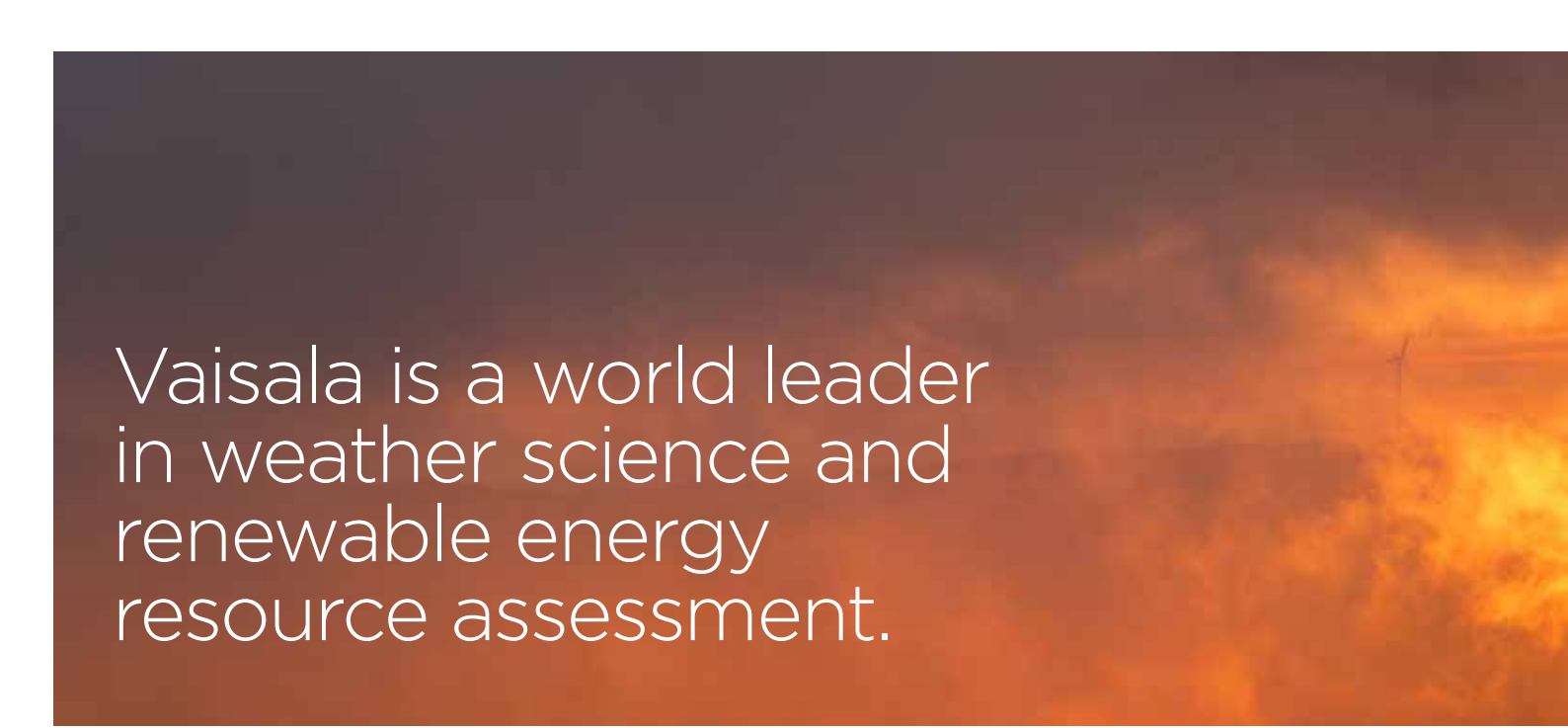


An abstract graphic at the top of the page featuring a network of white lines connecting various green and yellow circular nodes, set against a blue background with a subtle bokeh effect.

# Wind Energy Due Diligence

SUPPORTING PROFITABLE INVESTMENTS IN THE WIND SECTOR

The VAISALA logo is positioned in the bottom right corner of the page. It consists of the word "VAISALA" in a bold, white, sans-serif font, set against a teal background that features a pattern of diagonal lines.



# Vaisala is a world leader in weather science and renewable energy resource assessment.


For over 80 years Vaisala's technology has guided high-risk decisions in weather-impacted industries—from national meteorology offices to air and ground transportation.

With over 35 years as a leader in renewable energy measurement, assessment, and forecasting, Vaisala helps clients develop and operate projects better, faster, and more profitably.

