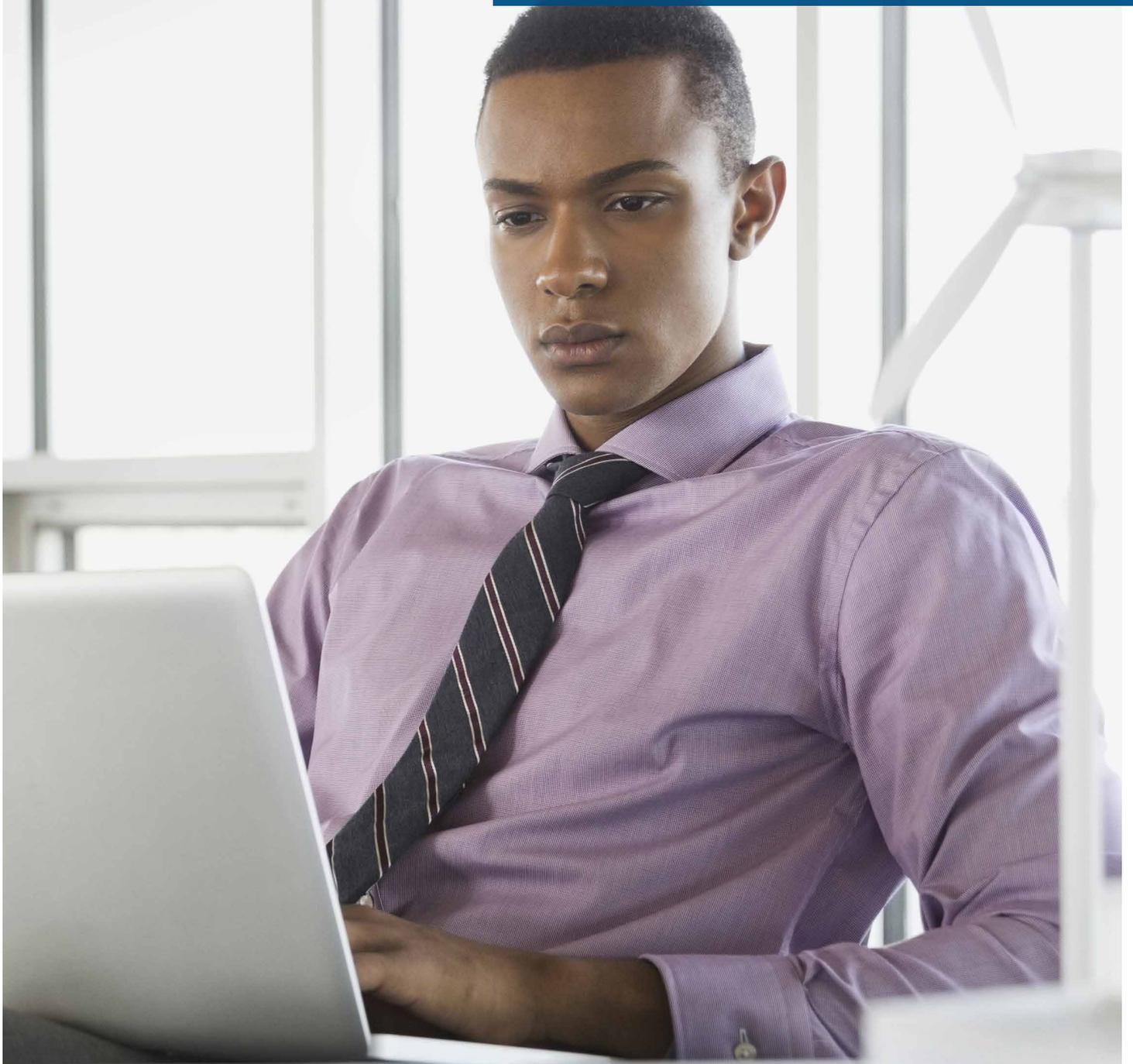


Renewables

Software
Data/Analytics



Empowering Trust™

About us

Leaders in Global Services for Renewable Energy

UL is a trusted independent advisory, testing, inspection and certification body for a broad range of industries. In the renewable energy space, UL works to help manufacturers, developers, owners, investors, lenders, utilities and policy makers navigate the risk and complexity associated with renewable resources. We have become a trusted advisor by providing access to proven science and expert engineering, and by offering innovative solutions to meet the unique challenges of the renewable energy industry. We pride ourselves on being accessible, flexible and keenly responsive to the needs of our clients.

