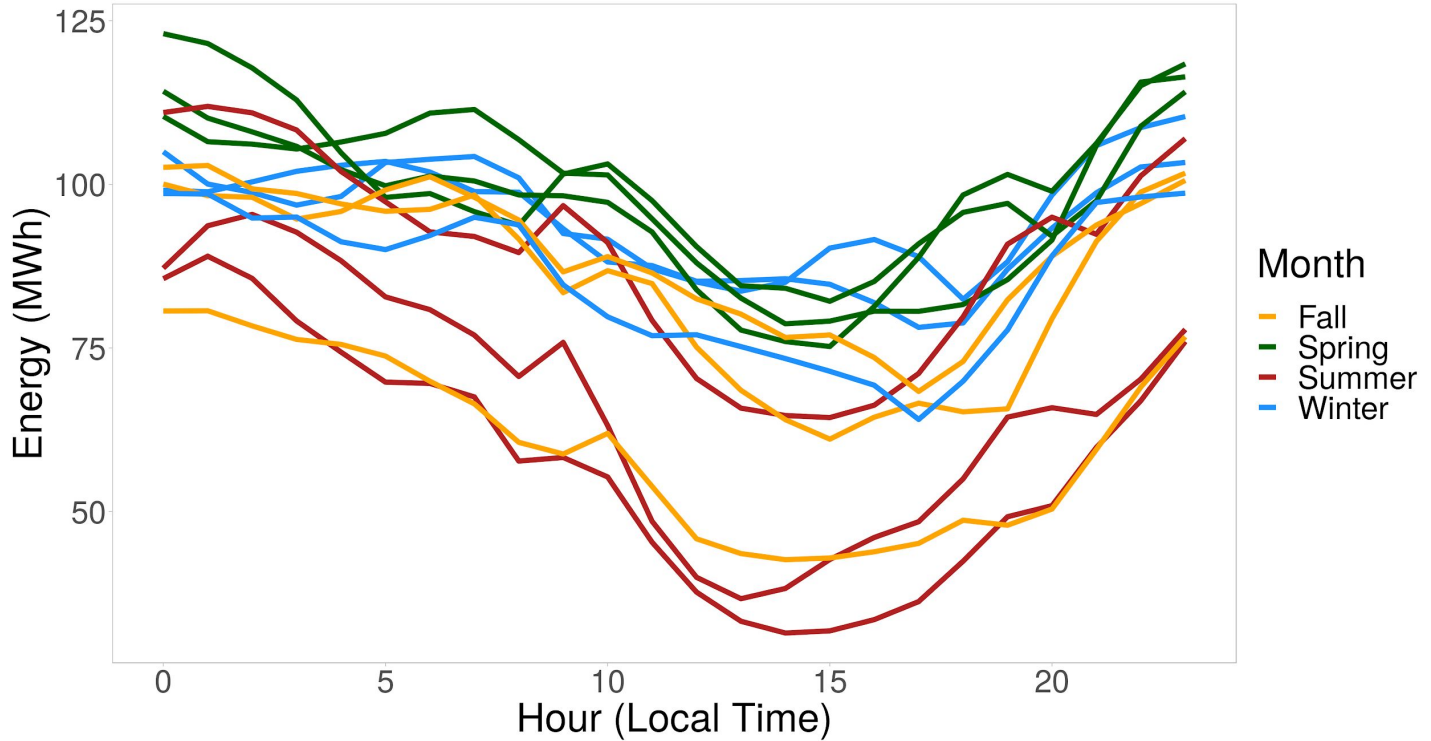
What Does REsurety Do?

- REsurety structures and settles risk management contracts for buyers and sellers of renewable energy.
- To date, we've structured over 6 GW of transactions across the U.S. and Australia.
- We model hourly plant generation and hourly power prices, as well as the covariance between the two.



