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WIND POWER PROJECT SITE

Identification and Land Requirements

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This document is one of a series of reports and guides that are all part of the NYSERDA Wind Energy Tool Kit. Interested parties can find all the components of the kit at: www.powernaturally.org. All sections are free and downloadable, and we encourage their production in hard copy for distribution to interested parties, for use in public meetings on wind, etc.

Any questions about the tool kit, its use and availability should be directed to:
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In addition, other reports and information about Wind Energy can be found at www.powernaturally.org in the on-line library under "Large Wind."

NOTICE

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Wind Power Project Site Identification and Land Requirements

Introduction

This paper provides detail on the type and amount of land required for wind power projects, as well as information on how wind power developers identify land they may want to utilize through option or leasing agreements. The land requirements to be addressed encompass all components of a conventional wind power project, including the wind turbines, service roads, crane pads, and the electrical interconnection to the grid.

In general, land requirements for wind power projects vary considerably and mostly depend on two sets of factors. The first set pertains to the developer's goals in terms of preferred windy locales and desired project size or power capacity (i.e., number of turbines). Larger projects naturally require more land area, and larger projects also tend to yield lower costs of energy due to economies of scale. Therefore, for future projects, most developers desire land areas that can accept enough wind turbines to achieve a project capacity of at least 30 megawatts, and preferably more.

The second set of factors pertains to local landform characteristics and existing patterns of land use and land ownership. Various New York landforms—coastal plains, valley floors, hills, ridges, plateaus, and mountains—have differing exposures to prevailing wind conditions. They also offer differing wind power project siting opportunities. For example, only the tops of ridges are practical sites for wind turbines due to superior wind exposure, whereas a coastal plain can experience similar wind conditions across a broad area. Accordingly, land requirements for a wind power project will vary depending on the landform type. Even after a given landform is identified, other factors such as land ownership patterns and land use/land cover patterns will influence how a wind project is ultimately designed and how much land is ultimately required.

The following sections provide further insight into the leading factors that influence the location of projects as well as determine the land requirements of wind power projects of various sizes for different landform settings.

Site Identification

Before entering into agreements to acquire the use of lands, developers first need to determine where to focus their siting efforts, with an aim on finding areas possessing at least five qualities: 1) attractive wind conditions, 2) reasonable access to electrical transmission, 3) terrain favorable to construction, 4) land use and environmental compatibility, and 5) sufficient land area with the foregoing qualities to achieve an economical project size.

Wind Conditions: A wind project's energy production and life-cycle economics depend more on the strength of the wind resource than any other factor. Therefore developers must seek windy locations when prospecting for potential development sites. A rule-of-thumb is that a site's annual average wind speed should be seven meters per second (15.7 mph) or stronger at the wind turbines' hub height to be considered at least marginally attractive for project development. Other project cost variables may require stronger average winds in order to realize economic viability.

The most common tools used by developers to find windy sites are topographic maps, wind maps, and the expertise of meteorological consultants. In addition to terrain contours, topographic maps provide detailed information on the location of political boundaries, populated areas, roads, parks, transmission lines, and other relevant siting features. Wind maps are similar in nature but show predicted wind speeds and prevailing directions based on sophisticated numerical weather model predictions that also take into account local terrain and land cover influences. NYSERDA has supported the development of a statewide wind map: http://www.windexplorer.com/NewYork/NewYork.htm. that provides wind and other land use information at a spatial resolution of approximately 10 acres. Meteorological expertise can supplement map information with local knowledge of wind conditions and recommendations for an on-site wind measurement program. Site-specific measurements of the wind resource, using tall meteorological towers, are required to confirm the wind conditions (including the diurnal and seasonal variability) within the area of interest.

