Assessing the Feasibility of Wind Power Production for the University of Rhode Island’s Bay Campus

Kenneth A. Critz
University of Rhode Island

Follow this and additional works at: http://digitalcommons.uri.edu/srhonorsprog

Part of the Engineering Commons

Recommended Citation
http://digitalcommons.uri.edu/srhonorsprog/147

This Article is brought to you for free and open access by the Honors Program at the University of Rhode Island at DigitalCommons@URI. It has been accepted for inclusion in Senior Honors Projects by an authorized administrator of DigitalCommons@URI. For more information, please contact digitalcommons@etal.uri.edu.
Feasibility of Wind Power Production at the URI Bay Campus

Presented By: Kenneth Critz
Advising Professor: Dr. Malcolm Spaulding
Ocean Engineering
Overview

• Site Description and Selection
  – Land use, topography, and adequate space

• Characterize Demand on the Bay Campus
  – Yearly trends (2003-2008), and monthly trends

• Available Wind Data and Scaling

• GE 1.5MW WTG

• Characterize Wind Power Production Potential
  – Annual production, monthly production, directionality

• Standards and Regulatory Environment
  – RI standards and international standards
  – Special use permitting, net-metering, environmental regulation

• Summary of Major Results

• Summary of Cost and Return
Lower Narragansett Bay and Points of Interest
Site Description and Selection
Possible Locations for 65m Hub

- 100 ft contour
- 50 ft contour
- 65m Hub Height
  - Fall Radius = 103.5 m
- Required Area = 8.32 Acres
- Direction of Most Significant Power Production

Note: The map shows potential locations for a 65m hub, considering contour lines and required area for power production.
Possible Locations for 80m Hub

- 100 ft contour
- 80m Hub Height
  - Fall Radius = 118.5 m
- Required Area
  - = 10.9 Acres
- 50 ft contour

Direction of Most Significant Power Production
Characterization of Demand

• 5 years of electricity data (2003 – 2008)
• Annual Power Usage
  – Increases annually
• Total Annual Cost of Electricity
  – Cost per kWhr and usage increases
• Monthly Variations in Power Usage
  – Greatest from December to March
  – Least in May and June
Annual Electricity Usage

Annual Electricity Cost

$0.10 / kWhr

$0.11 / kWhr

$0.12 / kWhr

$0.13 / kWhr
Selection of Wind Data and Scaling

• Limited Available Wind Data
    • Mean Annual Wind Speed at 80m for all of RI and coastal ocean
  – Pt. Judith Lighthouse
    • 3 years of hourly mean wind speed at 22.5m elevation (2005-2007)
  – Army Corp WIS Station 79
    • 20 years of hourly mean wind speed at 10m elevation (1980-1999)

• Scale WIS Wind Speed Time History to Represent Site
• Assume Scale Factor Constant for All Wind Speeds
  – Method used by ATM (2007) for Portsmouth Assessment

• Scale WIS Station 79 Data to Site
  – Scale Factor is the ratio of AWS mean annual wind speeds
  – Verify assumption with Pt. Judith wind data
    • Calculate mean annual wind speed of WIS and Pt. Judith data
    • Scale Factor from data is within 3% of AWS Scale Factor
Mean Annual Wind Speed at 80m derived from AWS TrueWinds

~6.8 m/s
SF = 0.756

~7.85 m/s
SF = 0.872

~9.0 m/s

Legend:

VMS_79
State Boundary

Mean Wind Speed
m/s

9 - 9.5
9.5 - 9
8.5 - 8.5
7.5 - 8
7 - 7.5
6.75 - 7
6.5 - 6.75
6.25 - 6.5
6 - 6.25
5.75 - 6
< 5.75
GE 1.5 MW Turbine

- Power Production Estimates Based on the GE 1.5sle Turbine

- Turbine swept area is 4657 m²
- Cut-in Speed = 4 m/s
- Cut-out Speed = 25 m/s
- Rated Speed = 14 m/s

~GE 1.5MW Turbine Product Brochure
Annual Power Production at Bay Campus

Annual Power from Scaled WIS Station 79 Data Set @ 80m
where $\alpha = 0.143$ and $\text{SF}_{\text{AWS}} = 0.756$

<table>
<thead>
<tr>
<th>Mean Wind Speed, $U_{\text{ave}}$ (m/s)</th>
<th>Standard Deviation (m/s)</th>
<th>Power Density (W/m$^2$)</th>
<th>Wind Energy (kWhrs)</th>
<th>Turbine Energy (kWhrs)</th>
<th>Extracted resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.80</td>
<td>3.05</td>
<td>371.2</td>
<td>15.143 e6</td>
<td>4.217 e6</td>
<td>27.8 %</td>
</tr>
</tbody>
</table>

