Update on Wind Curtailment in Europe and North America

Kevin Porter, Jennifer Rogers, Ryan Wiser
Consultants to the Center for Resource Solutions

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Germany

• Distribution grid operators are allowed to curtail wind generation if no other alternative is available. Wind projects are compensated.
  ➢ In 2009, 74 GWh were curtailed out of a total of 37,809 GWh generated (much less than 1%).
  ➢ Preliminary analysis suggests increased wind curtailment in 2010.

• Transmission system operators are allowed to interfere with any kind of supply, demand or transmission if grid security is jeopardized. Wind projects are not compensated.
  ➢ Did not occur in 2009.
  ➢ Preliminary analysis suggests some limited wind curtailment occurred in 2010.
Germany

- New rule implemented in 2010: If load falls below 60% of the peak load of the previous year, while wind production is above 60% of installed wind capacity, wind curtailment is allowed.
  - No data on wind curtailment is available yet.

- As of 2011, transmission system operators may place limited bids in the spot market’s second auction, which occurs if the clearing price is below -150 EUR/MWh.
  - Four transmission system operators would divide their total RES-E by ten, and place ten random limited bids between -150 and -350 EUR/MWh.
  - Preliminary analysis suggests no wind curtailment has occurred under these circumstances as of yet.
Denmark

• Minimal (<< 1%) wind curtailment because of strong interconnections with Germany and Norway and availability of hydro resources in Nordic Countries.
  - Transmission System Operator has only actively curtailed wind twice, both on New Year’s day.

• Negative prices occur about 0.5% of the year.
  - This could theoretically be considered curtailment, although the Transmission System Operator did not order wind plants to stop generating at any of these times.
Alberta, Canada

- The Alberta ESO reported:
  - January – December 2010:
    - 3055 hours of wind curtailment
    - 155 facilities affected
  - January – April 2011:
    - 839 hours of wind curtailment
    - 100 facilities affected
  - No estimate available of amount of curtailed wind generation.
Spain

- In 2010, wind curtailment totaled 315,230 MWh (~0.7% of potential wind generation).
  - 64% were reduced due to over-generation.
  - 27% were reduced due to insufficient distribution lines.
  - 9% were reduced due to insufficient transmission lines.

- Between January 2011 – April 2011, wind curtailment totaled 23,994 MWh.
  - 17% were reduced due to over-generation.
  - 82% were reduced due to insufficient availability of distribution lines.
  - 1% were reduced due to insufficient availability of transmission lines.
Spain (con’t)

- REE (Spain’s transmission operator) expects to curtail 1.6 Terrawatt hours of renewables by 2016, or about 2.2% of available renewable energy generation.

- For 2020, REE projects that 3.6% of wind and solar generation may be curtailed.
MWh of Wind Curtailment in Spain in 2010

Limitations reasons:
• RDT: insufficient transmission lines.
• RdD: idem distribution lines
• LVRT: Low voltage Ride Through risks
• Generation excess, not enough demand.
MWh of Wind Curtailment in Spain in January: April 2011

- RdT: 268 MWh
- RdD: 19,636 MWh
- LVRT: 0 MWh
- Generation excess: 4,090 MWh
Ireland and Portugal

- Publicly available data not readily available, but...
- Ireland – curtailment appears to be below 1% to this point
- Portugal – no curtailment in 2009 and 2010 partly because only contracts signed after 2007 allow curtailment, and then only for technical reasons
  - Portugal exported wind for free to Spain in 2009-10
  - Pumped hydro and limiting imports from Spain have reduced need to curtail to this point
  - Some expectation for low levels of curtailment in 2011 based on contracts that allow for it
United States

- Curtailment varies dramatically by location / market, as do policies for when curtailment is allowed, compensation, etc.
- Comprehensive data only available for a subset of regions
- Curtailment has grown somewhat with time, though new transmission investment in Texas reducing curtailment in 2010 relative to 2009
- On average, over last 3 years, aggregate total US curtailment has been ~5% of potential total US wind generation; curtailment was much lower in earlier years
- Most curtailment has occurred in Texas as a result of transmission constraints
Estimated Capacity Factors of Wind Facilities in U.S. over Time, with and without Curtailment

<table>
<thead>
<tr>
<th>Year</th>
<th>Projects</th>
<th>MW</th>
<th>Year</th>
<th>Projects</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>6</td>
<td>549</td>
<td>2000</td>
<td>12</td>
<td>1,005</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2001</td>
<td>41</td>
<td>1,545</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2002</td>
<td>85</td>
<td>3,285</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2003</td>
<td>98</td>
<td>3,826</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2004</td>
<td>118</td>
<td>5,182</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2005</td>
<td>144</td>
<td>5,894</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2006</td>
<td>169</td>
<td>8,726</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2007</td>
<td>212</td>
<td>10,712</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2008</td>
<td>256</td>
<td>15,686</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2009</td>
<td>358</td>
<td>24,403</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2010</td>
<td>338</td>
<td>31,986</td>
</tr>
</tbody>
</table>

Capacity Factors
- Based on Estimated Generation (if no curtailment in subset of regions)
- Based on Actual Generation (with curtailment)
- 4-Year Moving Average (based on estimated generation)
Wind Curtailment in Various Areas of US, in GWh (and % of potential regional wind generation)

<table>
<thead>
<tr>
<th>Area</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Reliability Council of Texas (ERCOT)</td>
<td>109</td>
<td>1,417</td>
<td>3,872</td>
<td>2,067</td>
</tr>
<tr>
<td></td>
<td>(1.2%)</td>
<td>(8.4%)</td>
<td>(17.1%)</td>
<td>(7.7%)</td>
</tr>
<tr>
<td>Southwestern Public Service Company (SPS)</td>
<td>N/A</td>
<td>0</td>
<td>0</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0%)</td>
<td>(0.0%)</td>
<td>(0.0%)</td>
</tr>
<tr>
<td>Public Service Company of Colorado (PSCo)</td>
<td>N/A</td>
<td>2.5</td>
<td>19.0</td>
<td>81.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.1%)</td>
<td>(0.6%)</td>
<td>(2.2%)</td>
</tr>
<tr>
<td>Northern States Power Company (NSP)</td>
<td>N/A</td>
<td>25.4</td>
<td>42.4</td>
<td>42.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.8%)</td>
<td>(1.2%)</td>
<td>(1.2%)</td>
</tr>
<tr>
<td>Midwest Independent System Operator (MISO), less NSP</td>
<td>N/A</td>
<td>N/A</td>
<td>250</td>
<td>781</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2.2%)</td>
<td>(4.4%)</td>
</tr>
<tr>
<td>Bonneville Power Administration (BPA)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>4.6*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.1%)</td>
</tr>
<tr>
<td><strong>Total Across Just These 6 Areas:</strong></td>
<td>109</td>
<td>1,445</td>
<td>4,183</td>
<td>2,978</td>
</tr>
<tr>
<td></td>
<td>(1.2%)</td>
<td>(6.4%)</td>
<td>(10.4%)</td>
<td>(5.1%)</td>
</tr>
</tbody>
</table>

Across the entire U.S., curtailment has averaged ~5% from 2008-2010; curtailment was much lower in earlier years
Overall Summary

- Level of curtailment, situations in which curtailment is allowed, and compensation for curtailment all vary dramatically by location
- U.S. appears to experience more curtailment than other regions surveyed: ~5% over last three years, but much less in previous years, and driven largely by curtailment in Texas but, increasingly, in other areas
- Most other countries appear to have experienced curtailment far below this level to this point