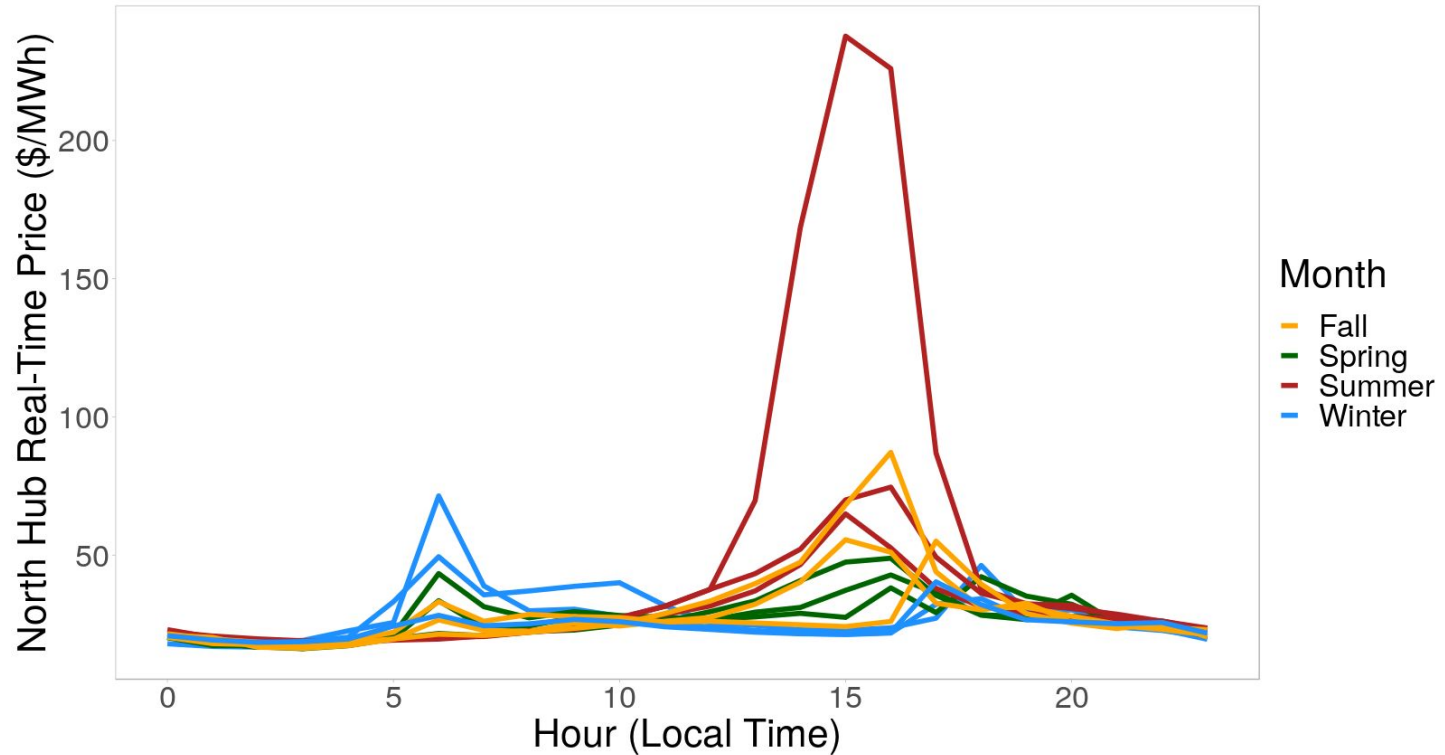
How Does Generation Vary Seasonally and Diurnally?

Observed Average Diurnal Profiles - Pyron Wind Farm



How Do Power Prices Vary Seasonally and Diurnally?

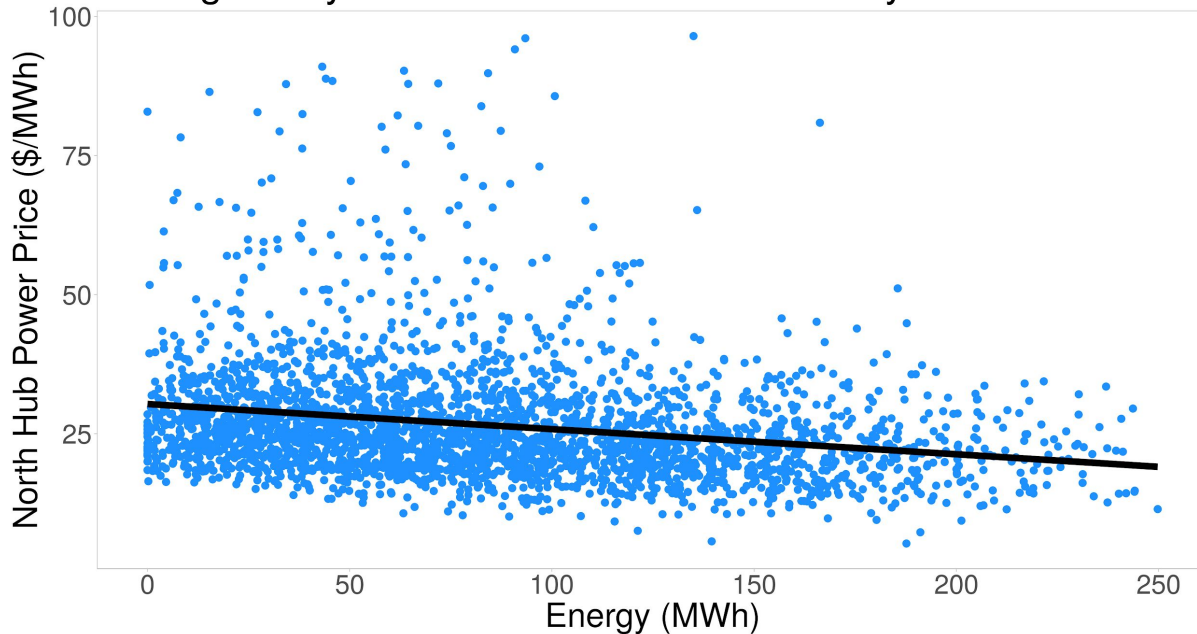
Observed Average Diurnal Profiles - Power Price



