Offshore Wind Energy Yield Assessment

A Case Study on Offshore Wind Resource Assessment and Energy Yield Estimation in the NY Bight

Garrett Wedam - Natural Power
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Goals and Process

Goals: Estimate long-term wind resource and energy yield for a hypothetical offshore wind project in the New York Bight

Process: Discussed here in standard energy yield assessment order of operations, supplemented by related topics for consideration
Project Introduction

- Conceptual Project located in New York State Energy Research and Development Authority (NYSERDA) Indicative “East” Wind Energy Area

- Project configuration informed by NYSERDA Offshore Wind Renewable Energy Certificate (OREC) solicitation
  - Two Phases, Focus on “Hudson North 1”
  - 1330 MW Phase 1, 1162 MW Phase 2
  - 140 m HH, 14.0 MW turbines

- NYSERDA E05 floating lidar system (FLS) used as the primary measurement station, full year of data
QA/QC run on measurements; compared with E06 floating lidar buoy (in “West” candidate WEA) and other regional observations

Measurements supported by Vortex Large Eddy Simulation (LES) time series for TI and temperature

POR Speed: 10.2 m/s @ 140 m above mean sea level (AMSL)

Other Topics for consideration

- Campaign design
- Floating lidar system (FLS) selection & validation
- Metocean measurements & models
Data Analysis: Long-term Adjustment

- Evaluated observed and modeled long-term references
  - NOAA NDBC
  - Vortex, ERA5, CFSR, MERRA-2
- Scrutinized Speed & Direction Distribution
- In-house MCP process applied to observed data using a range of statistical techniques to generate and evaluate long-term synthetic series
- Long-term Speed: \(10.0 \text{ m/s} @ 140 \text{ m AMSL}\)

Topics for consideration
- Review the long-term reference data carefully
- Coastal Marine Automated Network (C-MAN) observations are scarce, but useful

<table>
<thead>
<tr>
<th>Reference Source</th>
<th>Hourly</th>
<th>Monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERRA2 40N 72.5W</td>
<td>0.85</td>
<td>0.88</td>
</tr>
<tr>
<td>ERA5 40N 72.75W</td>
<td>0.92</td>
<td>0.94</td>
</tr>
<tr>
<td>VORTEX-MERRA2</td>
<td>0.86</td>
<td>0.93</td>
</tr>
<tr>
<td>VORTEX-ERA5</td>
<td>0.90</td>
<td>0.99</td>
</tr>
<tr>
<td>VORTEX-CFSR</td>
<td>0.84</td>
<td>0.98</td>
</tr>
<tr>
<td>Buoy 44025</td>
<td>0.64</td>
<td>0.83</td>
</tr>
</tbody>
</table>
Data Analysis: Vertical Extrapolation

- Measurements may be at hub height, but shear profile & distribution still relevant to rotor plane energy flux
  - Mean annualized shear exponent: 0.10
- Other conditions required vertical extrapolation
  - Temperature & density

- Topics for consideration
  - Air temp gradient varies seasonally
  - Hub height turbulence
  - Veer, low level jets, and very large rotors

Long-term mean of temperature gradient by month
Flow Modeling

- Spatial modeling with WRF, provided by Vortex (FARM)
- Adjusted with long-term data at E05
  - Mean Project area wind speed: 9.9 m/s
  - Wind speed range: 9.8 – 10.0 m/s
- WEA size required integrating two modeled areas

Topics for consideration
- Model configuration: coverage, resolution, & computing implications
- Input data (e.g. sea surface temperature) & validation
- Datum and hub height!

White and yellow rectangles outline two Vortex modeled areas. Wind speeds represent spatial modeling prior to adjustment to E05. Irregular rectangle overlays show the outlines of NYSERDA East project area and the two smaller individual phases.
Energy Yield: Inputs

→ Power curve
  → Hypothetical turbine: **NP 14.0-238**
  → Synthesis of contemporary turbines

→ Layout
  → 1 x 1 nautical mile spacing, 8 x 8 RD
  → Wake and blockage effects are not trivial, but wind rose is favorable

→ Topics for consideration
  → Temp limits & de-rates; PC variation by shear & TI
  → Room for creativity in optimization, but bottom conditions and other inputs can drive layouts

June 2021
Employed multiple commercial software packages for energy calculations

Demonstrated an array of wake model settings and configurations used across industry

On Phase 1 alone, and considering Phase 2

Topics for consideration

There are various industry viewpoints on offshore wakes methods, including configuration, loss value, and uncertainty

Time series energy capture will be necessary for high-fidelity analyses

Example Wake Losses by Model Configuration – Phase 1 only, including Blockage

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Loss Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV (Ti by DIR) + LWFC</td>
<td>7.7</td>
</tr>
<tr>
<td>Modified Park wdc of 0.03 + LWFC</td>
<td>9.7</td>
</tr>
<tr>
<td>EV (Ti by DIR and WS) + LWFC</td>
<td>8.1</td>
</tr>
</tbody>
</table>
Energy Yield: Outputs

→ Losses
  → Offshore specific: electrical, turbine, environmental
  → 21.7% total loss 47.0% Net CF

→ Uncertainties
  → Standard processes supplemented by assumptions for this case
  → 10-year energy uncertainty: 7.2%

→ Topics for consideration
  → Required outputs, e.g. time series of production
  → Targeted analyses, e.g. summer capacity estimates, winter price spike mitigation
  → Campaign Design (again!)

### Energy Yield Assessment Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P50 Gross Energy / Capacity Factor (GWh/yr, %)</td>
<td>6998.7 / 60.0</td>
</tr>
<tr>
<td>Wake and turbine interaction loss (%)</td>
<td>9.3</td>
</tr>
<tr>
<td>Availability loss (%)</td>
<td>6.1</td>
</tr>
<tr>
<td>Electrical efficiency loss (%)</td>
<td>4.0</td>
</tr>
<tr>
<td>Turbine performance loss (%)</td>
<td>2.2</td>
</tr>
<tr>
<td>Environmental loss (%)</td>
<td>2.1</td>
</tr>
<tr>
<td>Curtailment loss (%)</td>
<td>0.0</td>
</tr>
<tr>
<td>Total loss (%)</td>
<td>21.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P50 Net Energy / Capacity Factor (GWh/yr, %)</td>
<td>5479.1 / 47.0</td>
</tr>
</tbody>
</table>

### Total uncertainty (% P50 Energy)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total uncertainty (1-year)</td>
<td>7.9</td>
</tr>
<tr>
<td>Total uncertainty (10-year)</td>
<td>7.2</td>
</tr>
<tr>
<td>Total uncertainty (20-year)</td>
<td>7.1</td>
</tr>
</tbody>
</table>
Thank you for your Attention!

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Special thanks to the Vortex team for their support and data sets!