# Appendix 3-A

# Wind Energy As A Siting Criteria For Potential Wind Parks

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## 1.0 INTRODUCTION

Wind velocity, and the quality of the wind resource (e.g. sustained velocity, turbulence, etc.), as a selection criteria for the siting of wind generating facilities predominantly relates to energy-generating capability, efficiency, and reliability. These performance factors also relate to the economic viability of a project, an economic variable that is very site specific and has a major impact on project viability.

This paper will consider the variation of potential energy generation due to wind velocity and its impact on the commercial viability of a potential project site.

## 2.0 POWER IN THE WIND

Wind turbines extract power from the wind by converting the kinetic energy of the moving air into power. The power, in watts, can be determined from the formula for kinetic energy in an air stream, which is $^1/_2\,\rho V^2$ per unit volume. For an air stream flowing through an area A the mass flow rate is $\rho AV$, therefore:

Power, $W = (\rho AV)\,^1/_2 V^2 = {}^1/_2 \rho AV^3$

Where $\rho$ is the air density, V is the wind velocity (m/s) and W is the power (watts)[1]. Hence, it can be seen that the power in the wind is a function of the cube of the wind velocity. Thus a 50% increase in wind velocity, for example from 6m/s to 9m/s, increases the power available by 3.4 fold. Even a small increase in wind velocity can substantially boost the kinetic energy contained in the wind available for conversion to electrical energy by a wind turbine, and therefore greatly increase potential energy generating capability.

## 3.0 US DEPARTMENT OF ENERGY (DOE) WIND POWER CLASSIFICATION

In 1986 the DOE compiled a wind energy resource atlas of the United States to show areas potentially suitable for wind energy projects (http://rredc.nrel.gov/wind/pubs/atlas/). This atlas established wind resource maps which estimate the renewable resource in terms of wind power classes, ranging from Class 1 (the lowest) to Class 7 (the highest). Each class represents a range of mean wind speed at specified heights above the ground.

According to the 1986 Atlas, and referenced in Cape Wind's Section 10 Individual Permit Application (November 21, 2001) and MEPA ENF (November 15, 2001), "Areas designated class 3 or greater are suitable for most wind turbine applications…." This statement however must be placed into present day context. The regulatory environment in 1986 was markedly different then today. Government incentives to the wind power industry were substantially more liberal than they are now. This enabled sites with lower classification wind densities to be considered commercially viable.

By more current standards, areas designated as Class 4 or greater onshore are generally considered to be the minimum suitable for larger scale wind project development by the industry[2,3,4,5,6,7,8,9]. Currently, Class 3 wind regimes are not generally considered commercially viable for private development since infrastructure costs are greater for the larger wind turbine units of today[,,,,,,,].

[1] http://www.windpower.org/tour/wres/enrspeed.htm
[2] "Areas designated class 4 or greater are suitable with advanced wind turbine technology under development today." Wind Energy Potential in the United States; D.L. Elliott and M.N. Schwartz 1993. http://www.nrel.gov/wind/wind_potential.html
[3] Renewable Energy: Wind Power. Chris Tuttle, March 5-6, 2002. http://www.usda.gov/rus/electric/engineering/sem2002/tuttle.htm
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[8] Low Wind Speed Technology Development in the U.S. Department of Energy Wind Energy Research Program. S. Calvert, R. Thresher, S. Hock, A. Laxson, and B. Smith. May 2002. NREL/CP-500-32512. http://www.nrel.gov/docs/fy02osti/32512.pdf
[9] Elliott, Schwartz, Bailey & Phillips, 1997: Availability of Renewable Resources: Wind Energy. **CRC Handbook of Energy Efficiency** (edited by F. Kreith and R. West), CRC Press, New York, pp 751-780.

## 4.0 COMPARISON OF DOE WIND MAPPING VS. MTC WIND MAPPING

Until recently the 1986 DOE Wind Atlas has been the standard for estimating the wind resources of the United States. The DOE maps established the wind power classification system based on ranges of mean wind speeds estimated at a height of 50 meters, and uses the color coded wind power classes as the basis of their mapping.

Recently the Massachusetts Technology Collaborative (MTC) commissioned TrueWind Solutions to develop updated wind resource maps of New England[10]. The MTC maps, which have been widely distributed during meetings related to the MTC's Cape and Islands Offshore Wind Public Outreach Initiative, predict the mean wind speeds at a height of 65 meters above ground, and do not specifically incorporate the DOE wind power classification system. The MTC maps use color coded mean wind speed ranges (in .5 m/s increments) as the basis of their mapping.

A simplified comparison of the scales used to develop the two maps shows that DOE wind classes of 4 and 5 compare exactly with MTC mapped contours of wind speeds 7.0 m/s – 7.5 m/s and 7.5 m/s – 8.0 m/s respectively. DOE based its wind class 3 on speeds of 6.4 m/s – 7.0 m/s which compares very closely with the MTC contour of wind speeds of 6.5 m/s – 7.0 m/s.