How Does Generation Impact Power Price?

There tends to be a negative correlation between renewable generation and the price of power due to the position of renewables as an inexpensive energy source.

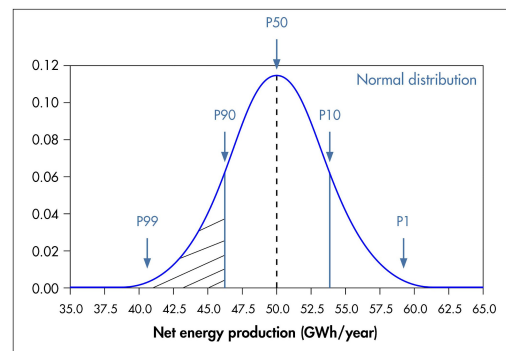
Average Daily Price vs. Wind Generation - Pyron Wind Farm



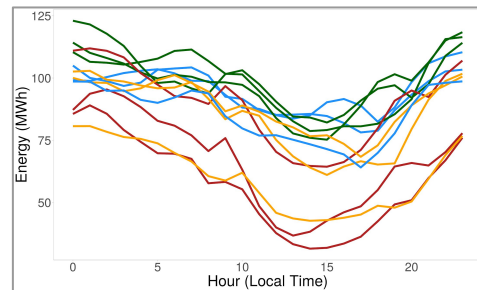
What We Have: Short-Term Meteorological Time Series



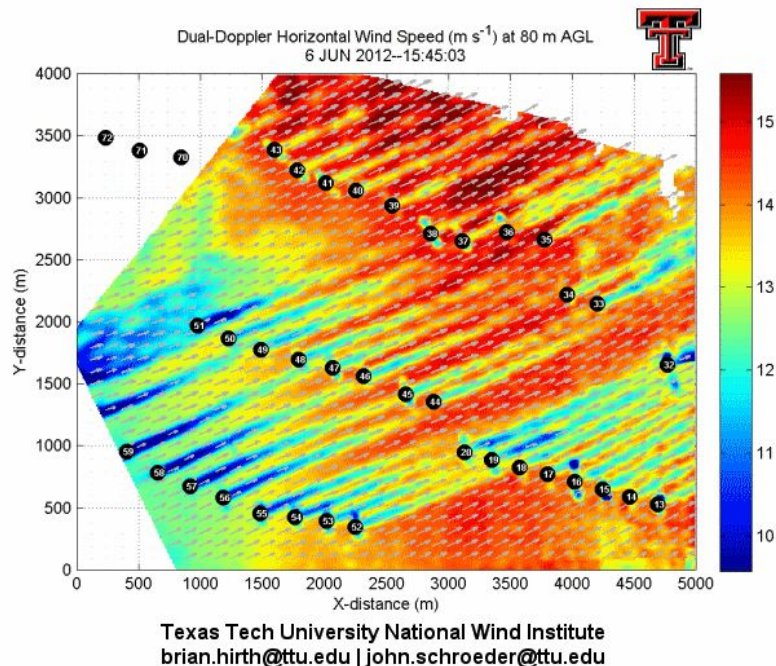
What We Need: Long-Term P50 *in addition to* expectations of seasonal and diurnal generation



Source: [UL](#)



Two key components in wind resource assessment are **wind flow modeling** (modeling the spatial variation in wind speeds at different turbine locations) and **wake modeling** (traditionally, modeling the impact of turbines on downstream flow; recently, definition has expanded to include impacts of turbines on the upstream flow).



