Utility-Scale Wind Energy Potential in Whatcom County

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ArcVera Renewables

Consistently Providing Trustworthy Advantages

Established March 2017
• Merger of Chinook Wind & V-Bar
• V-Bar roots to 1978
• Chinook Wind roots to 1990
• Technology/engineering and wind experience cuts risk

Deep Experience
• 1989 first financeable wind assessment in California
• Work on over 60% of all wind capacity in the US ~64k MW
• Turbine knowledge: 40+ models

Based in Golden, CO and Bellingham, WA
• Projects on 6 of 7 continents
• People based in the US, South Africa, Dubai and Brazil
• 25% of revenue international

26 people, growing
• Engineers, meteorologists, data analysts, administrative support
• Most have 10+ years experience
Growth of Wind Turbines Over Time

Upper tip heights were \( \sim 105 \, \text{m} \) in 2003 and now can exceed 180-m.

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2008</th>
<th>2013</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor Dia. (m)</td>
<td>50-75</td>
<td>70-100</td>
<td>80-110</td>
<td>100-150</td>
</tr>
<tr>
<td>Rated Power (MW)</td>
<td>0.75 -1.5</td>
<td>1.0-1.8</td>
<td>1.7-2.5</td>
<td>2.0-4.5</td>
</tr>
<tr>
<td>Typical NCF (%)</td>
<td>25-35</td>
<td>30-40</td>
<td>35-48</td>
<td>40-55</td>
</tr>
</tbody>
</table>

As wind turbines have grown, the cost of wind energy has dropped. Costs are down >50% over the past 10 years.
GE 5.8 MW 158 m Rotor Diameter

GE’s Cypress Platform
Onshore Wind Turbine

Pitch System
Independent blade pitch angle adjustment combined with generator torque enables rotor to regulate speed depending on wind conditions

Hub
Mounted on main shaft, entered through hatch located on the nacelle to simplify service access

Blades
158 m rotor diameter, carbon two-piece blade by LM Wind Power

Nacelle
Larger nacelle platform brings more comfort to service personnel and facilitates up-tower repairs

Generator & Gearbox
Based on a proven doubly-fed induction generator (DFIG) electrical system, available at 50 Hz and 60 Hz

Electrical System
High power density electrical system for performance and grid integration

Control System
Fully digitally enabled, 24/7/365 remote control operations, Wind SCADA, cybersecurity

Tower
Hub heights available at 101 m, 120.3 m with tubular tower and 150 m, 161 m with hybrid concrete tower

Services
Planned, condition-based and predictive services to ensure more reliability, uptime and production

Perfect for low and medium wind speed sites
• Platform can power the equivalent of 5,000+ residential homes in Europe
• 5.3-158, GE’s largest, high efficiency onshore wind turbine to date with a 49% increase in AEP over the 4.8-158
Vestas 5.6 MW 162 m Rotor Diameter
Siemens Gamesa 5.8 MW 170 m Rotor
Whatcom County Wind Resource
Whatcom County Wind Resource

NREL

Wind Speed at 100 m Height (m/s)
- <4
- 4.0 to 4.5
- 4.5 to 5.0
- 5.0 to 5.5
- 5.5 to 6.0
- 6.0 to 6.5
- 6.5 to 7.0
- 7.0 to 7.5
- 7.5 to 8.0
- 8.0 to 8.5
- 8.5 to 9.0
- 9.0 to 9.5
- 9.5 to 10.0
- >10.0
Whatcom County Wind Resource

Vaisala
Wind Speed at 100 m Height (m/s)

[Map showing wind speed distribution]
Whatcom County Wind Resource

UL Renewables
Wind Speed at 80 m Height (m/s)
Whatcom County Wind Resource

- Wind Speeds in the range of 5.0 to 5.5 m/s near the coast
- Wind Speeds near the coast could be up to 6.0 m/s at 120+ m hub height
- Wind Speeds on hilltops in the range of 6.5 to 7.5 m/s
- Uncertainty is at least +/- 10%
- This compares to wind speeds of 7 to 8.0 m/s for Columbia Gorge and Kittitas Valley sites
### Whatcom County Wind Resource

<table>
<thead>
<tr>
<th>Area</th>
<th>Wind Speed (m/s)</th>
<th>Net Capacity Factor</th>
<th>Approx. Cost of Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whatcom Coastal</td>
<td>5.0 to 5.5</td>
<td>20% to 24%</td>
<td>8 cents/kWh</td>
</tr>
<tr>
<td>Whatcom Coastal with 120 m Tower</td>
<td>5.5 to 6.0</td>
<td>24% to 29%</td>
<td>7 cents/kWh</td>
</tr>
<tr>
<td>Whatcom Hilltop</td>
<td>6.5 to 7.5</td>
<td>32% to 38%</td>
<td>5 cents/kWh</td>
</tr>
<tr>
<td>Eastern Washington</td>
<td>7.0 to 8.0</td>
<td>37% to 44%</td>
<td>4 cents/kWh</td>
</tr>
</tbody>
</table>

- Capacity Factors based on a low wind turbine such as GE 3.03-140
- Above power prices assume a Production Tax Credit and have significant uncertainty (wind resource, CAPEX, OPEX, interest rates, etc)
Example Western Washington Wind Project

Coastal Energy Project

- Built by Coastal Community Action Program in 2010
- Grayland, WA – near Aberdeen
- Wind speed = 6.6 m/s
- Capacity factor = 26%
- Utilized Production Tax Credits and New Market Tax Credits
- Provides ~$500k annually for CCAP social service programs
- Uses 77 m rotor diameter 1.5 MW wind turbines. Much larger and more cost effective technology is available today.
Example Western Washington Wind Project

Coastal Energy Project
Key Messages

1. Wind technology is developing rapidly and costs are declining
2. Whatcom county has a moderate wind resource, but there are developable sites
3. Wind resource is better, and power prices are cheaper, for wind energy generated in Eastern Washington

2. At least one other wind project has been developed in Western Washington with significant local community benefits
Consistently providing trustworthy advantages throughout the project lifecycle

Thank you!

John Bosche, President and Principal Engineer
September 4, 2019