UL now delivers an even more extensive portfolio of renewable energy services, through the acquisitions of AWS Truepower (2016) and DEWI (2012). With offices in over 140 countries, a team of over 500 experts and 35 years of experience, we advise on wind and solar projects as well as battery and energy storage technologies, helping our clients make them safer, compliant and perform to the highest standards. Our goal is to empower trust in renewable energy throughout the project lifecycle and across the supply chain.

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Wind Developer Suite

Our suite of software and data products supports the entire wind farm development process, from initial site prospecting to final design and energy estimation. We provide you with the tools your team needs to work on its own, as well as a platform to collaborate powerfully and efficiently with our experts.

	Windnavigator	Windographer	Openwind
Value your TIME	<ul style="list-style-type: none"> • Best resolution in industry: 200 m site prospecting online or in your preferred spatial analysis platform • Rapid screening of sites with resource & energy comparisons 	<ul style="list-style-type: none"> • Quickly import virtually any data file and see the results in multiple graphs • Combine multiple data files into one data set for easy analysis 	<ul style="list-style-type: none"> • Create the optimal wind turbine layout before construction begins, saving time & money • Apply constraints to produce buildable designs • Advanced multi-threading to handle large complex sites
Enjoy the CONVENIENCE	<ul style="list-style-type: none"> • Enter any hub height between 10m and 140m • Generate PDF maps and reports 	<ul style="list-style-type: none"> • Spot and fill gaps in data quickly • Track all modifications to the data set for your records 	<ul style="list-style-type: none"> • 5 wake modules to choose from • Perform many common GIS functions within the software
Be CONFIDENT	<ul style="list-style-type: none"> • High quality data leads to optimal site selection • The world's most validated resource modeling system • Long-term time series data for MCP and energy modeling 	<ul style="list-style-type: none"> • Apply Measure-Correlate-Predict (MCP) to your data with a suitable reference data set • Graphically compare any number of data sets even if they have different time steps 	<ul style="list-style-type: none"> • Leading-edge Deep Array Wake Model • Time-series energy modeling for more accurate simulation of wakes, curtailment, and other losses, and to account for time-of-day pricing • Road and cabling design and costing

Windnavigator

Rapid, effective site selection with the best resolution and most accurate maps in the industry. Interactive global, 200-meter-resolution wind maps, speed and direction frequency data, downloadable reports, and a wide range of resource data (WRGs) including reanalysis data and custom WRF-based time series.

Windographer

The market-leading software for importing, flagging, and analyzing wind resource data collected at wind project sites. It allows rapid quality control and statistical analyses including MCP and for preparing the data for use in wind flow and plant design software.

Openwind

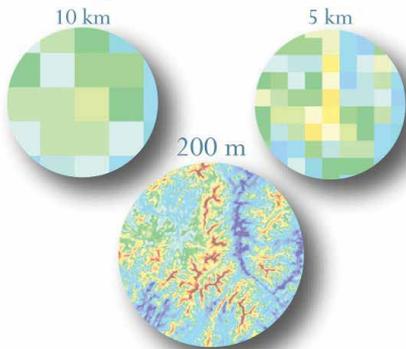
The industry's most advanced software for creating and optimizing turbine layouts, designing and costing balance-of-plant (roads and electrical), performing energy estimates, and conducting ancillary analyses to produce a plan banks will approve.