*In 2013 Vaisala acquired 3TIER, a leading renewable energy consulting firm.*

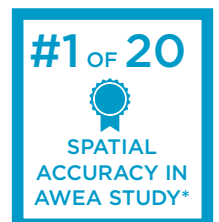
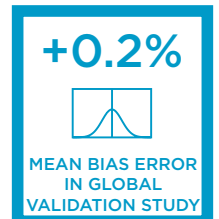
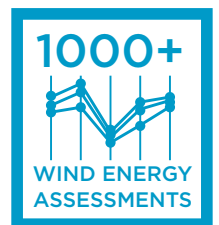
*Now with a larger, global footprint, we continue to provide bankable resource assessments and due diligence services driven by weather science.*

*Our clients use our consulting services to manage the variable fuel of weather, minimize financial risk, and maximize returns at every stage of their wind and solar energy projects.*



# Wind Energy Due Diligence Services

- Quality control of observational and operational production data
- On-site visits for reviewing met campaign and site conditions
- Met campaign design
- Extrapolation of observational data to hub height
- Spatial modeling of the wind resource
- Analysis of past climate to derive the long-term adjustment
- Turbine layout design and optimization
- Calculation of gross P50 capacity factor
- Wake modeling and calculation of all wind farm loss factors
- Derivation of net P50 annual energy production (AEP)
- Comprehensive uncertainty analysis
- Probability of exceedance values
- Recommendations for optimizing energy and reducing uncertainty



\*AWEA ROUND-ROBIN STUDY 2013

# Our Approach to Due Diligence

## Numerical Weather Prediction (NWP) Modeling

- Physics-based approach that simulates the spatial and temporal variability at your site
- Vaisala pioneered the broad integration of NWP models into the wind resource assessment process

## High Performance Computing Center

- Largest commercial super-computing center dedicated to wind energy analysis and operations
- Enables industry-leading, advanced analysis with rapid turnaround times

## Climate Reference Ensemble

- All major reanalysis datasets are downscaled using NWP model simulations
- Multiple climate signals are considered to properly account for uncertainty and biases

## Model Output Statistics

- Proprietary technique for combining on-site observational data with NWP simulations that provides a significant improvement over traditional MCP methods
- Preserves long-term variability from NWP model simulations, while matching the energy content and monthly and diurnal variability of on-site observational data
- Proven accuracy via third-party validation across hundreds of met towers

## Time Series Power Simulations

- Allows for full simulation of the historic record using 300,000+ data points to account for seasonal and diurnal variability and the impact of infrequent events
- Does not condense the analysis into simple wind speed and direction distributions

## Uncertainty Framework

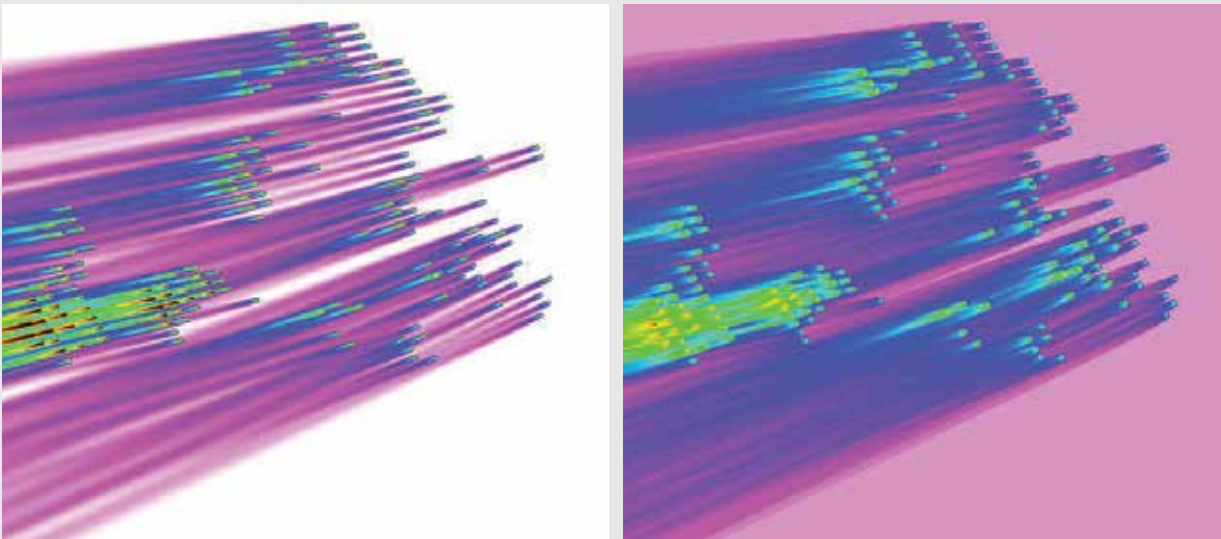
- Allows for the full propagation of uncertainty through all analytical steps
- Accounts for interdependencies to properly calculate the aggregate uncertainty
- Uncertainty optimization via quantitative analysis

## Robust Quality Control

- Automated error checking enables highest quality while meeting commercial timelines
- Visual quality control processes allow for quick detection of issues
- Multi-stage review across entire analysis from data ingest to final deliverables



With Vaisala's help, our clients are transforming the energy future with successful, profitable clean energy projects.



