EWEA CREYAP benchmark exercises: summary for offshore wind farm cases

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Wind Energy Denmark 2015
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- RES Ltd. for Gwynt y Môr data pack
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- 60 teams from 13 countries; thanks for making the comparison and presentations possible!
- EWEA for arranging Offshore CREYAP Part 1+2, thanks to Tim Robinson and his team.
Comparison of Resource and Energy Yield Assessment Procedures

**EWEA CREYAP concept**
- Industry benchmarking
- In-house training and R&D
- Identification of R&D issues

**Three issues today**
- Wakes and wake modelling
- Yield assessment uncertainties
- Modelled vs observed yields

**CREYAP history**
- Onshore Part 1, Bruxelles 2011
  - Scotland W, 14 × 2 MW (28 MW)
- Onshore Part 2, Dublin 2013
  - Scotland E, 22 × 1.3 MW (29 MW)
- Offshore Part 1, Frankfurt 2013
  - Gwynt y Môr, 160 × 3.6 (576 MW)
- Offshore Part 2, Helsinki 2015
  - Barrow, 30 × 3 MW (90 MW)

**Summary**
- 157 submissions from 27 countries
  - 97 for onshore
  - 60 for offshore
Barrow estimated turbine yields and wake effects
Barrow estimated turbine yields and spread of results
Barrow wind farm (only) – which wake model is best?

![Graph showing specific model (median) wake effect (%) vs. all models (median) wake effect (%) for different wake models: WindPRO Park (5), WASP Park (4), CFD-type (3), Ainslie EV (3), WindFarmer EV (2), FUGA (3), Other models (3).]
## Wake modelling uncertainty (CREYAP 1-4, Nygaard 2015)

<table>
<thead>
<tr>
<th>Wind farm</th>
<th>Size</th>
<th>Layout</th>
<th>Wake loss</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore 1 Hilly</td>
<td>28 MW</td>
<td>Irregular 3.7-4.8 D</td>
<td>6.1%</td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td>14 WTG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onshore 2 Complex</td>
<td>29 MW</td>
<td>Irregular 4-5 D</td>
<td>10.3%</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td>22 WTG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offshore 1† Gwynt y Môr</td>
<td>576 MW</td>
<td>Regular 6-7 D</td>
<td>14.3%</td>
<td>22%</td>
</tr>
<tr>
<td></td>
<td>160 WTG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offshore 2 Barrow</td>
<td>90 MW</td>
<td>4 staggered 5.5 × 8.5 D</td>
<td>7.9%</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>30 WTG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 offshore‡ DONG 2015</td>
<td>90-630 MW</td>
<td>10 layouts</td>
<td>one model</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>30-175 WTG</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Without two rather unusual outliers  
‡ N.G. Nygaard, EWEA Offshore 2015
Uncertainty for offshore wind farm predictions

- Offshore CREYAP exercises Part II+I
  - Barrow, 30 WTG, 90 MW (2015)

<table>
<thead>
<tr>
<th>Component</th>
<th>Coefficient of Variation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT wind @ mast</td>
<td>1</td>
</tr>
<tr>
<td>Reference yield</td>
<td>2</td>
</tr>
<tr>
<td>Gross yield</td>
<td>3</td>
</tr>
<tr>
<td>Potential yield</td>
<td>4</td>
</tr>
<tr>
<td>Net yield, P50</td>
<td>5</td>
</tr>
<tr>
<td>Net yield, P90</td>
<td>9</td>
</tr>
<tr>
<td>Long-term adjustment</td>
<td>1.5</td>
</tr>
<tr>
<td>Yield calculation</td>
<td>2.5</td>
</tr>
<tr>
<td>Flow modelling</td>
<td>3.5</td>
</tr>
<tr>
<td>Wake modelling</td>
<td>4.5</td>
</tr>
<tr>
<td>Loss estimation</td>
<td>5.5</td>
</tr>
<tr>
<td>Uncertainty est</td>
<td>9.5</td>
</tr>
</tbody>
</table>
Barrow predicted vs observed \( P_{50} \) (1 year)

Data points used = 20 (of 22)

Mean predicted \( P_{50} = 324 \) GWhy\(^{-1} \)
Standard deviation = 9.6 GWhy\(^{-1} \)
Coefficient of variation = 3.0%
Range = 300 to 343 GWhy\(^{-1} \)

Prediction bias = +4%
(cf. Cox, EWEA Offshore 2015)
Summary and conclusions – offshore wind farms

• Important issues offshore
  – Yield calculations
  – Wake modelling
  – Technical losses
  – Uncertainty estimation

• Wake modelling
  – Represent a significant loss
  – Uncertainty $\propto$ WTG wake loss
  – Models and spec’s important
  – Configuration essential too!
  – Classic models seem to provide realistic results for Barrow
  – Many more farms necessary...

• Yield assessment uncertainties
  – About 5-9% (minimum)
  – Consistent self-evaluation

• Modelled vs observed yields
  – Data for Barrow only
  – Estimated = 104% of obs. AEP
  – Spread (uncertainty) = 3%

• Standards and guidelines
  – Vocabulary and definitions
  – Best practice calculations and reporting
  – IEC, IEA, Measnet, ...

• ‘Human factor’ largely unknown
Thank you for your attention!

Handouts and papers from CREYAP exercises available from DTU web site
CREYAP references


Offshore