Software Training Hours

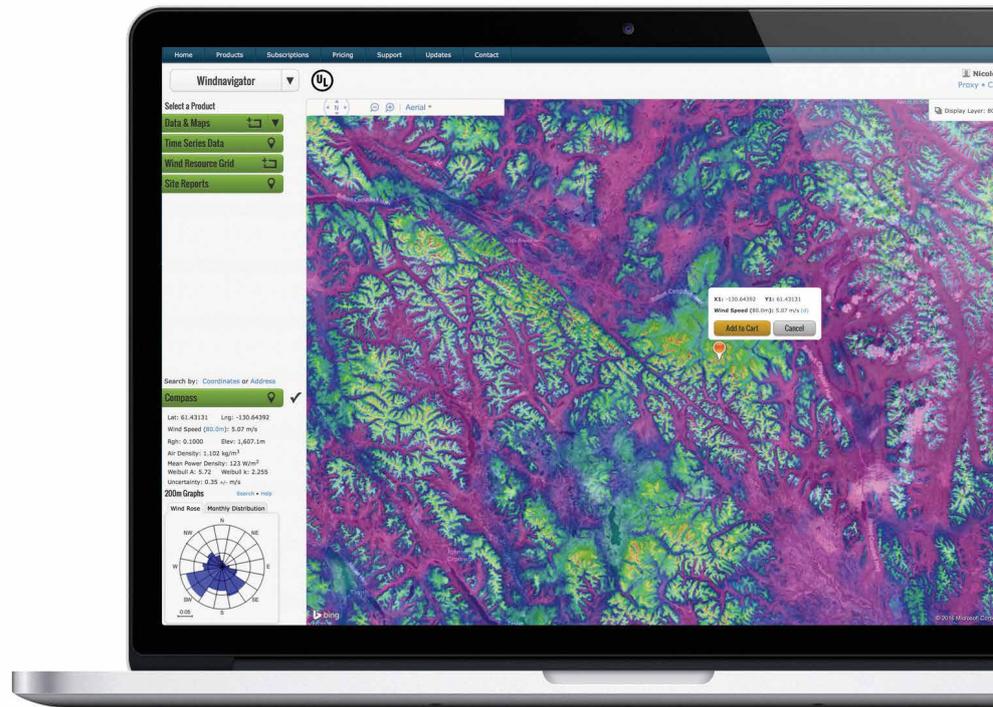
The Wind Developer Suite includes 10 hours of custom training time per year. You decide what software to be trained on and how many hours per session. We find this close working relationship makes our customers' teams far more efficient and successful.

Windnavigator

The High-Resolution Difference



Images display the wind resource for the same project area at three resolutions.



Windnavigator

Windnavigator is an online platform for prospecting green-field sites, identifying locations for a wind monitoring campaign, or assessing competing projects.

- View best resolution: 200 m global resource maps in Google Maps™ or Bing Maps environment
- Query wind statistics at user-selected heights (between 10m and 140m)
- Wind statistics: Weibull values, wind roses, & monthly distributions
- Multiple options for custom time series data
 - Typical-year time series*
 - WRF long-term time series*
- Global reanalysis
 - ERA-Interim, CFSR, MERRA and MERRA-2
- Perform GIS-based prospecting in your preferred spatial analysis platform
- Product discounts for reports, time series and WRGs
- API (application programming interface) for automated or bulk access to resource data*

*Available for an additional cost.

Wind Data Management

With the Wind Data Management online platform we can collect and analyze your wind data with support from our wind resource experts.

- Manage your data securely and conveniently on a dashboard interface
- Achieve high uptime and avoid data gaps
- Be alerted of any issues with instruments on your tower for quick recovery
- Quality control you can trust
- Get monthly reports summarizing your data
- Download raw, compiled, or screened versions of your data
- Web platform
- View and download resource statistics, plots and data files from any device with internet connection

Custom wind site assessment dashboards are also available.

