Wind capacity cost curves for off-shore versus on-shore wind / negative prices and curtailment of wind power

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Wind capacity cost curves for off-shore versus on-shore wind / negative prices and curtailment of wind power

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Wind cost curves and their comparison?

AGENDA

Background – Cost curves and efficient deployment of renewable energy sources

Wind cost curves for Denmark

- Off-shore cost curve
- Off-shore cost drivers
- Onshore costs
- Comparison and gap for adding transaction and acceptance costs

Wind cost curves in comparison to other countries

- Norway
- Netherlands

Price effects and diversification from mixing onshore and off-shore wind

- Correlation of generation between wind categories?
- Negative prices - yes
- Curtailment of wind generation
Background: Cost curves

Objective: To identify the least cost renewables investment options to meet national or EU targets for renewables in power generation

Used as input for optimisation models

Total lifetime generation costs including investment and operational costs

- Levelized costs: average cost per generated unit (kWh)
- Comparison between technologies including investment cost and with different generation profiles (full load hours)

Issues with levelized cost curves

- Do not distinguish between time of generation (generation at different hours has very different value)
- Difficult to compare technologies with very different lifetime
- Cost curves are normally static - the real world is not

Based on database from European projects 2010-2013: Resolve and Res4Less

- Covering all Member States and all renewable technology country specific costs and potentials
Offshore cost in the range 10-20 €ct/kWh
Off shore basic cost drivers

- Distance from shore: Cost of Cables etc.
  - 0-20 km
  - 20-50 km
  - 50-100 km
  - 100-200 km

- Depth: Cost of Foundations etc. (waves)
  - 0-20 m
  - 20-30 m
  - 30-50 m
  - >50 m

- Wind speed: (generation potential)
  - 9-10 m/s
  - 10-11 m/s

- Seabed condition

- Distance from service and support port
Onshore cost in the range 6-10 €ct/kWh for 9000 GWh per year

DK Onshore wind costs

Onshore wind cheaper than offshore
DK wind costs and potentials

Offshore vs Onshore costs and potentials.

Onshore potential limited, not sufficient for 100% wind deployment.
Near-shore data do not suggest cheaper cost potentials than further ashore potentials.
Distance from shore and cost curves

DK off-shore potentials (distance categories)

- Onshore
- 0-20 km
- 20-50 km
- 50-100 km
- 100-200 km

€ct/kWh vs. GWh per year
Off-shore versus onshore: Barriers and acceptance issues limits onshore development

- The cost advantage of onshore is clear but onshore development in DK has been rather slow during the last 5-10 years

- Preferences against onshore wind limits the sites actually available for onshore wind development

- Additional costs have to be added to facilitate further onshore development
  - Compensation payments (individual neighbours) can be brought to court
  - Green fund - Support for municipalities
  - Local minimum ownership (20%)
  - Developer risk of delay and spending on procedures/hearings increases basic technology costs

- Is the cost gap sufficiently large to account for these additional acceptance cost?
  - Probably yes for some part of the onshore potential
  - We investigate this in the Wind2050 Danish research project
Distance from shore and public preferences

- Distance from shore: Cost of Cables etc and depht (foundation costs) traded for public acceptance
  - 0-20 km
  - 20-50 km
  - 50-100 km
  - 100-200 km

- Preferences for placing further ashore - miss-match off distance categories in present dataset for Wind2050 project
  - 10 km
  - 15 km
  - >20 km
  - above that no significant difference/effect
Wind cost curve for Norway and the benefit of developing here compared to DK

Norway onshore wind costs

€ct/kWh

GWh per year
Offshore wind costs 2020

Netherlands

Denmark

Potential gain from cooperation
Denmark have a politically agreed target for reaching a fossil fuel free energy consumption in the year 2050.

Wind energy is relatively cheap and will be a main contributor to this development. Target for 2020 is 50% of total electricity. For 2014 achieved around 40%.
Power market price effects of renewables?
Adding renewable capacity and the short term price effect

- Average wholesale power price is reduced

- Price is reduced the most when demand is high (peak load) and the least when demand is low

- The effect is the same as when adding other low variable cost generation. Base load technologies with low marginal cost would also shift the supply curve to the right.

