Abstract
This work describes and evaluates optimal strategies for bidding wind energy in a liberalised electricity market, innovatively making use of forecasts of spot prices, imbalance prices, and wind power production in an operational set-up. Five different strategies, with different levels of risk aversion to regulation costs, are implemented and compared. Subsequently, the efficiency of these strategies in decreasing imbalance costs is evaluated through the test-case of the participation of a wind power producer in the NordPool spot and real-time market during a period of 10 months. This study will support a demonstration in the frame of EU project ANEMOS.plus.

Objectives
- Determine operational strategies for trading wind power in deregulated electricity markets, with particular focus on the Scandinavian NordPool market
- Prove their validity by benchmarking with the current practice of the industry (point forecast bidding)
- Assess the market value of state-of-the-art forecasts of wind power production and market prices

Methods
Two markets are considered:
- Elspot: day-ahead spot market (bidding 12-36 hours in advance)
- regulation market (real-time)

Under these assumptions the wind power producer faces a linear terminal opportunity loss, with asymmetric penalties proportional to the deviation of its production from the spot market bid (imbalance).

It is shown that the optimal bid is a certain quantile of the distribution of wind power production. Specifically, this quantile is a dynamic function of the forecast of spot and regulation market prices. In this work market price forecasts are issued according to [1]. The final bid can then be extracted from a probabilistic forecast of wind power production, see [2].

### Results
A real-world test-case simulated the trading of power of a 115 MW wind farm in the DK-2 area during 10 months in 2008, using real data and forecast. The performance of the proposed strategies has been benchmarked against the point prediction bidding.

<table>
<thead>
<tr>
<th># Strategy</th>
<th>Lower bound</th>
<th>Upper bound</th>
<th>Interval expressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>/</td>
<td>95% quantile</td>
<td>/</td>
</tr>
<tr>
<td>2</td>
<td>point forecast - 10%</td>
<td>point forecast + 10%</td>
<td>in value [MWh]</td>
</tr>
<tr>
<td>3</td>
<td>point forecast - 20%</td>
<td>point forecast + 20%</td>
<td>in value [MWh]</td>
</tr>
<tr>
<td>4</td>
<td>point forecast - 10%</td>
<td>point forecast + 10%</td>
<td>in probability</td>
</tr>
<tr>
<td>5</td>
<td>point forecast - 20%</td>
<td>point forecast + 20%</td>
<td>in probability</td>
</tr>
</tbody>
</table>

### Conclusions
- More rational trading strategies can increase the market value of wind power, compared to the industry current practice
- Probabilistic wind power forecasts and market price forecasts can be combined efficiently in practice
- The improved market performance of wind power producers highlights the value of forecasts of wind power and market signals.

### References

Figure 1: expected loss of the producer as a function of the imbalance.

Figure 2: example of probabilistic wind power forecasts during a week in 2008. The forecasts for each day are issued at noon of the previous day, so seven daily forecasts are concatenated at the vertical dashed lines.

Figure 3: revenues added by the proposed trading strategies compared to the point forecast bidding.

- Strategy #1 results in a 35% reduction of the imbalance costs
- This value represents the current upper limit in imbalance cost reduction: higher performances are not obtainable in the same market conditions and with the current forecasting techniques
- Around 25% reduction of the imbalance costs is obtained with strategies #3 and #5
- Strategies #2 and #4 result in approximately 15% reduction of the imbalance costs
- Strategies with stricter bounds are expected to have a smaller impact on the market (the producers cause less imbalance)