Design of European Balancing Power Markets
An empirical study of 24 European countries

Fabian Ocker, Sebastian Braun and Christian Will
S01 - Electricity market design, regulation and monitoring: EU Energy Market

Source: NASA
Agenda

1. Research Question and Applied Method
2. Market Design Interactions
3. Inconsistency in Auction Characteristics
4. Conclusion
Main Research Question: *How are European balancing power markets designed?*

- empirical study of 24 European countries
- members of the ENTSO-E
- using procurement auctions

**Fig. 13**: Dynamic hierarchy of Load-Frequency Control processes (under assumption that FCR is fully replaced by FRR)

<table>
<thead>
<tr>
<th>Time to Restore Frequency</th>
<th>Reserve Replacement Process</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
</tr>
<tr>
<td>Frequency Occurrence</td>
<td>manual FRR</td>
</tr>
<tr>
<td></td>
<td>FRR</td>
</tr>
<tr>
<td>Joint Action</td>
<td>FCR</td>
</tr>
</tbody>
</table>

Source: ENTSO-E 2013

---

**Research Question and Applied Method**

extensive overview and qualitative assessment of market design interactions
### Research Question and Applied Method

<table>
<thead>
<tr>
<th>Power market characteristics</th>
<th>Balancing power market characteristics</th>
<th>Auction characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>vRES share (2014)$^1$</td>
<td>FCR (automatic)</td>
<td>FRR (automatic)</td>
</tr>
<tr>
<td>Austria</td>
<td>7.3%</td>
<td>30min</td>
</tr>
<tr>
<td>Belgium</td>
<td>9.2%</td>
<td>5min</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>4.4%</td>
<td>Day-ahead</td>
</tr>
<tr>
<td>Denmark (DK1/DK2)</td>
<td>44.7%</td>
<td>60min</td>
</tr>
<tr>
<td>Estonia</td>
<td>8.7%</td>
<td>60min</td>
</tr>
</tbody>
</table>

FCR = Frequency Containment Reserve  
FRR = Frequency Restoration Reserve  
RR = Replacement Reserve

**Additional Research Question:** How can the heterogeneity be explained?
countries with high shares of power consumption served from volatile renewable energy sources (vRES) tend to have more flexible auction procedures.

Example: France and Denmark

- France: 6% vRES-share, 24 time slices per day, daily auction frequency, n/a min. bid [MW]
- Denmark: 45% vRES-share, 6 time slices per day, monthly auction frequency, 10 min. bid [MW]

<table>
<thead>
<tr>
<th>vRES-share</th>
<th>Time Slices/Day</th>
<th>Auction Frequency</th>
<th>Min. Bid [MW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>24</td>
<td>Daily</td>
<td>n/a</td>
</tr>
<tr>
<td>Denmark</td>
<td>24</td>
<td>Monthly</td>
<td>10</td>
</tr>
</tbody>
</table>

vRES-share: 45% / 0% not considered

- Frequency Containment Reserve
- Frequency Restoration Reserve
- Restoration Reserve
Market Design Interactions: Short Term Trading Flexibility

- Short-term trading flexibility: reduced necessity for balancing power

- Short-term intraday markets were introduced in all considered countries, except the Czech Republic, Iceland and Serbia

- Applied trading mechanisms:
  - Intraday continuous
  - Intraday auction (Spain, Portugal, Italy)

Example Germany

- Two complementary intraday markets
  - Continuous since 2011: especially wind forecast corrections until 30 mins before delivery
  - Auction since 2014: precise trading day-ahead especially for solar power supply

- New trading flexibility options reduced procured capacity by 15% between 2008 and 2015

Source: Hirth and Ziegenhagen, 2015
Market Design Interactions: Market Coupling

- Larger balancing regions provide more opportunities for positive/negative load compensations ("pooling effect"):
  - supply security ↑
  - balancing cost ↓

Examples

- TSO-cooperation in Germany introduced 2009/2010
- IGCC in central Europe: cooperation for FRR-activation
- Joint FCR-market
  - successful in reducing costs
Inconsistency in Auction Characteristics

- auction characteristics, i.e. scoring and pricing rules, vary greatly – why is that?

**Theory**

- design of balancing power auctions is highly complex
  - multi-part auction: power bid (PB) & energy bid (EB), scoring rule, pricing rules, regular repetition, same suppliers, activation strategy
  - Chao & Wilson (2002) theorize a design with desirable properties → strong assumption: incentive-compatible bidding (ensuring efficiency)

**Application**

- scoring rules:
  - **lowest PBs**: selection of suppliers with lowest opportunity costs
  - **lowest total prices**: one-dimensional total price [EUR/MWh]
  - **stochastic programming**: minimizing expected costs

- pricing rules:
  - **Pay-as-Bid Pricing (PaB)**: submitted bids equal compensations
  - **Uniform Pricing (UP)**: all suppliers receive an uniform price

- main challenges: overall efficiency & robustness against repetition
Conclusion and Outlook

**How are European balancing power markets designed?**

- extensive overview of 24 European countries
- no predominant market design across Europe

**How can the heterogeneity be explained?**

- certain power market characteristics influence balancing power design elements and demand

share of vRES  
short-term trading flexibility  
market coupling  
flexible auction procedures  
reduced demand for balancing power

- inconsistency in auction characteristics is due to high complexity

Further research on European balancing power markets required
Thank you for your attention!