Losses and Uncertainties

What’s new?

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Wind Energy Denmark
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The journey

• P50 – where are we?
• Uncertainties – some critical thoughts
• Losses
• Are we getting wiser?
P50 – where are we?

Methodology: Pre-construction AEP ↔ post-construction data (SCADA)

WP3 Benchmark, US (= Super-size CREYAP)
• Phase 1: 10 projects, 8 participants (incl EMD)
• Planned in total: >100 projects
• Challenge: Public database of annual production might bias results

Validation Studies
• ArcVera, DNV, EMD, Natural Power, Vaisala, and others
• Challenge: Time lag between pre- and post-construction
P50 – Preliminary Result WP3 Phase 1

• Spread of results (how certain are we?): around 5ish %

Are industry’s uncertainty assumptions (often around 10%) too high?

Source: AWEA WRA workshop Renton 10-11 September 2019: WP3 preliminary results
Uncertainties – some critical thoughts

• Anemometer calibration -> classification:
  • Known: Inter-tunnel deviations of 1% wind speed
  • Known: Bias are converted to uncertainty
  • Asymmetry

Svend Ole Hansen 2017: Impact of Azimuth
Uncertainties – some critical thoughts

• Anemometer calibration -> classification:
  • Known: Inter-tunnel deviations of 1% wind speed
  • Known: Bias are converted to uncertainty
  • Asymmetry
  • Classification processes?

<table>
<thead>
<tr>
<th>Wind speed uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>u [m/s]</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
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</tbody>
</table>

• Now the more or less correct anemometer is used to benchmark lidars...
Uncertainties – some critical thoughts

• Initiative from Carbon Trust

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Calculation</th>
<th>Revised Methodology</th>
<th>Indicative Wind Speed Standard Uncertainty (%)</th>
<th>Indicative AEP Standard Uncertainty (%), Average Wind Speed = 7 m/s</th>
<th>Indicative AEP Standard Uncertainty (%), Average Wind Speed = 10 m/s</th>
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<tbody>
<tr>
<td>Onshore</td>
<td>Lidar</td>
<td></td>
<td>4.0</td>
<td>6.9</td>
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<tr>
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<td>Lidar</td>
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<td>2.5</td>
<td>4.7</td>
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<td>Offshore</td>
<td>Float. Lidar</td>
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<td>2.1</td>
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</table>
Improvement: Impact of Map Quality on AEP

- Example: Midtfjellet, Norway
  - Benchmark: AEP calculated with DHM1 (1m resolution lidar data)
  - Compared on WTG level with AEP calculated with various maps (all available in windPRO)

<table>
<thead>
<tr>
<th>Map</th>
<th>Mean deviation [% AEP]</th>
<th>Stdev [% AEP]</th>
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<tbody>
<tr>
<td>DHM10</td>
<td>0.1</td>
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<tr>
<td>STRM1</td>
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<tr>
<td>AW3D30</td>
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<tr>
<td>View Finder</td>
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<tr>
<td>SRTM3</td>
<td>-0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>EUDEM</td>
<td>-2.6</td>
<td>1.2</td>
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Losses – the good part of the story

- Time-varying calculations leads to more precise/accurate calculation of losses:
  - Environmental curtailment (noise, bats, flicker...)
  - Power Matrix: TI and shear impact, boost, de-rating etc
  - WTG performance: hysteresis (depending on documentation from OEM)
  - Time-varying wake decay constant

![Graph showing ratio of modelled to measured production for NW Sector with different Wind Data Collection (WDC) factors: Fixed WDC 0.075, Fixed WDC 0.064, and Time-varying WDC factor 0.4.](chart.png)
New Kids in Town: Wind Farm Blockage
New Kids in Town: Wind Farm Blockage

Layout 1: 50 MW; 3 RD

Layout 2: 150 MW; 4 x 8 RD

Layout 3: 300 MW; 6 x 12 RD

<table>
<thead>
<tr>
<th>Expert</th>
<th>Blockage loss [% energy]</th>
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<tbody>
<tr>
<td>ArcVera</td>
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<td>DNV GL</td>
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</table>

Source: AWEA WRA workshop Renton 10-11 September 2019

Uncertainty AEP

1/3 of loss

20% of loss
Both blockage models went through some validation process.

UL points out that P50 validation study shows no bias -> re-categorising some losses.
Important to keep perspective right

• General
  • p50 is not too much off

• Uncertainty:
  • Some indications that assumptions are conservative
  • Large discrepancies anemometer classification (factor 2)
  • Uncertainty in IEC 12-1 (lidar) disputed (factor 4)

• Losses:
  • Better grip on some components through time-varying calculations
  • Blockage creates confusion, in some cases it contradicts P50 validation studies of main players
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