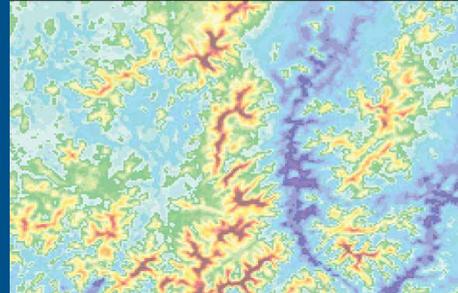
Windnavigator

Our data and maps are derived from simulations of historical atmospheric conditions performed by a numerical weather prediction (NWP) model. Most of these products are available through the Windnavigator platform. The model output is further downscaled with a microscale model accounting for local terrain and surface influences, and adjusted using available high-quality wind measurements. Our approach has been thoroughly validated and uncertainty statistics are available.

Data and Maps

- Quickly prospect and analyze sites
- 200 m resolution data
- User-entered hub height (between 10m and 140m)
- GIS formats compatible with standard GIS software

Formats: GeoTIFF, ESRI Point Shapefiles (.shp)



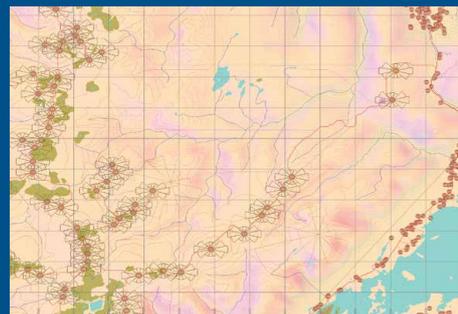
Time Series

- Typical year virtual met masts for preliminary energy estimates
- Global reanalysis data from MERRA-2, ERAI, and CFSR
 - 1979 to the present
 - Useful for MCP in many simple sites
- Custom WRF-based historical time series (up to 35 years)
- Great for MCP, especially in complex sites
- Includes winds, temperatures, solar irradiance and precipitation variables for complete conditions analysis
- CSV format – Imports easily to Openwind, Windographer and other plant design and resource assessment software

19970101	0	-18.3	954.2	18	5.57
19970101	100	-19.2	953.5	26	5.33
19970101	200	-20.2	952.8	17	5.09
19970101	300	-20.4	954.5	19	4.61
19970101	400	-20.5	951.5	23	4.23
19970101	500	-20.6	952.8	37	3.52
19970101	600	-20.5	952.1	52	2.47
19970101	700	-20.4	954.1	55	1.6
19970101	800	-20.3	955.2	75	1.64
19970101	900	-20.2	953.9	64	1.05
19970101	1000	-20.1	952.6	77	1.61
19970101	1100	-19.8	951.7	119	2.76
19970101	1200	-19.2	952.7	141	4.16
19970101	1300	-18.7	953	152	5.42
19970101	1400	-18.2	953.3	164	6.68
19970101	1500	-17.4	949.7	163	7.04
19970101	1600	-16.1	949.4	162	6.26
19970101	1700	-14.6	948.2	162	6
19970101	1800	-13.1	947	168	5.89

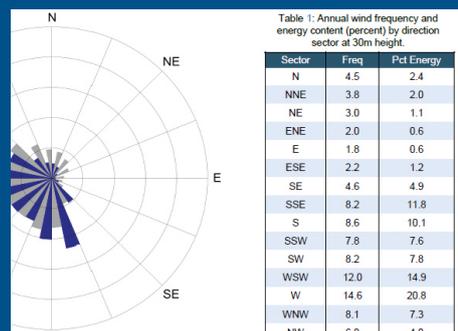
Custom Wind Resource Grids

- Site met towers
- Design preliminary turbine layouts and obtain preliminary energy estimates
- User-entered hub height (between 10m and 140m)



Site Reports

- Comprehensive resource summaries for a point
- Compare energy for up to 3 turbine models
- Extensive charts and graphs including wind rose, frequency, distribution & monthly diurnal data
- Based on 200m resolution data
- Many additional features included
- PDF format





Windographer

Windographer is the industry-leading software for importing and analyzing wind resource data measured by met tower, SODAR, or LIDAR. It quickly imports virtually every data format, allows rapid quality control and statistical analyses including MCP, and exports to all wind flow models common to the wind power industry.

