Cold climate impacts on WTG performance

It’s not only icing that has an impact

Ben Buxton | Winterwind 2024

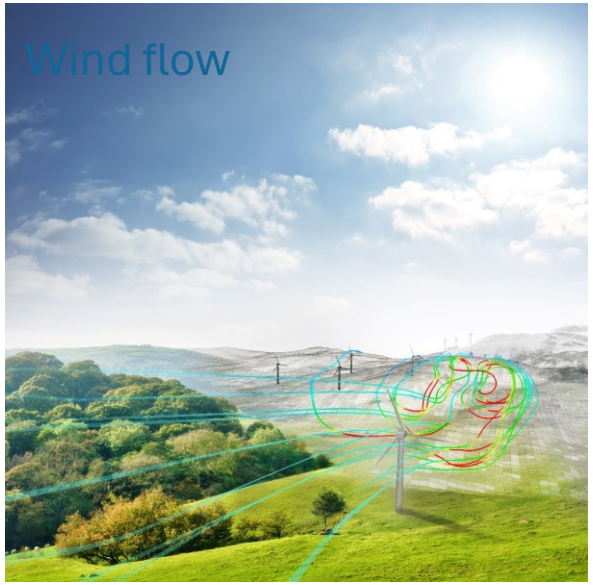
For the best energy projects

K2 Management

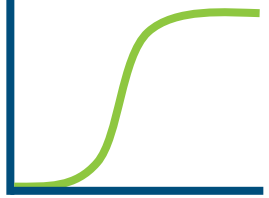
MOTIVATION

- Icing is a major issue – what else affects yield?
- Does the performance on paper match reality?
- What impact does this have on EYA…
- …and project financing?
- What can be done to mitigate this?

WHAT IS AEP (YIELD)?



POWER CURVE



VALIDITY

Availability

%

Other efficiencies and losses

η%

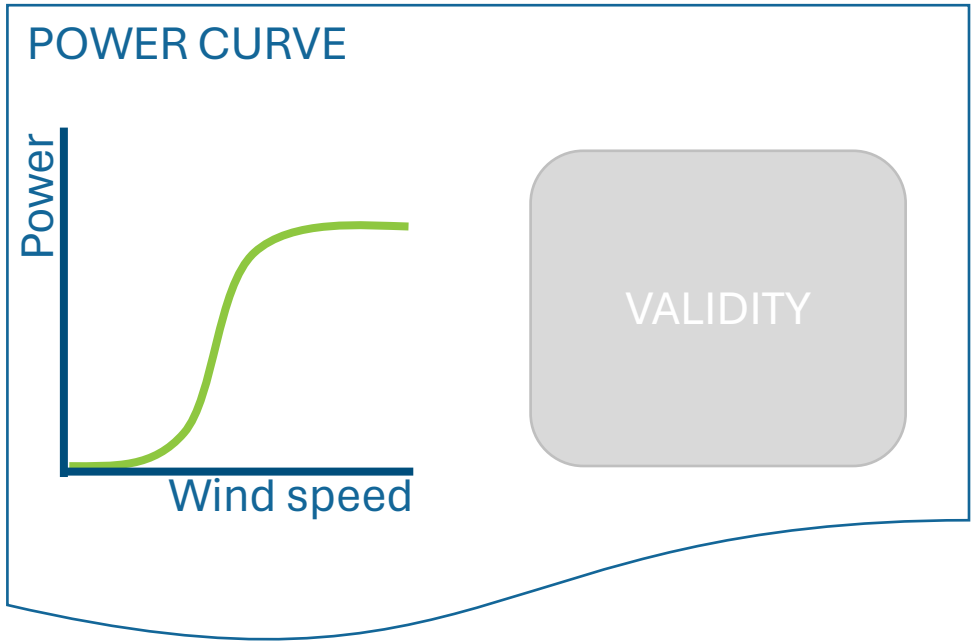
WHAT IS A POWER CURVE?

And are they all the same?

