Wind Power Explorer

# Abstract

Wind Power Explorer (WPE) software promotes adoption of wind driven electric power generation by facilitating the calculations required for determining wind speeds and amounts for user-specified locations. Lack of good quality wind data is a significant impediment to wind power adoption. Among other capabilities, WPE provides wind interpolation of wind characteristics from known sources to areas of interest to potential wind farm developers.

Its architecture includes pluggable data sources, wind estimation algorithms, and power simulation algorithms making WPE easily adoptable to variety of situations. Additionally, it offers two scaling options: conventional splitter-aggregate messaging based computations and Hadoop framework computations.

# Business Problem Domain

Clean wind power is a $10 billion a year industry supplying more than 5% of total US generated electrical power. As of 2012, wind energy became the fastest growing segment of energy generation in the US. This business is expected to grow 30% annually (see references I.1 and I.2 for some background.) Wind power generation reduces greenhouse gases and helps decrease dependence on foreign fuels.

**Related Existing Software**

Wind power simulation and wind flow simulation programs already exist; examples include WindPRO, WindSim and WAsP. However, these are detailed simulations of individual farms that take into account topography, local wind conditions, turbulence, sound, and other detailed factors. WPE, by contrast, focuses on less accurate simulations but applied to much broader geographic areas so one can locate feasible wind farm sites. With WPE calculations completed, then these more detailed simulation programs can be applied providing more detailed economic forecasts.

# Wind Technical Background

Wind power is generated on “wind farms” deploying many “wind turbines” (see references I.3 and I.4.) Wind farms often have a mix of turbine types that are upgraded from time to time to increase power output. Prospecting for potential wind power is an international effort (see reference I.5.)

Sites are geographic locations of sufficient size that may be acquired and used for a wind farm. A common size is 4,000 acres. A wind farm is a cluster of co-located sites managed by a central operator.

A wind turbine generates power with average wind speeds between 6 and 10 m/s (22 to 36 k/h.) Interestingly, more is not always better; at 33 mph, most large turbines generate their rated power capacity, and at 45 mph (20 MS), most large turbines shut down (see II.2.) Generally, higher placement of turbine blades increases power because winds are faster higher up. Increased air density also increases power generation. Larger blades are associated with increased power generation. Finally, commercial turbines have varying “efficiency”; higher efficiency leads to greater net power generation.

Large geographic scale data analysis can answer questions like:

* Based on prevailing wind conditions, where should we locate wind farms of maximum capacity?
* What mix of turbines generates power most economically for the prevailing wind?
* What is the power generation value of enhancing turbines at existing wind farms?

Power output depends on a number of wind factors and generator characteristics. Economic power generation depends on the cost versus output of a mix of generators.

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# WPE Calculations and Outputs

With sufficient data defining wind characteristics, power generation capability, and economy of power generation associated with all sites of interest, WPE can assist decision makers with the following types of issues:

1. Select promising clusters of sites (farms) based in wind characteristics and geographical constraints
2. Select promising clusters of sites (farms) based on economic power generation capability and geographical constraints
3. Select wind characteristics associated with a specific cluster of sites (a farm)
4. Select potential economic power generation capability associated with a specific cluster of sites (a farm)
5. Orchestrate more accurate, data-driven simulations for a cluster of sites (a farm) to evaluate specific equipment or operational procedures.

Turbine manufacturers will be particularly interested in scenario E.

# Solution Architecture

WPE consists of four loosely-coupled subsystems described in the table below:

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| --- | --- | --- |
| Name | Responsibilities | Dependencies |
| *Data Collection System* | Gathers raw wind speed data to define prevailing wind values in the area of sites over time (e.g., four time periods during a day averaged over each month of the year.) | * Raw data source * Smoothing algoriths |
| *Wind Speed Data* | Defines estimated wind speed and other parameters for select time periods for a site, based on the Data Collection System and an estimation rule. | * Data Collection System * Wind Flow Algorithm |
| *Maximum Power Generation Potential* | Defines the maximum possible wind power generation potential for a site, based on the Wind Speed Data supplying estimated wind conditions. | * Wind Speed Data * Power Estimation Algorithm |
| *Net Power Generation Potential* | Defines a more accurate estimate of the achievable power generation on a specific site. | * Detailed Wind Speed Data * Advanced Power Estimation Algorithm |

**Sample Windfarm Economic Calculation**

Reference II.7 offers data that provides some idea of the scale of working wind farms. This sample of 112 wind farms shows us that the modal energy capacity of wind farms is 119 MW. Each hour of operation for the modal wind farm is worth about *$29, 750* (San Francisco rates average about $0.25 per Kilowatt hour.) Reference II.8 shows the cost of wind power generation is $75-$110 MWH, which amounts to about $0.10 KWH; this is less than half of the retail cost. The model farm size was 8,000 acres (3,237 hectares, 32.4 km2, or 12.5 mi2.) The model farm consumes about 40 acres per MW of energy product [0.025 MW per acres.)

**Resources**

1. These references define business considerations:
2. BLM overview: <http://www.blm.gov/wo/st/en/prog/energy/wind_energy.html>
3. Wind Energy Foundation: <http://www.windenergyfoundation.org/interesting-wind-energy-facts>
4. Wiki, Wind Farm: <http://en.wikipedia.org/wiki/Wind_farm>
5. Wiki, Wind Turbine: <http://en.wikipedia.org/wiki/Wind_turbine>
6. Wiki, Wind Power Resource Assessment: <http://en.wikipedia.org/wiki/Wind_resource_assessment>
7. These references define calculation aspects of Wind Turbine power generation:
8. Calculating power output: <http://www.raeng.org.uk/education/diploma/maths/pdf/exemplars_advanced/23_wind_turbine.pdf>
9. Overview of Power Generation: <http://science.howstuffworks.com/environmental/green-science/wind-power4.htm>
10. Alternative power calculations: <http://www.engineeringtoolbox.com/wind-power-d_1214.html>
11. Another alternative power calculation: <http://www.smallwindtips.com/2010/01/how-to-calculate-wind-power-output/>
12. A theoretic view: <https://docs.google.com/viewer?url=http://www.ocgi.okstate.edu/owpi/educoutreach/library/lesson1_windenergycalc.pdf>
13. Another theoretic view: <https://docs.google.com/viewer?url=http://www.mmpa.org/Uploaded_Files/ab/ab5c7c5c-79d9-48bd-b64d-833001b7e230.pdf>
14. Wind Farm Size and Energy land consumption: <http://www.aweo.org/windarea.html>
15. American Wind Energy Association – energy generation cost comparison: <http://www.awea.org/Resources/Content.aspx?ItemNumber=5547#ComparativeCost>
16. These references define Wind Speed Data Sources:
17. A commercial source: <http://www.3tier.com/en/package_detail/wind-time-series-and-prospecting-tools/>
18. NRCS: <http://www.wcc.nrcs.usda.gov/climate/windrose.html>
19. Public Data: <http://www.windenergy.org/datasites/>
20. NOAA data: <http://www.ncdc.noaa.gov/data-access>
21. NCDC of NOAA: <http://www.ncdc.noaa.gov/>
22. Theory and Data: <http://www.winddata.com/>