Data Management

- Import virtually every data format including: RWD, RLD, Nomad, Ammonit, Kintech, Campbell Scientific, Triton, AQSystem, ZephIR, Windcube and Pentalum
- Combine multiple data files into one data set for easy analysis
- Reads/writes to SQL databases
- Calculate rotor-equivalent wind speed or solar azimuth
- Combine co-located anemometers, extrapolate vertically, fill gaps, and apply time shifts
- Reads calibration constants from raw data files, shows full calibration history of your data, and lets you adjust slopes and offsets easily
- Download MERRA-2 data for free

Data Visualization

- Transform your data into numerous interactive graphs for rapid analysis
- Export images easily to documents

Windographer



Quality Control

- Flagger capability for highlighting, classifying and filtering data without harming the data
- Define any number of your own flags
- Apply flags to any number of data segments (manually or automatically)
- Use flags as criteria to include or exclude data from calculations, graphs, and export files
- Share flags and rules within a team easily

Detailed Analyses

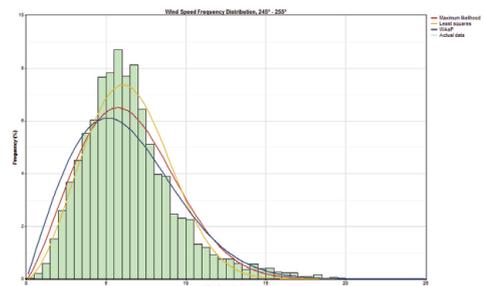
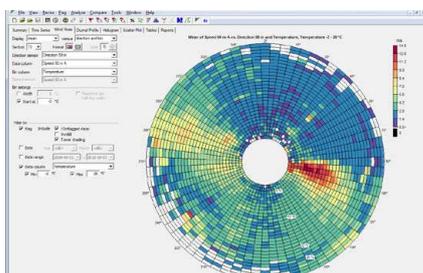
- Investigate shear, turbulence, tower distortion, vertical temperature profile, long-term trends, and other aspects of the wind regime
- Estimate wind turbine energy production
- Predict extreme wind speeds
- Create a representative year
- Compare and correlate with other data sets

Measure - Correlate - Predict

- Choose from several MCP algorithms including linear least squares, orthogonal regression, variance ratio, and the matrix method
- Compare algorithms and settings in terms of their performance and their uncertainty
- Lengthen or scale the target data set to the expected long-term average wind speed

Create Professional Output

- Export reports to PDF
- Export graphs to PNG or spreadsheet formats
- Use data from Windographer in Openwind, WAsP, WindSim and Meteodyn WT





Openwind

A state-of-the-art wind farm design and optimization software used throughout a wind project's development to create optimal turbine layouts that maximize energy production, minimize energy losses, account for plant development costs and generate overall project efficiencies.

Maximize energy production

Cost of Energy Optimization

Optimize layouts and turbine positions to minimize the cost of energy, taking into account energy production, O&M costs and capital costs including turbine and plant development costs. Understand the impact each turbine has on the bottom line.

Arrive at the best layout by taking into account:

- Access road costs
- Collector system costs
- Waterways, pipelines, fence-lines, wetlands and more
- Substation & grid connection locations
- Electrical losses
- Power Purchase Agreement length
- Operations & Management costs
- Wind resource and wake losses

Gridded Turbine Layers

- Quickly create and modify gridded turbine layouts using the user-friendly GIS interface
 - Design by hand using intuitive graphical tools
 - Allow optimizer to determine downwind and crossing spacing, grid orientation and obliquity

Openwind Benefits

- Determine the best layout balancing energy output with construction costs using the Cost of Energy Optimization module