Typical conditions for Sales Power Curve

Turbulence Intensity	**8%-15%**
Power Law shear exponent	**0-0.2**
Inflow angle	**< 2 deg**

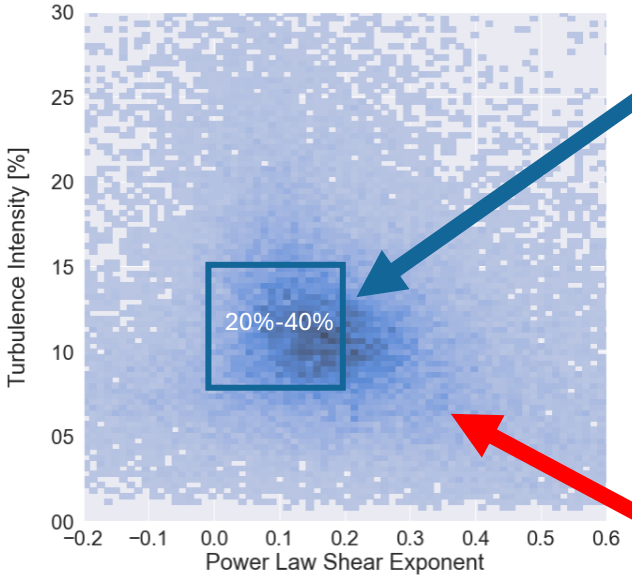
Conditions for site-specific power curves (should) cover a range suitable for the location



IN THE REAL WORLD

“Inner” and “outer” ranges

Example onshore shear/TI distribution



Inner range

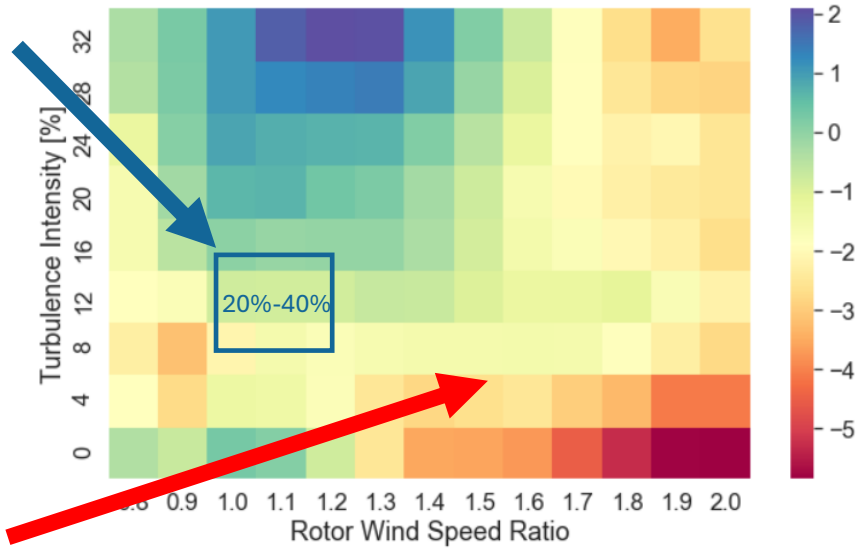
TI: 8%-15%

Shear: 0-0.2

Outer range

???