**Table 1: Comparison of Wind Mapping**

| Wind Power Class | DOE (50 meters) | MTC (65 meters) |
|---|---|---|
| 2 | 5.6-6.4 m/s | 5.5-6.0 m/s |
| | | 6.0-6.5 m/s |
| 3 | 6.4-7.0 m/s | 6.5-7.0 m/s |
| 4 | 7.0-7.5 m/s | 7.0-7.5 m/s |
| 5 | 7.5-8.0 m/s | 7.5-8.0 m/s |
| 6 | 8.0-8.8 m/s | 8.0-8.5 m/s |
| | | 8.5-9.0 m/s |
| 7 | 8.8-11.1 m/s | 9.0-9.5 m/s |
| | | >9.5 m/s |

As a result of predicting the wind speeds at a greater height above ground, the MTC mapping results in most offshore areas being rated as a higher wind power classification as compared to the DOE mapping.

Both maps are useful tools in the analysis of siting criteria for a wind park. For purposes of clarity it is suggested that any future reference to the wind resource should include the DOE wind power class followed by (the wind speed in m/s at 65 m.), so that either map may be referenced.

## 5.0 WIND PARK ECONOMICS

The costs involved with today's state-of-the-art MW scale installations, particularly when installed in offshore conditions (where installation, operation and maintenance costs can run 50% or higher than comparable land based installations), preclude the commercial viability of any site with less than Class 4 winds[11].

Consider the following comparison of Class 3 and Class 4 sites. The Class 3 site designation is 6.4 – 7.0 m/sec vs. the Class 4 site range of 7.0 – 7.5 m/sec. Taking the means of each at 6.7 m/s for a Class 3 site and 7.2 m/s

[10] http://www.mtpc.org/RenewableEnergy/green_power/outreach/wind_resource_mapping.htm
[11] James F. Manwell Ph.D University of Massachusetts Renewable Energy Research Laboratory. http://wind.raabassociates.org/articles/offshore%2011_02x.ppt

for a Class 4 site, the following analysis will quantify the increased power potential of a Class 4 site using the following equations[12]

$P_2/P_1 = (V_2/V_1)^3$

$P_2 = (7.2/6.7)^3 P_1 = 1.24P_1$

This analysis shows that the mean difference between a Class 3 site and a Class 4 site represents an increase in power of 24%. Considering the potential power of a hypothetical 200-MW project with a 28% capacity factor that developed 490,560-MWh/year (200*.28*8760) in a Class 3 site, the same project in a Class 4 site would produce 608,294-MWh/year or 117,734 MWh/year more. This is a significant difference in output, particularly with infrastructure costs being equal.

Expanding the comparison of Class 3 versus Class 4 sites, assuming the installation of a 200 MW project and a $50.00 per mWh power sale price, the increased revenue on the Class 4 sites would be $5,886,700 per year. The power rate would have to be $62/mWh at the Class 3 site to generate the same revenue as the Class 4 site at $50/mWh. It is important to note that if the only difference between two sites were the wind power classification, the costs for construction, development, financing, O&M, taxes, etc. would be approximately equal.

Wind turbine installations, recently constructed in the U.S. are most commonly built in areas designated as Class 4 (7.0-7.5 m/s) or higher wind speeds. As examples, the wind speeds in West Texas's Southwest Mesa Wind Energy Project, with 107 WTGs installed, has a mean wind speed of 9.5 m/s (Class 7). Another example is the Cerro Gordo Project in Ventura, Iowa, with 56 WTGs installed, with a mean wind speed of 7.8 m/s (Class 5). Due to the cost of offshore wind farm development being 50% greater than onshore development, it is intuitive that a higher wind class, and therefore greater capacity factor, is required for the development of an economically feasible offshore utility-scale project. When offshore sites are evaluated, wind classes of 5 (7.5 – 8.0 m/s) are considered to be the minimum reasonable classification in today's market due to the higher cost to construct and maintain Wind Parks in offshore environments.

In addition to wind velocities, many other factors influence site economics. These include: site attributes (mountain vs. flat terrain), onshore vs. offshore, cost and complexity of the interconnection, land availability, etc.

Another way to evaluate the suitability of a site's wind resource is to consider the annual revenue per square meter of rotor area, and whether government funding incentives or pricing initiatives may affect the commercial viability of a project. The vast majority of existing European offshore wind projects are subsidized by the government or have been developed as demonstration projects, rather than privately financed merchant projects. For example, Germany guarantees a high price for renewable wind energy. This makes it possible to site wind turbines in areas of low wind resources. Conversely, the United Kingdom pays relatively lower prices for renewable electricity, resulting in the necessity to site installations in higher wind resource areas.

## 6.0 SUMMARY

In conclusion, wind classification as a criteria for wind park site selection is largely an economic issue based on the scale and performance characteristics of the Wind Park for a given site location. It is a variable which is site-specific that must be evaluated in conjunction with the anticipated local power rate. This will ultimately drive the project's commercial viability. Based on the anticipated rate structure in the New England region, any onshore site with a wind class less than 4 would not be considered commercially viable for the foreseeable future. The required wind class for offshore conditions must be higher compared to land-based sites to offset the higher construction and operating cost for an equivalent offshore facility.

[12] These formula are a derivation from the power formula previously stated.