- Deep Array Wake Modules are more accurate than leading competing modules and are essential for estimating wake losses for utility-scale wind farms
- Software developed drawing on over 30 years of consulting expertise assures confidence from financial institutions
- Compatibility with other wind software enables seamless file sharing and easy migration of existing procedures

Reduce and Quantify Uncertainty

- Model environmental and directional curtailments
- Take account of measurement uncertainty, MCP uncertainty and modelling uncertainty
- Assign turbines to met masts, adjust WRGs and run energy estimates
- Let the software suggest additional sites for met masts to extend the monitoring campaign and minimize project uncertainty

Multiple Design Turbine Layout Option

- Analyze multiple turbine layout options for cost effectiveness including different hub heights and turbine types

"Compared to competition, Openwind is greatly adaptable, tweakable, detailed, useful and GIS compatible. It could surpass other software applications (such as WindPRO, WAsP, Meteodyn, WindSim, WindFarmer, etc) in many respects using different built in Openwind features. I would like to emphasize the fast and effective customer support."

— Kornel Rozsavolgyi, Orion Renewable Energy Group

Minimize energy loss

Deep Array Wake Models (DAWM) and Standard Wake Models

- Leading-edge wake models consider the dynamic interactions between turbines and atmospheric boundary layer as well as allowing wakes to vary with turbulence intensity and stability
- Openwind offers users 5 different customizable wake models to choose from including:
 - Modified Park
 - N. O. Jensen
 - Eddy-Viscosity
 - Deep Array Wake Models (Park and Eddy-Viscosity versions)

Time Series Energy Capture

(12x24s, annual or long-term time series at hourly or 10 minute intervals)

- Run energy capture calculations that take into account time-varying temperature, air density, and turbulence intensity
- Model realistic availability using Markov chain models, which can vary with season
- Model high wind hysteresis, low- and high-temperature shutdown losses
- Diurnally varying wake losses
- Icing losses based on met data
- Parasitic consumption, blade heating & electrical losses
- Effects of bat curtailment and NRO modes
- Output results for entire project or individual turbines

Directional Curtailment, Inflow Angle, Turbulence

Model effects of directional curtailment by specifying curtailment strategy in detail or by setting criteria for automatic sector management

Non-Ideal Performance Losses

Use multi-height met mast data to assess the effects of non-standard shear using the rotor equivalent wind speed and adjust power curves for different ranges of turbulence intensity

Environment Management

Noise modeling – based on ISO 9613-2

- Vary atmospheric attenuation based on ISO 9613-1
- Optional attenuating effects of foliage
- Automatically generate NRO strategies based on noise constraints
- Turbine Scheduling (Noise, Bat, Shadow-Flicker Curtailments)

Shadow Flicker

- Take account of wind time-series data and sunshine hours



Visual Impact Modeling

- Variety of ZVI measurements

Suitability

Effective Turbulence Intensity

- Implements IEC 61400-1 editions 2, 3, & 3 amendment 1
- Allows customization of those elements open to interpretation
- Facilitates easy comparison of turbines to their appropriate IEC curve
- Automatically generate wind sector management strategy to meet IEC requirement
- Optimize layouts while taking account of likely wind sector management losses
- Set suitability limits for turbine layouts based on the appropriate IEC standard

Work efficiencies

Exporting Options

- Users can output KML file (Google Earth/Maps) showing one or more wind farms from currently selected point of view
- Access and create online repositories of 3D turbine models and animate blades
- Provides digitally signed reports to ensure authenticity

Files Accepted

- Images (PNG, BMP, JPG, GIF, TIF),
- Vector Layers (WASP maps and Shape files containing points, polylines, polygons)
- Reclassify images and gridded data using a variety of tools
- Accepts gridded data files (ASC, ADF, TIF, GRD, RST, DTM, BIL, XYZ etc.)