Varying $\alpha$ and Hub Height w/ $\text{SF}_{\text{AWS}} = 0.756$

<table>
<thead>
<tr>
<th>$U_{\text{ave}}$-turb (kWhrs)</th>
<th>$\alpha=0.143$ (Stable atm)</th>
<th>$\alpha=0.19$ (AWS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H = 65m$</td>
<td>3.97 e6 kWhrs</td>
<td>4.70 e6 kWhrs</td>
</tr>
<tr>
<td>$H = 80m$</td>
<td>4.22 e6 kWhrs</td>
<td>5.04 e6 kWhrs</td>
</tr>
</tbody>
</table>

Varying Scale Factors @ 80m w/ $\alpha = 0.143$

<table>
<thead>
<tr>
<th>SF</th>
<th>$U_{\text{ave}}$ (m/s)</th>
<th>Data Set Energy (kWhrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.72</td>
<td>6.403</td>
<td>3.936 e6</td>
</tr>
<tr>
<td>0.74</td>
<td>6.581</td>
<td>4.181 e6</td>
</tr>
<tr>
<td>0.76</td>
<td>6.759</td>
<td>4.431 e6</td>
</tr>
</tbody>
</table>
1.5 MW GE Directional Power Production

Mean Annual Power produced (MWhrs) by the GM 1.5 MW turbine @ 80m for 20 years of WIS data
## Monthly Mean Wind Speeds and Power Production

- Hub Height = 80m, SF = 0.756, and $\alpha=0.143$

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Wind Speed $U_{ave}$ (m/s)</th>
<th>Standard Dev. (m/s)</th>
<th>Power Density (W/m²)</th>
<th>Available Resource in Swept Area (kWhrs)</th>
<th>Data Set Turbine Power (kWhrs)</th>
<th>Extracted Resource (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>9.23</td>
<td>3.62</td>
<td>59.40</td>
<td>2.42 e6</td>
<td>6.19 e5</td>
<td>25.5</td>
</tr>
<tr>
<td>Feb</td>
<td>8.75</td>
<td>3.61</td>
<td>47.91</td>
<td>1.95 e6</td>
<td>5.18 e5</td>
<td>26.5</td>
</tr>
<tr>
<td>Mar</td>
<td>7.95</td>
<td>3.64</td>
<td>42.83</td>
<td>1.75 e6</td>
<td>4.8 e5</td>
<td>27.5</td>
</tr>
<tr>
<td>Apr</td>
<td>6.44</td>
<td>3.25</td>
<td>24.47</td>
<td>1.00 e6</td>
<td>3.05 e5</td>
<td>30.6</td>
</tr>
<tr>
<td>May</td>
<td>5.12</td>
<td>2.70</td>
<td>13.22</td>
<td>5.39 e5</td>
<td>1.82 e5</td>
<td>33.8</td>
</tr>
<tr>
<td>Jun</td>
<td>4.75</td>
<td>2.33</td>
<td>9.48</td>
<td>3.87 e5</td>
<td>1.3 e5</td>
<td>33.6</td>
</tr>
<tr>
<td>Jul</td>
<td>4.44</td>
<td>2.08</td>
<td>7.76</td>
<td>3.16 e5</td>
<td><strong>0.97 e5</strong></td>
<td><strong>30.8</strong></td>
</tr>
<tr>
<td>Aug</td>
<td>4.82</td>
<td>2.32</td>
<td>10.27</td>
<td>4.19 e5</td>
<td>1.34 e5</td>
<td>32</td>
</tr>
<tr>
<td>Sep</td>
<td>5.85</td>
<td>2.75</td>
<td>17.25</td>
<td>7.04 e5</td>
<td>2.28 e5</td>
<td>32.4</td>
</tr>
<tr>
<td>Oct</td>
<td>7.10</td>
<td>3.13</td>
<td>29.88</td>
<td>1.22 e6</td>
<td>3.78 e5</td>
<td>31</td>
</tr>
<tr>
<td>Nov</td>
<td>8.69</td>
<td>3.46</td>
<td>48.73</td>
<td>1.99 e6</td>
<td>5.42 e5</td>
<td>27.3</td>
</tr>
<tr>
<td>Dec</td>
<td>9.16</td>
<td>3.71</td>
<td>60.01</td>
<td>2.45 e6</td>
<td>6.04 e5</td>
<td>24.7</td>
</tr>
</tbody>
</table>
Standards and Regulatory Environment

- AWEA suggests IEC international standard
  - Compatibility with foreign market for turbine selection
- Rhode Island Standard Building Codes
  - International Building Code 2006 (SBC-3)
  - National Electric Code (NEC) (SBC-5)
- Special Use Permits
  - A permit must be filed with the town of Narragansett
  - Subjective criteria is reviewed by the zoning board
    - Access, Safety, Noise, Health, Compatibility with surrounding environment, etc...
- Net-Metering Legislation
  - Actively being changed yearly to best suit project development
  - Recently municipalities given consideration
  - State facilities likely to soon be granted consideration
    - South County Wind Energy Forum (URI Energy Center)
- Environmental Assessment and Permitting through DEM
Summary of Major Results