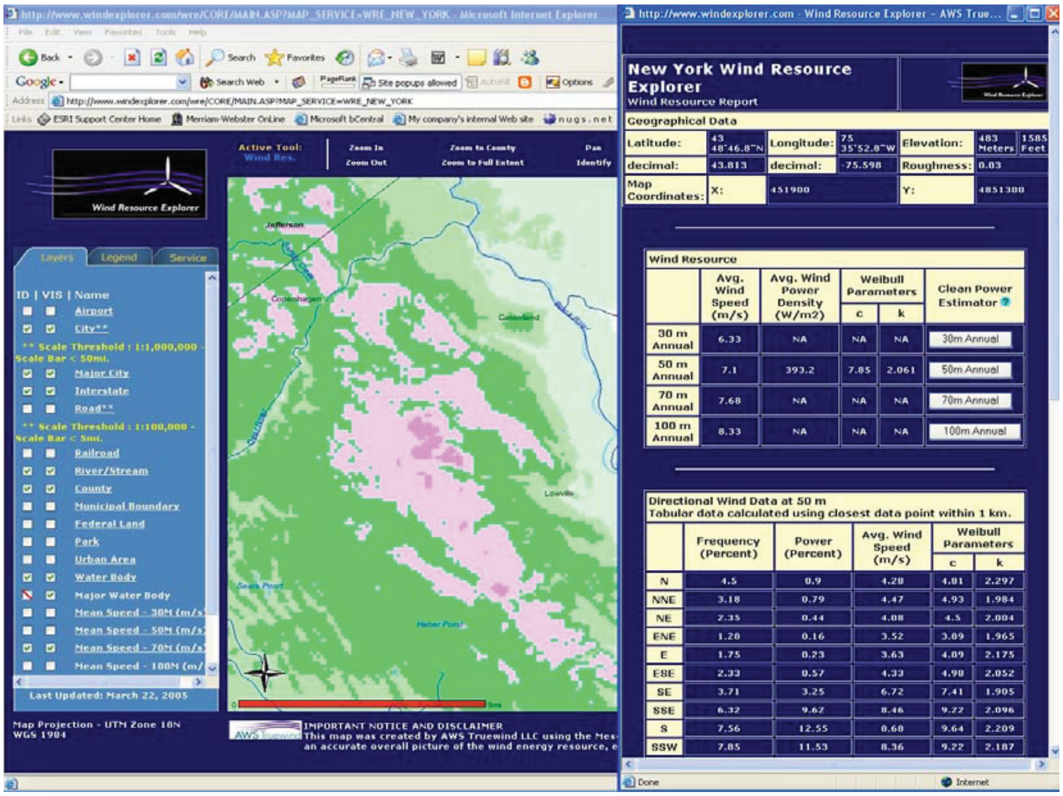

Figure 1. Example of Wind Map For A Portion of the Tug Hill Plateau Region of New York

<u>Proximity to Transmission:</u> To minimize land use impacts and control costs, developers desire project sites that are in close proximity to the existing electric transmission grid. The power from a wind project needs to be delivered to the grid at an approved interconnection point (typically a new or existing substation). Acquiring a route for the interconnection circuits will involve the negotiation of rights-of-way from one or more landowners, plus permitting and construction costs. New interconnection circuits are expensive, with costs depending on the voltage level, the types of terrain and associated land uses along the interconnection route, and whether or not a portion of the installation is underground. Consequently, relatively small wind projects are normally built near existing transmission facilities, while larger wind projects can justify the costs of interconnection at greater distances from existing transmission.

<u>Terrain Favorable for Construction</u>: The delivery and construction of wind power project equipment requires that the terrain be accessible by heavy-duty vehicles (e.g., tractor trailers, cement trucks) and cranes. Areas with excessively steep slopes or deep gullies can be difficult to access and impose unacceptable safety risks. Existing roads may need to be widened or redesigned to provide larger turning radii so that vehicles carrying oversized components (blades, tower sections) can negotiate them. Soil conditions must be favorable for road construction and for installing underground facilities such as wind

turbine foundations, fiber-optic communication lines, and electrical conductors. All of these factors have cost and land use implications and are therefore an important consideration when evaluating prospective project sites.