Key Wind Flow/Wake Modeling Challenges

- Simple linear wind flow models still outperform higher-fidelity models at some locations
- Wind farm blockage is difficult to quantify and model (with little consensus on the magnitude of impact)
- Incorporating the effects of stability into wind flow/wake modeling is difficult without going to a full time series approach

WAsP vs. Higher-Fidelity Models

Why do CFD models sometimes have higher RMSE than a simple linear wind flow model?

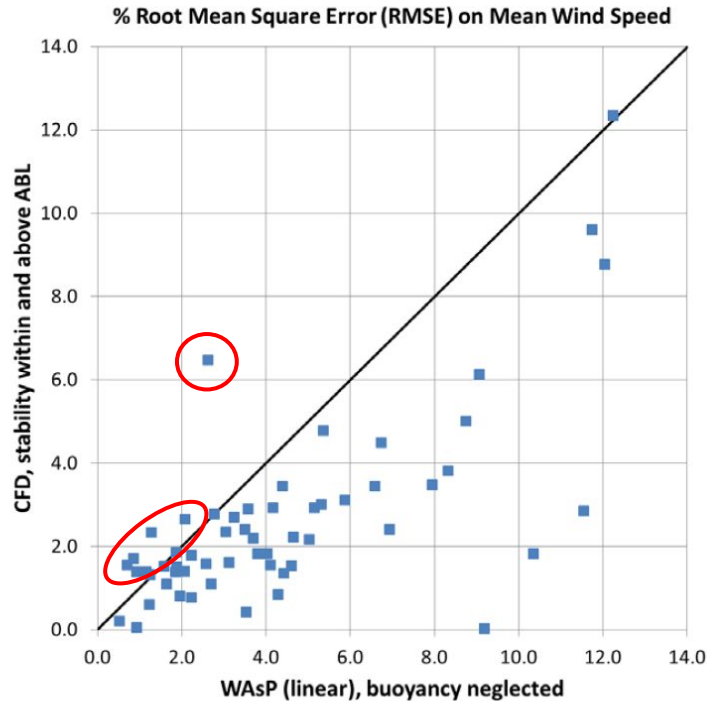


Figure 8 – %RMS error on MWS predictions at each of 57 wind sites, CFD vs. WAsP.

From Bleeg et al. (2015).

Estimating Blockage Losses

In an exercise during the 2019 AWEA WRA Conference, 4 IEs were given the same wind farm configuration and came up with very different views on blockage losses

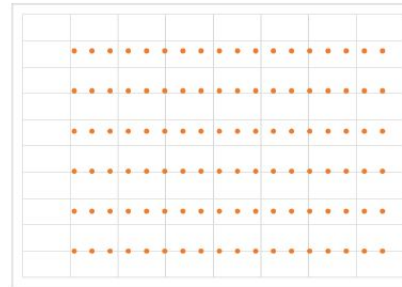
Layout 1: 50 MW; 3 RD



Layout 2: 150 MW; 4 x 8 RD



Layout 3: 300 MW; 6 x 12 RD



Expert		Blockage loss [% energy]
ArcVera	(Eron)	-
DNV GL	(Jessica)	0.94
Natural Power	(Taurin)	0.21
UL	(Nick)	0.0

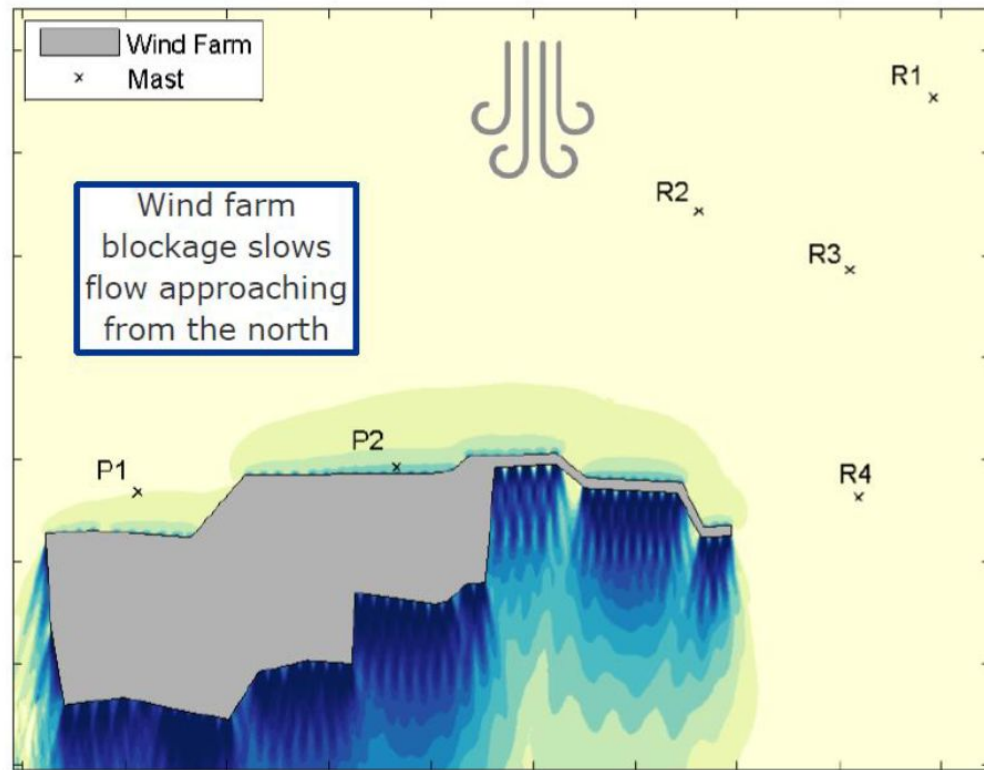
Blockage loss [% energy]
-
1.76
0.53
2.0