*Snapshots of velocity deficit (left) and turbulence intensity (right) from Vaisala's proprietary time-varying wake model. Utilizing NWP model output to drive the wake model allows for a more detailed understanding of wake propagation through a wind farm.*

# Validation of Our Methodology

Vaisala's approach leverages many of the industry's standard best practices, but is founded on new innovative technologies. These techniques have demonstrably advanced the science of wind energy assessment.

Because project stakeholders, and investors in particular, require a high level of comfort with wind due diligence reports, Vaisala employs a continuous validation feedback process. This is the key to accurate assessments that simultaneously achieve stability and innovation.

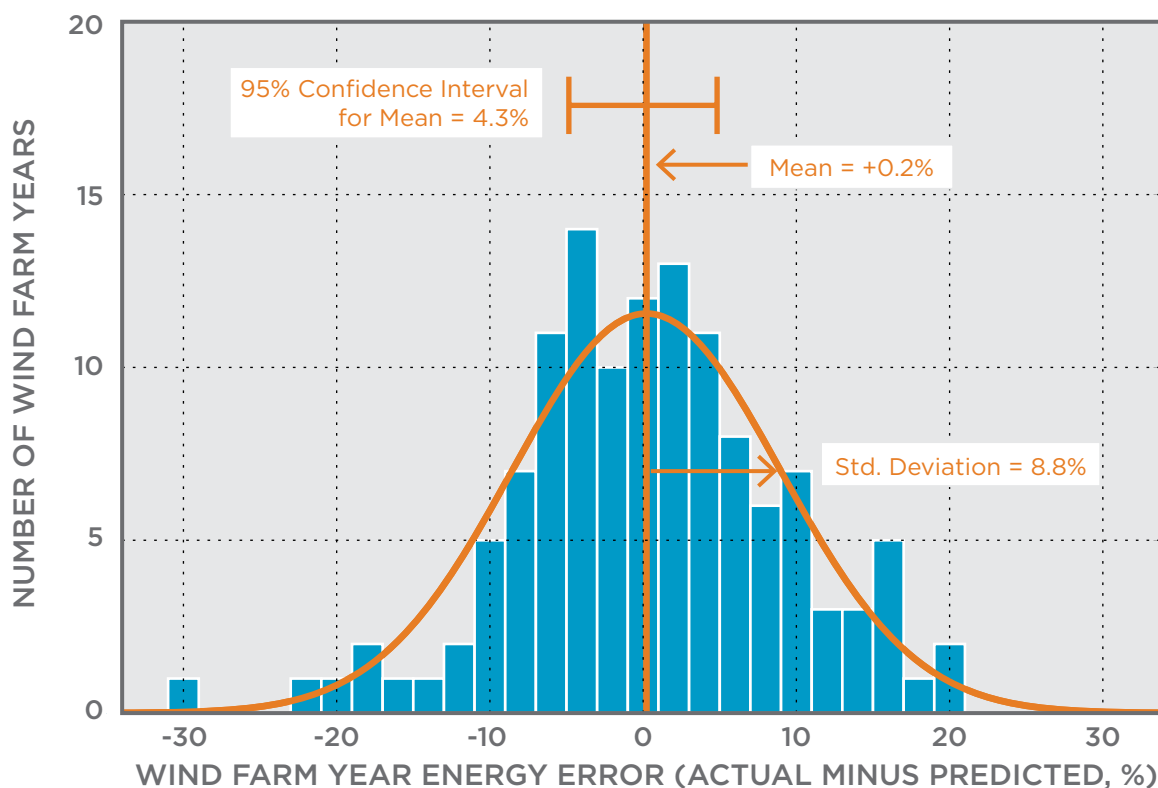
In 2015 Vaisala completed a global validation study across a broad base of operating wind farms to confirm accuracy and agreement with actual production data.