Land Use and Environmental Compatibility: When initially evaluating prospective land areas, developers make a preliminary assessment of known land uses and local environmental sensitivities in terms of their likely compatibility with wind development. Considerations are given to the availability of open spaces and cultivated or inactive lands, the number of residences and the spacing between them, the number of landowners, the proximity to parks and recognized wildlife habitats, and other factors. All factors are then weighed together to determine if a wind project has a reasonable chance of receiving all permits approvals. These factors also will influence how a wind project can be physically arranged on the landscape to minimize land use conflicts. A given wind project in an agriculturally active area with scattered homes, for example, may require more land area than a remote, uninhabited ridgetop. Therefore, the land requirements of a wind power project will be a function of local land use patterns.

Sufficient Land Area: As stated previously, developers look for suitable land areas that can accommodate minimum project sizes that meet their economic objectives. Accordingly, an eligible site must have a sufficient land area available to meet all of the site qualities discussed above.

Land Area Required

Once a wind power project is selected for development, land area requirements are determined in greater detail. The primary objective of a wind project design is to locate the wind turbines in the best wind sites to maximize energy production. The developer uses tailored design tools and software to optimally place wind turbines at eligible sites.

Wind turbines are typically arranged in single or multiple rows, depending on the size and shape of the landform. A single row is most often found on ridgelines and hilltops where the amount of well-exposed land is very limited. Broader and flatter land features can accommodate multiple rows of turbines. In both cases, rows are laid out to be as perpendicular as possible to the prevailing wind direction(s).

The distance between wind turbines (between turbine rows and between turbines within a row) is commonly described in terms of rotor diameters. For example, if a project design is described as having 3 by 10 spacing, it means that the turbines are generally spaced 3 rotor diameters apart within rows, and the rows are spaced 10 rotor diameters apart (see Figure 2). For a project using wind turbines with a 70-m (230 ft) rotor diameter, this would mean spacing the turbines 210 m (690 ft) apart within a row, and 700 m (2,300 ft) apart between rows.

The interference of one wind turbine on the wind experienced by a downwind turbine is called the "wake effect" or "array effect". Turbines that are closely spaced will experience higher wake-effect-induced energy losses. Because wide spacing between wind turbines generally maximizes energy production but increases land and infrastructure requirements (i.e., cabling, roads), cost considerations must be analyzed before finalizing turbine locations.

The distance between rows in complex terrain is typically dictated by the terrain characteristics (i.e., turbines will be placed on ridgelines in hilly terrain to take advantage of the better wind exposure, and the layout will be dictated by the orientation of the ridgelines). On relatively flat terrain, turbine rows are ideally spaced depending on the in-row spacing between turbines. The objective is to optimize the balance between the higher wake effects and lower costs associated with tighter spacing.