Example wind turbine performance variation



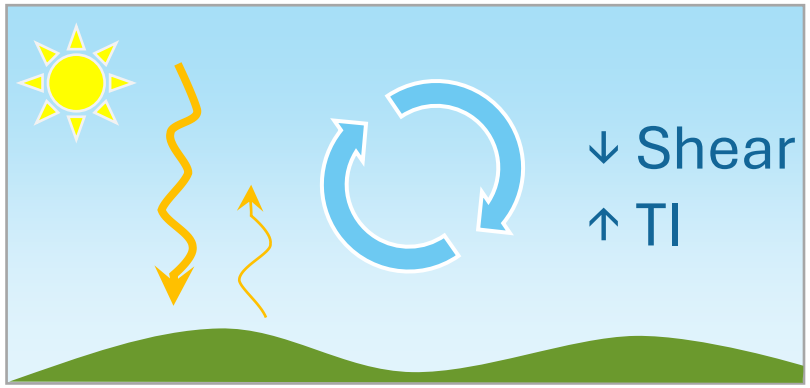
PERFORMANCE MATTERS

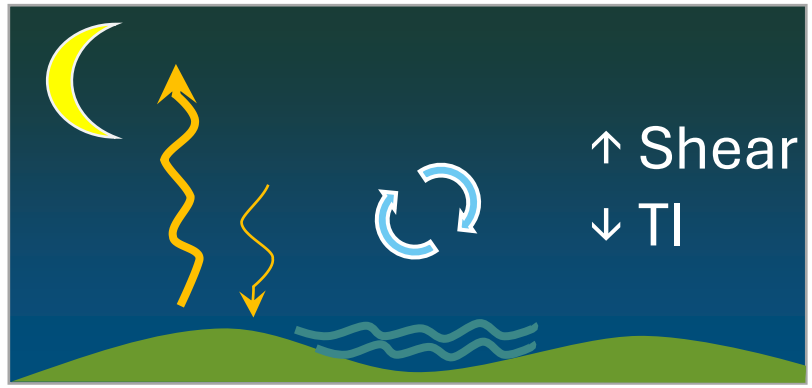
Does the performance on paper match reality?

- The valid/inner range doesn't represent all conditions
- Power performance (warranty) tests heavily filtered
  - Test prolonged and more difficult
- **Yield assessments** should estimate overall expectations
- One of the most common questions as projects approach FC
- Can be considered through uncertainty
  - Thereby reducing P90/P75 – fair?
  - P50 may still be unrealistically high

A BIT OF THEORY

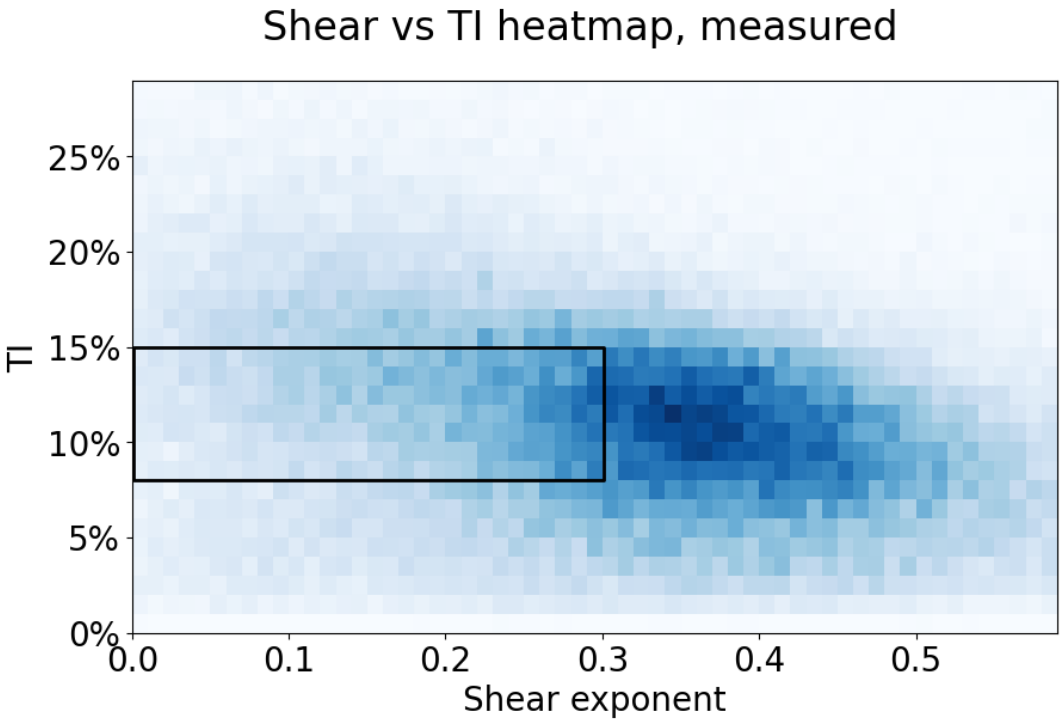
Wind shear and turbulence intensity are varying quantities



