Resource adequacy with increasing shares of wind and solar power: a comparison of European and U.S. electricity market designs

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KEY QUESTIONS

- How does rapidly increasing wind and PV generation impact electricity markets in the short- and long-term?
- Have wind and PV generation been the (only) drivers for wholesale electricity market price decreases in recent years?
- What are the pros and cons of the key electricity market design characteristics in Europe and the U.S. (for hosting high shares of wind and PV generation)?
- What are the possible electricity market design options for resource adequacy?
- What are the recommendations for improvements in electricity market design (general, Europe, U.S.) supporting further increasing wind and PV generation?
ELECTRICITY & NATURAL GAS PRICES IN EUROPE & U.S.

Europe (1999-2016)

U.S. (1999-2016)

Sources: EEG-EEMD (2017) and BAFA (2017)

Data Sources: Data Source: ABB Velocity Suite and U.S. EIA

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RENEWABLE SUPPORT SCHEMES IN EUROPE & U.S.

Europe (2017; 29.6% RES-E)  

U.S. (2017, 15.6% RES-E)

Source: EEG Green-X (2017)

Data Source: DSIRE (2017)

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DRIVERS FOR ELECTRICITY PRICE DECREASES IN EUROPE & U.S.

Europe

• Merit Order Effect: 5-13 €/MWh (Praktiknjo/Erdmann (2016))
• VRE mainly responsible for price decline at least since 2011/2012
• Price decline 0-1 €/MWh in relative terms for 1% VRE increase (Welisch et al (2016))

| Merit order effect estimates of wind and PV in Germany, 2006–2012 |
|---------------------------------|-----------------|
|                                 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| Sensfuß et al. (2008)          | -7.8 | -6.2 | -10.4| -13.0|      |      |      |
| Weigt (2009)                   |      |      | -10.4| -13.0|      |      |      |
| vbw (2011)                     |      |      |      | -8.0 |      |      |      |
| Sensfuß (2012)                 | -5.8 | -5.3 | -6.0 | -5.2 | -8.7 | -8.9 |      |
| Speth, Stark (2012)            |      |      |      | -5.6 | -5.6 |      |      |
| Cludius et al. (2013)          | -10.8| -7.8 | -6.0 | -7.7 | -10.1|      |      |


Source: Praktiknjo/Erdmann (2016)

U.S.

• Merit Order Effect: 0-9 $/MWh (Wiser et al (2017))
• But: 5% VRE contribution only to overall price decline between 2008-2016 (85-90% gas)

In addition, we frequently have been observing negative electricity market prices in recent years, both Europe & the U.S.
### COMPARISON: SHORT-TERM MARKET OPERATIONS

<table>
<thead>
<tr>
<th>Europe</th>
<th>U.S.</th>
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<tbody>
<tr>
<td><strong>Introduced new power exchanges (PXs)</strong></td>
<td><strong>Build into existing system operators (ISOs)</strong></td>
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<tr>
<td>- Include long-term contracts</td>
<td>- Short-term system operation</td>
</tr>
<tr>
<td>- TSOs typically own transmission system</td>
<td>- ISOs do not own transmission system</td>
</tr>
<tr>
<td>- <strong>Emphasize markets and economics</strong></td>
<td>- <strong>Emphasize physics of the power system</strong></td>
</tr>
<tr>
<td><strong>Short-term market operations</strong></td>
<td><strong>Short-term market operations</strong></td>
</tr>
<tr>
<td>- Day-ahead and intraday markets (PX)</td>
<td>- Day-ahead market (ISO - hourly)</td>
</tr>
<tr>
<td>- Real-time balancing markets (TSO)</td>
<td>- Real-time market (ISO - 5 min)</td>
</tr>
<tr>
<td>- Simple bids/generator UC</td>
<td>- Complex bids/ISO UC</td>
</tr>
<tr>
<td>- <strong>Zonal pricing/market coupling</strong></td>
<td>- <strong>Locational marginal prices</strong></td>
</tr>
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<td>- Sequential reserve and energy markets</td>
<td>- Co-optimization of energy and operating reserves</td>
</tr>
<tr>
<td>- Market-based decentralised balancing through balance responsible parties</td>
<td>- <strong>More centralized control through ISO</strong></td>
</tr>
<tr>
<td><strong>Variable renewable energy</strong></td>
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<tr>
<td>- Strong policy support</td>
<td>- Intermittent policy support</td>
</tr>
<tr>
<td>- Feed-in tariffs/premiums, tenders/auctions</td>
<td>- Tax credits, renewable portfolio standards</td>
</tr>
<tr>
<td>- VRE as „must-take“</td>
<td>- „Dispatchable“ VRE</td>
</tr>
<tr>
<td><strong>Retail competition</strong></td>
<td><strong>Retail competition</strong></td>
</tr>
<tr>
<td>- Retail choice in all countries</td>
<td>- Retail choice in some states</td>
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</table>
THE REVENUE SUFFICIENCY CHALLENGE WITH INCREASING VRE