Blockage loss [% energy]
-
0.37
0.47
2.4

Quantifying Wind Farm Blockage

Quantifying blockage losses from observed data is difficult, as most pre-construction met towers are decommissioned prior to the start of operations for the wind farm.

Thus, most of our estimates of blockage impacts come from CFD models (figure at right) or wind tunnel experiments.



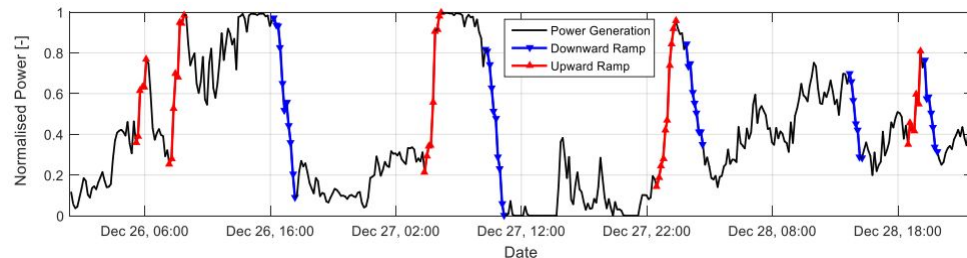
James Bleeg, "Accounting for Blockage Effects In Energy Production Assessments," 12 Sep 2019, WRA 2018

Power Matrix Approach

	0°	30°	60°	90°	...
2 m/s	0.05 kW	0.07 kW			
2.5 m/s	0.1 kW	0.12 kW			
3 m/s	0.3 kW	0.4 kW			
...					

- Create a look-up table of plant generation by wind speed and direction bin (represents average atmospheric conditions)
- Cross look-up table with hourly wind speed/direction data from trained re-analysis dataset

Time Series Approach



From Würth et al. (2019)

- Use WRF to simulate a long-term time series of wind speed, wind direction, and stability at the site
- Pass WRF time series through a stability-dependent wake model

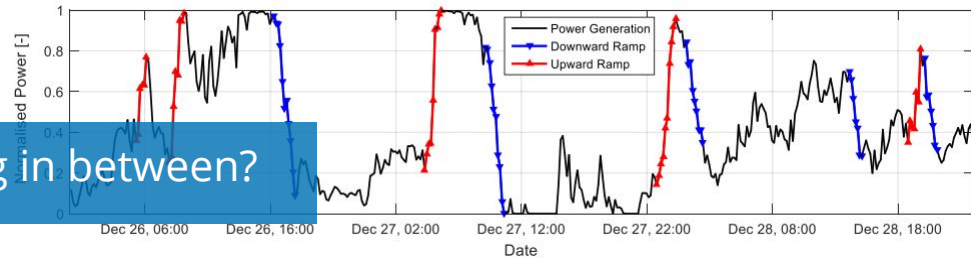
Power Matrix vs. Time Series Approach

Power Matrix Approach

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2 m/s	0.05 kW	0.07 kW			
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Is there something in between?

Time Series Approach



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Key Questions

- Are there specific regions/types of terrain where NWP/CFD approaches struggle?
- Is there a way to accurately estimate blockage effects without taking a full CFD approach?
- Is a full time series approach necessary for accurately modeling diurnal variation in plant production?

Thank You!

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