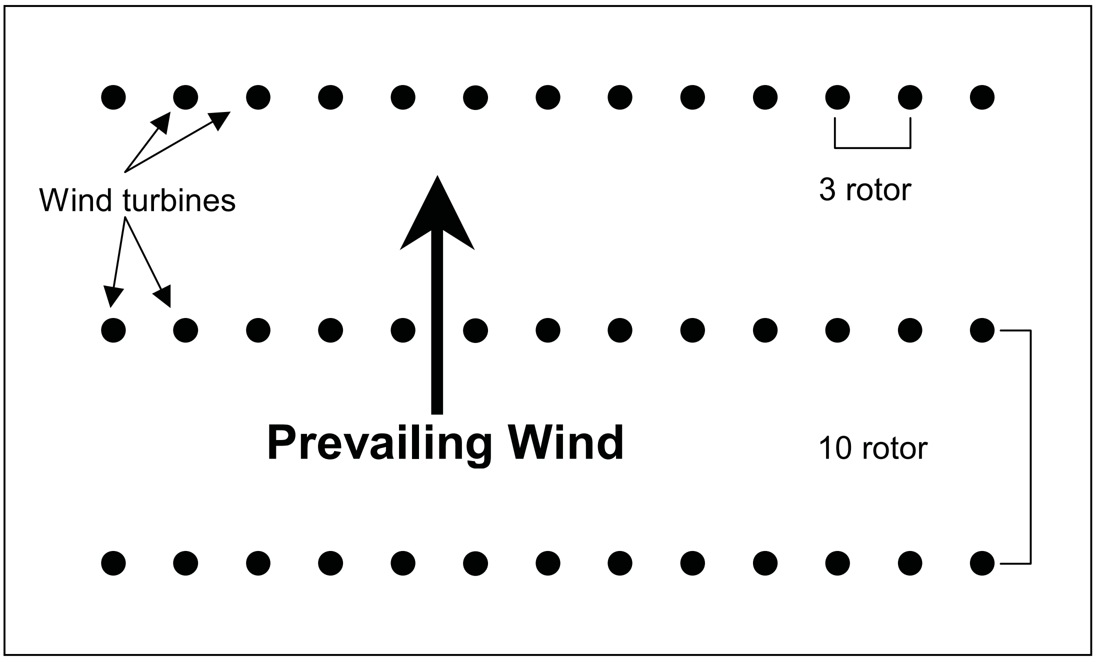

Figure 2. Illustration of Turbine Spacing (example: 3 x 10 spacing)

Within rows, the spacing is dictated by wind direction. In unidirectional environments (i.e., most of the energy-producing winds come from the same direction), turbines can be placed closer together within rows, typically 3 to 4 rotor diameters apart. Multi-directional winds (e.g., important prevailing directions are from the west and south) necessitate greater spacing. In this case typical spacing is 5 to 7 diameters between turbines and 7 to 8 diameters between rows. A turbine manufacturer may require or allow tighter or looser spacing depending on the characteristics of their turbine and the wind characteristics at the site.

Table 1 illustrates the actual turbine spacing for five different wind power projects in the northeastern United States. The three New York projects (as of mid-2005) show a range of turbine spacings and related spacing factors such as landform type. As more projects are built in New York in the future, there will be more examples of turbine spacing to illustrate the host of variables that influence project design and land requirements. In addition to those already described, the variables also include: setback distances of turbines from residences, property lines, and roads; preferential placement of turbines near the edges of cultivated fields and wooded lots; and consideration of landowner preferences for turbine number and placement.

The acreage required for a wind power project can be defined two ways. The first is the overall area containing the entire project, including the open spaces between turbines. In Figure 2, for example, there are 39 wind turbines arranged in three rows of 13 turbines each. The turbines are spaced three rotor diameters apart within rows, and 10 diameters apart between rows. Assuming a rotor diameter of 70 m (230 ft), the total area occupied by the turbines (including a small setback perimeter surrounding the rectangular project area) is approximately 1,040 acres. In other words, an average of 26.7 acres is required for every turbine. If each turbine has a generating capacity of 1.5 megawatts (for a project total of 58.5 MW), which would be consistent with the 70 m rotor diameter, the land requirement would be 17.8 acres per megawatt of generating capacity.

Table 1. Example Turbine Spacing

Project Location	Land Use and Type	Turbine Layout	Turbine Spacing (rotor diameters)
Madison, NY	farmed hilltop	circular row of 7 turbines along hill rim	4 diameters between turbines
Wethersfield, NY	open farmland, north-south ridgeline	single north-south row of 10 turbines perpendicular to prevailing wind direction	3 diameters between turbines
Fenner, NY	mixed farmland and woodlots on broad hill	variable layout of 20 turbines	generally 5 to 7 diameters between turbines
Meyersdale, PA	ridgetop, farmland	single northeast-southwest row of 20 turbines	3 diameters between turbines
Searsburg, VT	forested ridgeline	single northeast-southwest row of 11 turbines on ridge	variable (1.5 to 3.5 diameters) between turbines
Sources: Turbine Verification Program by the U.S. Department of Energy and the Electric Power Research Institute; AWS Truewind, LLC.			

