Update on Wind Curtailment in Europe and North America

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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.

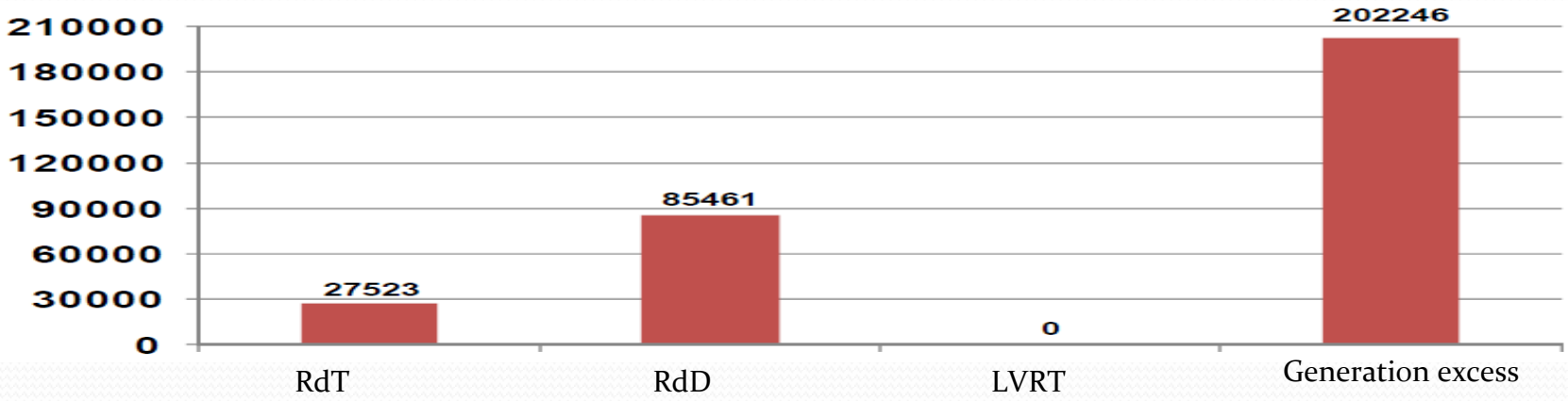
- Between January 2011 – April 2011, wind curtailment totaled 23,994 MWh.
  - 17% were reduced due to over-generation.
  - 82% were reduced due to insufficient availability of distribution lines.
  - 1% were reduced due to insufficient availability of transmission lines.

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.

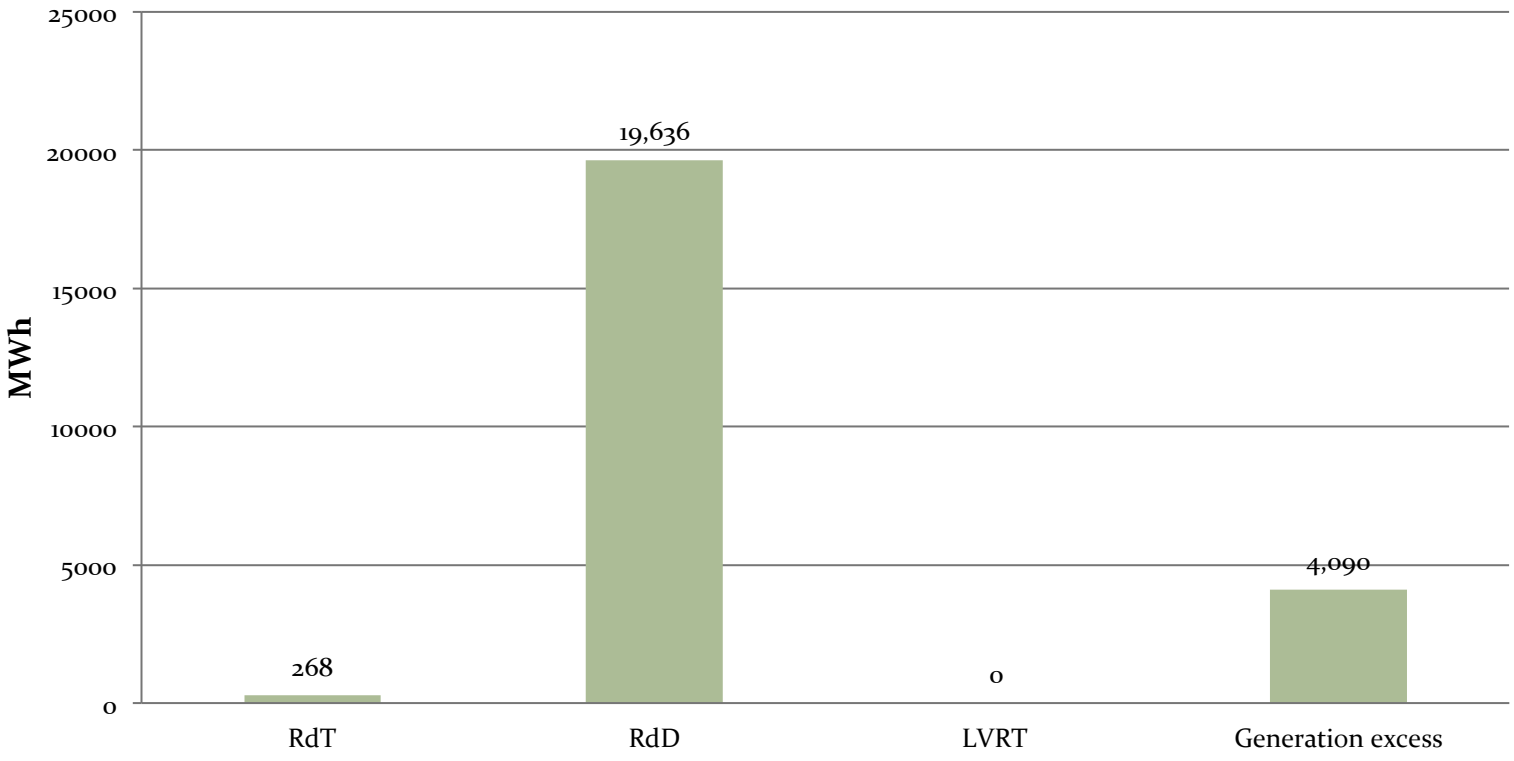
MWh of Wind Curtailment in Spain in 2010