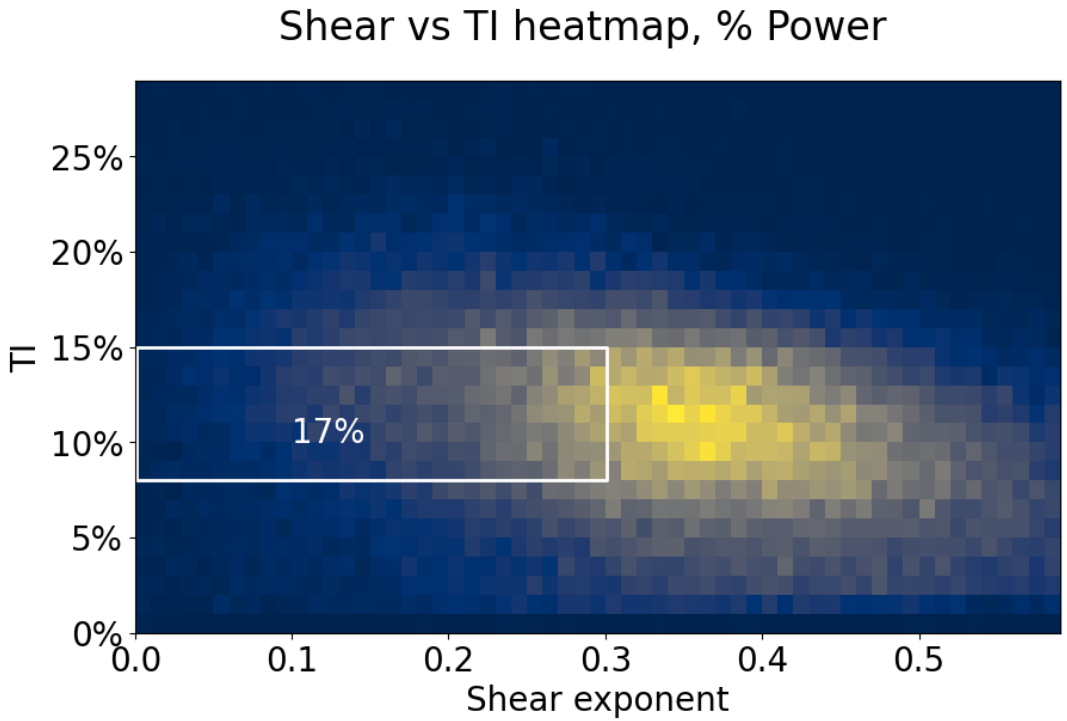


WHAT DO WE SEE AT COLD-CLIMATE SITES?