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RESOURCE ADEQUACY PARADIGMS

Several ways to close the gap between Average Cost (AC) and Marginal Cost (MC):

- **Energy-only market**
  - Prices in energy (and reserves) markets provide investment incentives
  - Importance of scarcity rents (higher offer prices in energy market)
  - Exploitation of several existing flexibilities in the electricity system

- **Capacity mechanisms**

![Diagram of capacity mechanisms]

Applied Energy Symposium
MIT A+B (AEAB2019)
CAPACITY MECHANISMS: CURRENT STATUS IN EUROPE & U.S.


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CAPACITY SUBSCRIPTION

The idea (Doorman 2005)
- Consumers buy the capacity they need under system scarcity
- Generators (and storage) receive capacity payments accordingly
- System operator limits consumer demand during scarcity
- A practical implementation of “priority service” (Chao and Wilson 1987)

Several advantages (Doorman and De Vries 2017)
- Consumers pay directly for the scarce resource: generation capacity
- Capacity adequacy moves in the direction of a private good (economically efficient rationing)
- Capacity price and quantity reflecting consumer preferences
- Reduced risk for consumers and producers

Challenges
- Cost of controlling loads at consumer level (load limiting devices)
GENERAL RECOMMENDATIONS FOR IMPROVED MARKET DESIGN

- Gradually remove technology specific subsidy schemes for VRE generation
- Adequate pricing of carbon and other environmental externalities in a more market-compatible manner
- Improve price formation in energy and reserve markets, particularly during scarcity conditions
- Move day-ahead markets closer to the operating day
- Improve incentives for provision of system flexibility
- Remove barriers for supply, demand and energy storage technologies to enable competition in several market segments
- Enable participation of distributed generation and demand response
- Reduce reliance on explicit capacity mechanisms to incentivize investments (if still needed, use more market-based designs like capacity subscriptions)
SPECIFIC RECOMMENDATIONS FOR IMPROVED MARKET DESIGN

Europe

- Improved representation of transmission in market clearing to better reflect congestion in prices
- Imbalance netting to avoid opposite activation of frequency reserves in neighboring zones
- Shortening timeframes in intraday market
- Higher time resolution of real-time dispatch and market clearing
- Co-optimization of energy and reserves instead of sequential/separate markets
- Economic dispatch of VRE
- Better coordination between TSOs to reduce dispatch needs
- Further develop retail competition, notably in terms of more flexible and variable pricing/tariff products

U.S.

- Increased liquidity and transparency in long-term contracts
- Implementation of intraday markets for market-based balancing
- Higher time resolution of settlements in real-time energy and reserve markets
- Further refinements of products in ancillary service markets
- Full co-optimization of energy and reserves in all regional U.S. markets
- Better coordination between regional capacity, energy, and reserve markets
- Open up for retail competition in larger parts of the country, along with innovations in flexible pricing/tariff design
CONCLUDING REMARKS

• The impact of variable renewable generation on electricity markets is more visible in European compared to U.S. electricity markets.

• U.S. electricity markets better aligned with physics of the transmission grid: more centralized coordination and control.

• European electricity markets more focused on market clearing via power exchanges (including also long-term contracts).

• One of the key questions: how much of the “optimization problem” should be solved by system operators vs. market participants?

• Getting the price formation in short-term energy/reserve markets is the key challenge.

• Capacity mechanisms should be a back-up only (and if needed, preference for a more market-based approach like capacity subscriptions).

• No single solution: lessons to be learned in both directions!
Acknowledgements / References

Collaborators

Audun Botterud Massachusetts Institute of Technology
Todd Levin Argonne National Laboratory
Andrew Mills Lawrence Berkeley National Laboratory
Ryan Wiser Lawrence Berkeley National Laboratory
Conleigh Byers Massachusetts Institute of Technology

References