This example illustrates a relatively flat site experiencing a single prevailing wind direction. For a site having two prevailing wind directions 90° apart, wider turbine spacing within rows is likely to require a larger per turbine project area. Assuming a 50-turbine array consisting of 5 rows of turbines with 10 turbines per row, with 7-rotor diameter spacing both between rows and between turbines within rows, the total project acreage would be approximately 2,956 acres. This translates to 59 acres per turbine or 39 acres per megawatt, which is more than twice the area than the previous example. In reality, even more acreage per unit turbine or capacity may be required by a project when accounting for terrain undulations, setbacks from local homes, and other site-specific considerations.

A second way to describe the land requirements of a project is to define only the area actually occupied by the project's facilities. A project's facility consists of the turbines and their foundations, service roads, crane pads, electrical equipment, and any associated buildings. Figure 3 is an aerial view of a small wind project in Madison, NY, with these facilities labeled. In general, a project's facilities occupy only about 5 percent of the total project area. This means that the large majority of the space within a project area can be used for traditional purposes, such as agriculture.

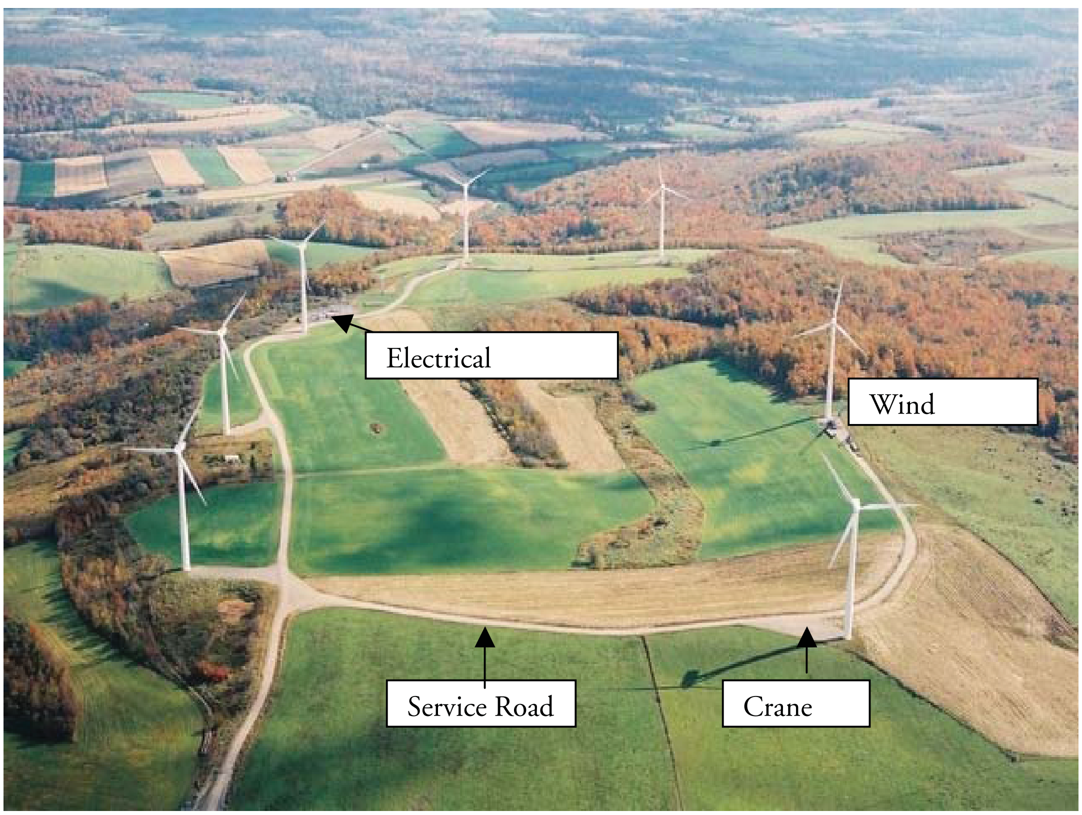

Figure 3. Aerial View of a Wind Power Project in Madison, NY (photo by Chris Milian)