- Comparison of Portsmouth Project to Bay Campus Project

<table>
<thead>
<tr>
<th></th>
<th>Mean Annual Wind Speed (m/s)</th>
<th>Annual Power Demand (kWhrs/year)</th>
<th>Power Produced by Turbine (kWhrs/year)</th>
<th>% Energy Used on Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portsmouth High</td>
<td>6.74</td>
<td>954,000</td>
<td>3,719,000</td>
<td>25%</td>
</tr>
<tr>
<td>Bay Campus</td>
<td>6.80</td>
<td>5,960,000</td>
<td>4,220,000</td>
<td>100%</td>
</tr>
</tbody>
</table>

- Percentage of campus energy generated
  - 70 - 84 % campus usage produced by wind turbine for 2008
- Greatest power generated at max. demand from November – March
  - Demand and Production ≈ 500k-600k (kWhrs)
- Expected useful life of turbine is 20 years
Monthly Energy Comparison

- Bay Campus Usage
- Power Generated

Month: July, August, September, October, November, December, January, February, March, April, May, June

Energy (kWhrs): 100,000 to 700,000
Summary of Cost and Return

- Potential Annual Electricity Savings
  - Behind meter savings from electricity
    - \(4.22 \times 10^6\) kWhrs \(*\) 0.13 $/kWhr \(\approx\) $550,000 per year
  - Expected grid sale price
    - \(4.22 \times 10^6\) kWhrs \(*\) 0.0776 $/kWhr \(\approx\) $325,000 per year

- Approximate Capital Cost
  - Portsmouth High 1.5 MW installment
    - Estimated at $3.23 Million (ATM 2007)
    - $2.9 Million actual cost

- Estimated Operation and Maintenance Costs
  - O&M \(\approx\) $68k per year (ATM 2007)

- Clean Renewable Energy Bonds (CREB)
  - Tax credit bond that is equivalent to interest free loan
  - Portsmouth Financed in this manner
  - Qualified projects have pay-back period approximately 12 years

- Bay Campus Break-Even Point
  - Behind meter pay back period
    - Approximately 6 - 7 years
  - In front of the meter
    - Approximately 12 years
Questions?
Extra Slides
Land Use and Description

- South Ferry Road
- URI Bay Campus
- Mixed Forest
- URI Property Deciduous Forest > 80% Hardwood

0 40 80 160 240 320 Meters
Possible Area and Topography
Local Topography and Obstructions
Assessing Appropriate Scaling Factor

<table>
<thead>
<tr>
<th></th>
<th>Data $U_{ave} @ 10m$</th>
<th>Data $U_{ave} @ 80m$</th>
<th>AWS $U_{ave} @ 80 m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIS</td>
<td>6.73</td>
<td>8.89</td>
<td>9</td>
</tr>
<tr>
<td>PT Judith</td>
<td>5.7</td>
<td>7.54</td>
<td>7.85</td>
</tr>
<tr>
<td>Bay Campus</td>
<td></td>
<td></td>
<td>6.802</td>
</tr>
</tbody>
</table>

- SF from WIS data to Pt. Judith data is 0.848 and 0.872 from AWS Data
  - Factors are within approximately 3%
  - 3 Years of data is not sufficient to suggest AWS not appropriate

- Scaling Factor for wind speeds @ 80m transformed to Site from AWS
  - Suggested $SF_{AWS} = 0.756$
Estimated Annual Power Production Potential

- Mean Annual Wind Speed and Standard Deviation
- Mean Annual Power Density
  - Available Resource
- Power Production of GE 1.5MW turbine
  - % resource extracted
- Variations of Alpha Coefficient and Hub Heights
  - Conservative stable atmosphere $\alpha=0.143$, AWS estimate $\alpha \approx 0.19$
- Sensitivity to Scaling Factors
- Directional Variations
  - Turbine Output Power
Frequency of Direction for 20 Years (1980-1999) of WIS79 Data
Monthly and Seasonal Variations in the Wind Resource

- Hub Height = 80m, SF = 0.756, and α=0.143
  - Monthly Mean Wind Speeds
  - Standard Deviation
  - Monthly Mean Energy Density
- Directional and Seasonal Variations
  - **Winter:** Dec-Feb,
  - **Spring:** Mar-May,
  - **Summer:** Jun-Jul,
  - **Fall:** Aug-Nov
  - Turbine Output Power
Frequency of Directions for 20 years (1980-1999) of WIS79 Data
Directional and Seasonal Variations

Directional Power (MWhrs) produced by GE 1.5 MW turbine @ 80m during the spring months annually

Directional Power (MWhrs) produced by GE 1.5 MW turbine @ 80m during the winter months annually

Directional Power (MWhrs) produced by GE 1.5 MW turbine @ 80m during the fall months annually

Directional Power (MWhrs) produced by GE 1.5 MW turbine @ 80m during the summer months annually