GPS Integration

Take Openwind into the field to conduct ground truthing and run energy simulations in the field on a laptop or tablet

Scripting Tool

Queue up operations and load sets of queued operations in XML format or run from command line (talk to us if you need headless HPC or Linux/Unix versions)

Validated Energy Capture

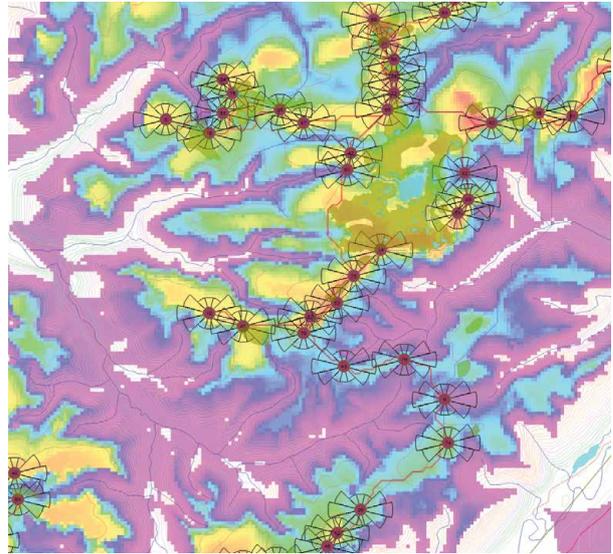
Validated against other models as well as many years of operational data to ensure you get quality results

How to save millions on a wind development project

Determining balance-of-plant (BOP: roads, collectors and crossings) is time consuming and expensive but so is the cost of not doing it at all or evaluating it too late.

Q: How can the lowest cost of energy be achieved?

A: *Use Openwind to minimize the cost of energy including balance-of-plant costs - while keeping production as high as possible.*



Texas Case Study*

Openwind's cost of energy optimization tool allows developers to account for balance-of-plant (BOP) costs much earlier in the development process, and to weigh them directly against energy production, producing more competitive project design.

The software considers

- Existing roads versus new roads
- Terrain steepness
- Water bodies & courses
- Fence lines
- Railroads
- Pipelines
- Substation location and cost
- System voltage
- Cable types and costs
- Financial forecasting

And many other parameters.

Openwind accounts for construction costs that can affect the value of your project. Early and regular communication with construction teams can help in the design cycle and benefit many participating parties.

To demonstrate Openwind's capabilities, we joined with EDF Renewable Energy, Mortenson, and Stanford University in a research study on a recently built Texas plant. The study showed that the cost-of-energy optimization model could have.

- Reduced road costs by 15%
- Reduced collection system costs by 7.8%
- Reduce total plant cost by 6.2%
- Compared to as-built, this would have lowered the overall cost of energy by a substantial \$1.3/MWh

Key to Success:

Increase collaboration with construction, operations, and financing teams to continually refine the cost of energy model and improve the balance of plant design.

*J. Kassebaum, "Improving Wind Turbine Layouts: Balancing Energy Production and Construction Costs to Minimize the Total Cost of Energy," AWEA Resource Assessment Workshop, Orlando, Florida, 10 December 2014.

Key Office Locations



AFRICA

Johannesburg, SOUTH AFRICA

ASIA PACIFIC

Beijing, CHINA

Suzhou, CHINA

Bangalore, INDIA

Ise, JAPAN

Tokyo, JAPAN

Seoul, KOREA

EUROPE

Lyon, FRANCE

Bremen, GERMANY

Cuxhaven, GERMANY

Hamburg, GERMANY

Oldenburg, GERMANY

Wilhelmshaven, GERMANY

Milan, ITALY

Ansoain (Navarra), SPAIN

Barcelona, SPAIN

Izmir, TURKEY

London, UNITED KINGDOM

LATIN AMERICA

Buenos Aires, ARGENTINA

São José dos Campos, BRAZIL

Rio de Janeiro, BRAZIL

Bogotá, COLOMBIA

Mexico City, MEXICO

NORTH AMERICA

Albany, New York, UNITED STATES

Northbrook, Illinois, UNITED STATES

San Diego, California, UNITED STATES

San Jose, California, UNITED STATES



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