Shear and TI mostly outside inner range



… and so is most power production



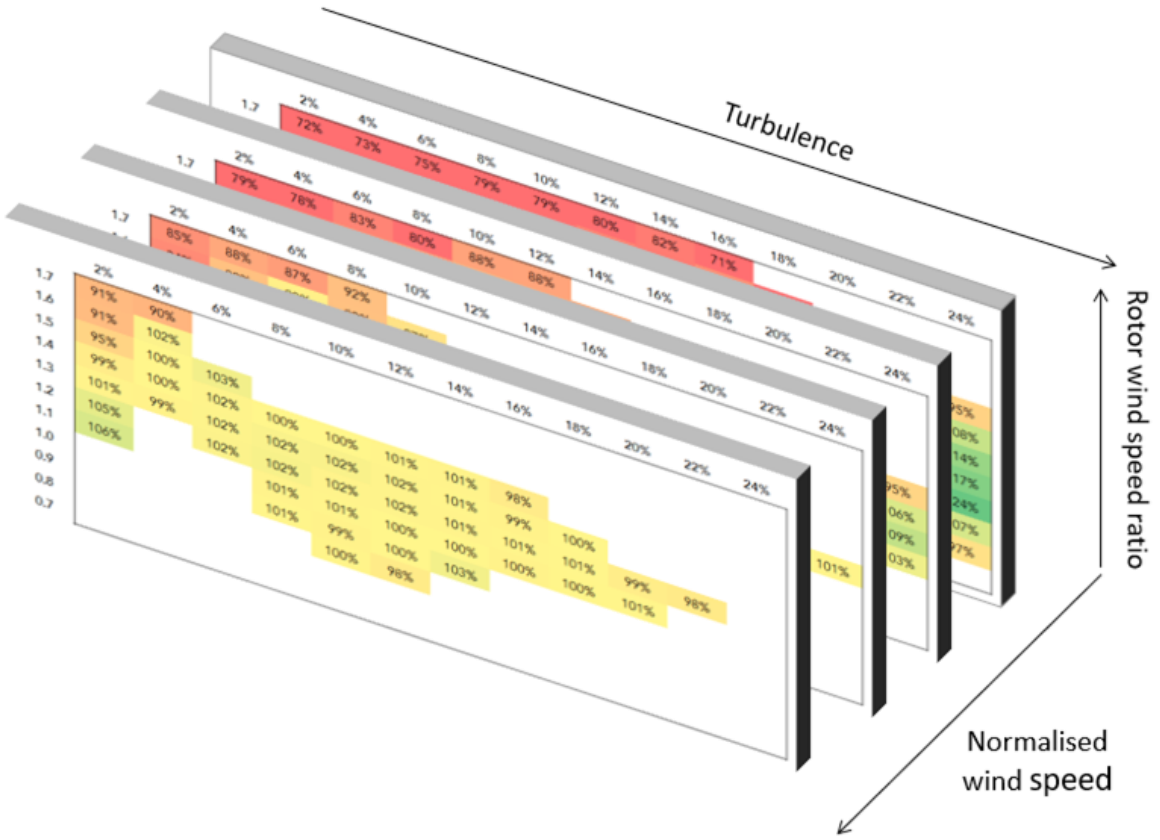
OUR APPROACH TO WTG PERFORMANCE

Our approach: to calculate using a data-driven method

- We consider WTG performance based on
  - Flow inclination
  - Extreme flow conditions
  - **Variations in wind shear and turbulence**
- 3-parameter **turbine performance matrix**
  - Wind speed (normalised)
  - Turbulence intensity
  - Rotor wind speed ratio (normalised shear)
- Respects different WTG geometries

LEADING WITH DATA

- First presented at AWEA in 2014, updated significantly in 2017 and 2024
- Operational data from around the world including cold-climate sites
- Operational wind farm power performance test datasets:
  - > 130 turbines
  - > 30 wind farms
  - 4 continents
- Range of hub heights, diameters, rated power
- Normalised parameters relevant to all configurations and sites



VALIDATED METHOD

A more reliable P50 that stakeholders trust

- An approach backed up by validation
  - Bias reduction of around 50%
- Informs turbine supplier negotiations
  - Motivates the provision of site-specific power curves
- Improves bankability of the EYA
  - Reduce questions during due diligence
  - Certainty drives more valuable assets and safer investments

Model description report:

https://info.k2management.com/turbine-performance-prediction

WHAT IMPACTS ARE EXPECTED?

No two sites are the same

- Timeseries approach
  - Measurements + wind flow model (CFD)
  - WTG geometry and location specific
  - Adding value to CFD calculations
- Typical sites see ~ 1 to 4% loss applied
  - Compare to icing losses
- Baltic nearshore with sea ice – more like onshore?

FUTURE DEVELOPMENTS

Keeping up with technology

- We add data to the model when available
  - More than doubled the input (measured) data
- Machine learning approach
  - Move away from fixed bins/parameters to identify further site parameters with impact
- Want to capture a broad range of geometries
  - Rotor tips reaching ever higher
  - “Stubby” WTGs – large rotor and low tip swing

- **Please cooperate/contribute if interested!**

KEY POINTS

The icing on the cake

- Power curves are valid for a specific range of flow conditions
- Cold climate sites largely outside of these conditions
  - Risks over-estimation of production
- A data-driven approach to performance reduces bias
  - Validated method – reliable results
  - Increase certainty and value
- Site and turbine-specific turbine performance loss
  - More valuable dialogue with WTG suppliers

THANK YOU FOR LISTENING – QUESTIONS?

Special thanks to Neil Atkinson and the Analysis Services team at K2 Management

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