- The relative effect for consumer price is not as great, since the network costs and all the taxes are added to the wholesale price.
Load duration curve Denmark West January-September 2013

MW

Load (demand)

hours
Subtracting the wind generation
Denmark West January-September 2013

MW

Load (demand)  Residual load

hours

-1000 -500 0 500 1000 1500 2000 2500 3000 3500

1 293 585 877 1169 1461 1753 2045 2337 2629 2921 3213 3505 3797 4089 4381 4673 4965 5257 5549 5841 6133
Electricity price and renewable generator revenues

- Renewable generators receive support
  - feed-in tariffs
  - premiums
  - green certificates
  - investment grants or tax credits

So why does prices matter for renewables?

- First
  - premiums create some market dependence
  - green certificates imply high market price dependence
  - feed-in given as fixed term (15 years) support and afterwards 100% market!

- Secondly
  - Most utilities portfolios include intermittent generation and conventional generation
  - Theirs and competitors investment in intermittent generation will influence the price patterns of power markets and their total revenues
Wind generator revenue and the value of the power generated from wind

Table 1 Wind generators market based revenues in the Western Denmark price area

<table>
<thead>
<tr>
<th>Year</th>
<th>Area Price €/MWh (direct average of hours)</th>
<th>Wind average price €/MWh</th>
<th>Difference €/MWh</th>
<th>Wind price relative to market</th>
<th>Wind generation (GWh)</th>
<th>Potential loss mill. €</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>44.19</td>
<td>40.54</td>
<td>3.64</td>
<td>92%</td>
<td>4614</td>
<td>16.8</td>
</tr>
<tr>
<td>2007</td>
<td>32.40</td>
<td>28.66</td>
<td>3.74</td>
<td>88%</td>
<td>5562</td>
<td>20.8</td>
</tr>
<tr>
<td>2008</td>
<td>56.42</td>
<td>51.20</td>
<td>5.22</td>
<td>91%</td>
<td>5190</td>
<td>27.1</td>
</tr>
</tbody>
</table>

On average the wind generation has a 10% lower value than the average market willingness to pay
Strong interconnections and additions facilitate use of pumped storage in reservoirs.

DK peak load: 6500 MW
Diversity renewable sources and location has benefits

On-shore and off-shore wind March 2013

MW

01/03/2013
02/03/2013
03/03/2013
04/03/2013
05/03/2013
06/03/2013
07/03/2013
08/03/2013
09/03/2013
10/03/2013
11/03/2013
12/03/2013
13/03/2013
14/03/2013
15/03/2013
16/03/2013
17/03/2013
18/03/2013
19/03/2013
20/03/2013
21/03/2013
22/03/2013
23/03/2013
24/03/2013
25/03/2013
26/03/2013
27/03/2013
28/03/2013
29/03/2013
30/03/2013
31/03/2013

On-shore
Off-shore
Negative prices and curtailment of wind?
Negative prices for electricity

- Does not sound logical
- The marginal value of using more electricity is negative?
- Does not fit with normal assumptions
- There are good explanations for negative prices in power markets
- Important to allow the negative price signals passed to all generators for efficient allocation of production
Price duration Denmark West

€/MWh

2009
Price duration Denmark West last 200 hours
Curtailment of generation as an option?
Price duration curve for day ahead hourly prices

- Low variable cost conventional generators
- Zero marginal cost generators: wind generation without subsidy
- Voluntary curtailment hours
- Wind generators with feed-in premium support
- Wind generators with fixed feed-in support

**Equations:**
- \( P = \text{marginal cost} \)
- \( P = -\text{feed in premium} \)
- \( P = -\text{feed in tariff} \)
Price duration curves – Texas west

Source: ERCOT (2010)
Negative prices: Explanation and solution

- Stop and start costs for conventional generators (minimum up and down times)

- Renewable generators are subsidised (feed-in tariff or production based tax credits)

- Renewable generation stay online as long as the negative price is less than the support

Solution:
- Use dynamic tariffs (tax) element of consumer price reduced when zero wholesale price
- Instruct renewables to shut down – involuntarily curtailment
- Reduce/remove the support when power prices are zero or below – voluntary curtailment

Result: Much less zero and negative prices after a bit of learning
Thank you for your attention!

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