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



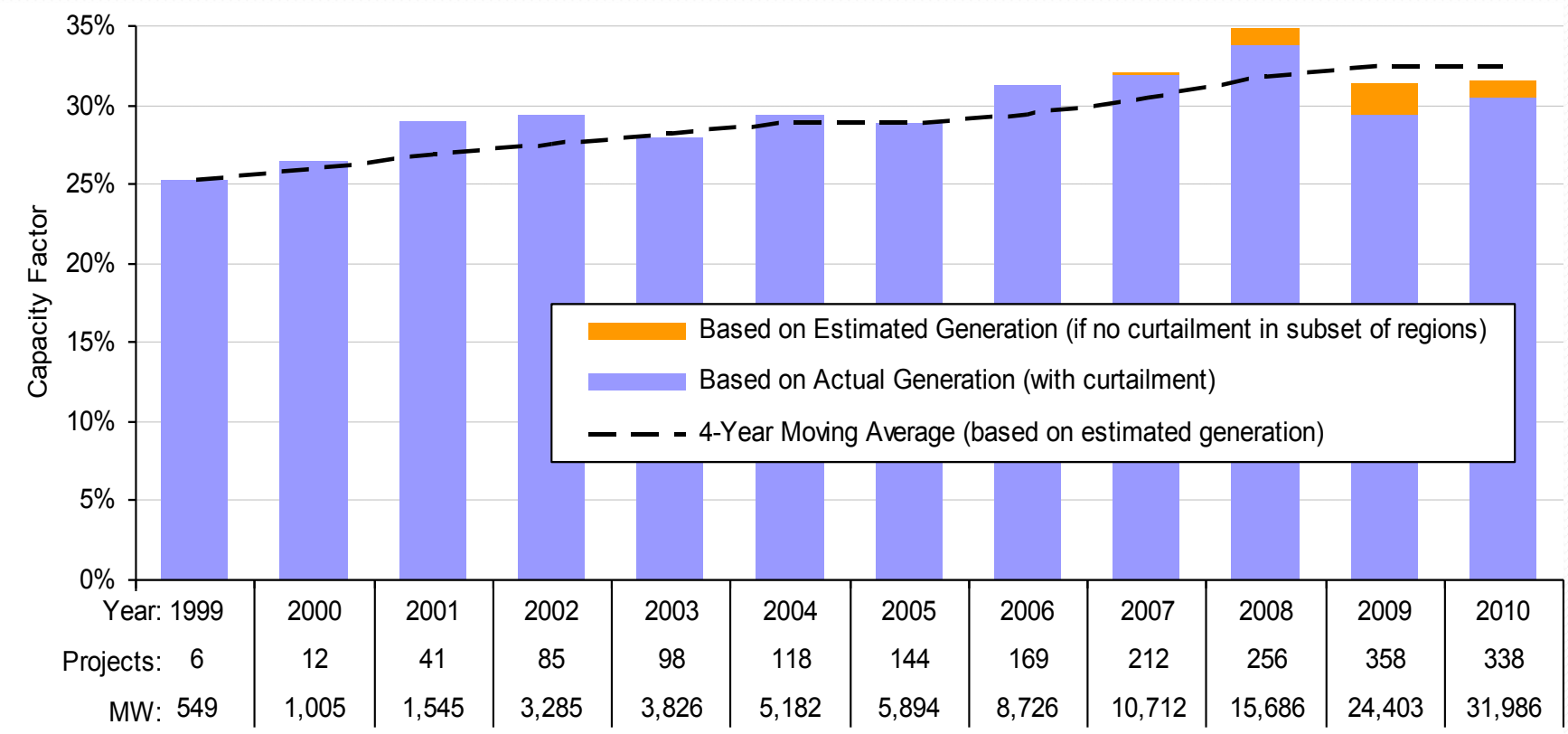
Ireland and Portugal

- 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



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

Wind Curtailment in Various Areas of US, in GWh (and % of potential regional wind generation)

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

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