## Validation Dataset Details

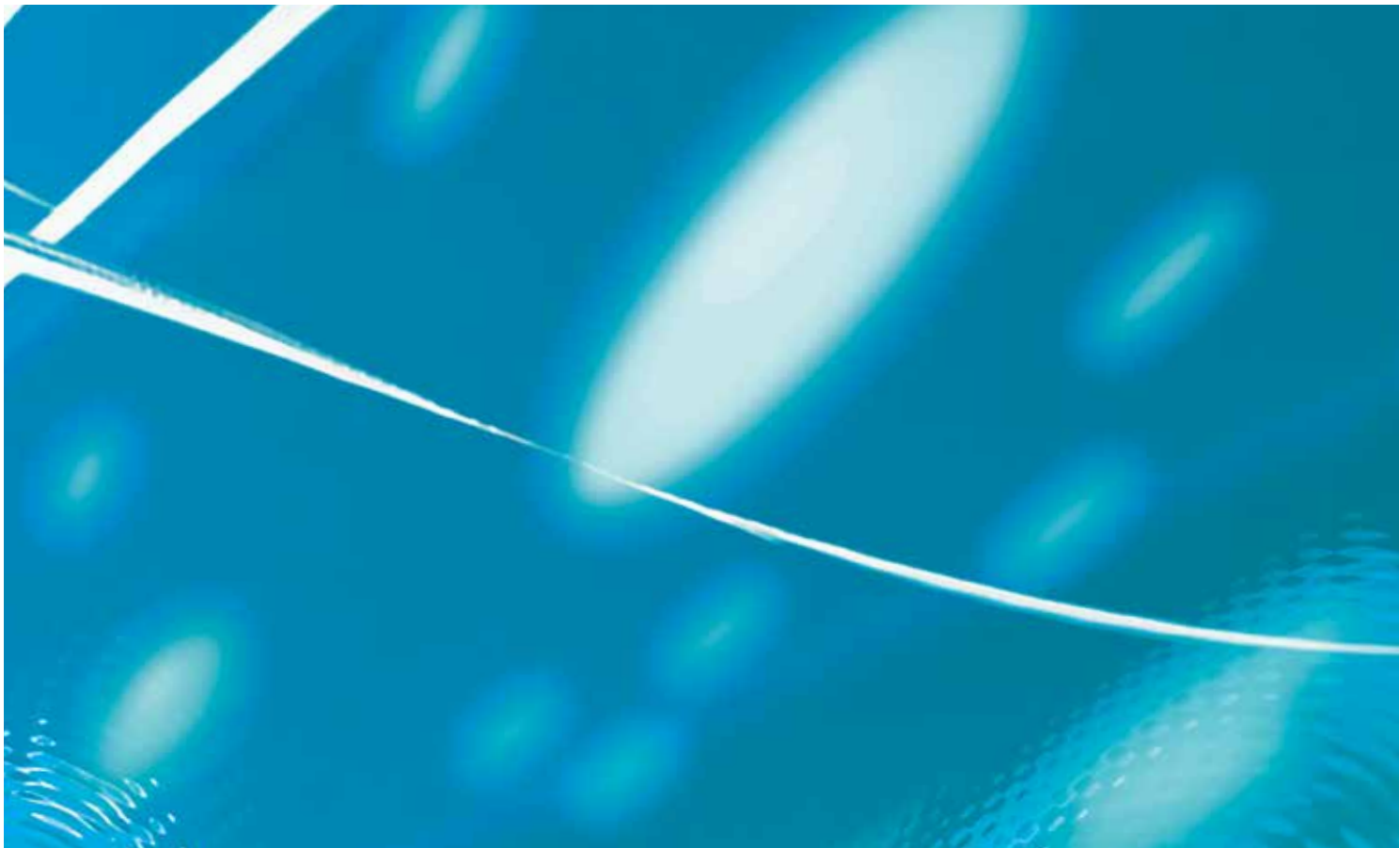
- 30 wind farms totaling 127 wind farm years (WFY)
- Approximate project size range: 20 MW – 300 MW
- Mean bias error: +0.2%
- Standard deviation of WFY errors: 8.8%

On average, wind project performance in this study was nearly unbiased relative to Vaisala's pre-construction estimates (mean bias error was +0.2%, very close to zero). This positive result must be tempered by the 95% confidence interval on this estimate of  $\pm 4.3\%$ , which is uniquely calculated in the Vaisala study. These validation results indicate that Vaisala's wind energy assessment methodology can be confidently used to estimate the expected generation of your wind farm.

Vaisala continuously validates our wind energy assessment methodology across a broad base of operating wind farms to confirm accuracy and agreement with actual production data.



*Histogram of wind farm year energy errors (1-year actual minus long-term predicted, %). The vertical line shows the mean bias error (+0.2%). The bell curve shows the fitted normal distribution using the mean bias and standard deviation of errors. The interval at the top indicates the 95% confidence interval on the mean bias error.*



**Vaisala Offices Worldwide**

Finland <i>(Headquarters)</i>	Japan
Australia	Korea
Brazil	Malaysia
Canada	Sweden
China	United Arab Emirates
France	United Kingdom
Germany	United States
India	

# VAISALA

[www.vaisala.com](http://www.vaisala.com)

For more information, visit  
[www.vaisala.com/energy](http://www.vaisala.com/energy)

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