Influence of balancing reserves on the electricity infrastructure in Europe until 2050

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Agenda

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2. Model
3. Application
4. Results
Introduction

• EU wide target of up to 80-95% CO₂ emission reduction until 2050 that requires far-reaching transformation of the electricity generation infrastructure

• Possible pathways for the generation infrastructure have been subject of many analyses (PRIMES, LIMES, DIMENSION, etc.)

• Very few studies on the implications of balancing reserves
  – Pineda et al., 2016; Stiphout et al., 2014
  – Predict a need for a large conventional base load

• Very high shares of fluctuating RES will induce an increased demand for balancing reserves in the long term

• These reserves must be provided by either (non-)dispatchable generation technologies or storages that therefore have to reduce their possible production

• These interdependencies must be included when deciding upon the optimal level of fluctuating RES expansion

• Question: What are the influences of balancing reserves on the optimal electricity infrastructure investments?
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Model: Dynelmod

Scope: Europe (EU 28)

Objective: System cost minimization
  - Variable and fixed generation
  - Investment into generation, storage and grid

Investments: ten-year steps
  - 2015, 2020, 2030, 2040, 2050

Plant dispatch: hourly resolution
  - Variable set of calculated hours (1-8760) for full investment options (including scaling)
  - Post-Calculation with reduced investment options for 8760 hours

Boundary condition examples
  - Decommissioning of existing plants
  - Electricity demand development per country
  - CO₂-Budget over time
  - Market coupling method: NTC or Flow-Based
Model: Dynelmod

Balancing Demand:
- Historical demand for all countries as basis
- Additional demand for each additional MW of fluctuating RES

Balancing Reservation:
- Technology sharp reservation of capacities (no difference to block sharp if no integer constraints)
- Reduced production flexibility during reservation
  - Maximum production output
  - Minimum run constraints
  - Minimum storage level
- Reduction of transmission capacity for exchanges

Solution Method:
- Formulated in GAMS as a linear program
- Solved with GUROBI/BARRIER
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Application to a European Data Set:
- Originally plant-block and line-sharp data accuracy for all EU-28 countries, as well as Norway, Switzerland and the Balkan countries
- Hourly RES feed-in and load for 2012
- Investment cost based on Schröder et al. (2013), Pape et al. (2014) and Zerrahn and Schill (2015)

Aggregation to a country resolution
- One node per country
- Distances between geographical centers are used for transmission expansion cost calculation

Other boundary conditions regarding the long-term development of prices, load, and CO₂ emission path are based on EC’s “Energy Roadmap 2050 Impact Assessment and Scenario Analysis” scenario “Diversified supply technologies”
Application 2

- Technical and market developments are uncertain which influences the system costs of balancing provision
- Three scenarios summarize these possible developments:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Pessimistic</th>
<th>Conservative</th>
<th>Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reserve dimensioning</td>
<td>static/dynamic</td>
<td>static/dynamic</td>
<td>static/dynamic</td>
</tr>
<tr>
<td>Additional demand from RES</td>
<td>10%</td>
<td>6%</td>
<td>3%</td>
</tr>
<tr>
<td>RES participation</td>
<td>5%</td>
<td>20%</td>
<td>50%</td>
</tr>
<tr>
<td>Balancing exchanges</td>
<td>5%</td>
<td>20%</td>
<td>50%</td>
</tr>
<tr>
<td>Storage commitment</td>
<td>24h</td>
<td>4h</td>
<td>1h</td>
</tr>
<tr>
<td>New exogenous nuclear plants</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

- Each factor/assumption has a different impact
- The influence of each factor is therefore assessed against the *Pessimistic Scenario* in a further sensitivity analysis (not presented)
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Results: Installed capacity

- Installed capacity in GW
- Years: 2015, 2020, 2030, 2040, 2050
- Sources: NoBal, Pessimistic S, Pessimistic D, Conservative S, Conservative D
- Technologies: Geothermal, Storage, PSP, Reservoir, Sun, Wind, RoR, Biomass, Waste, Oil, Gas, Hard Coal, Lignite, Uran
Results: Difference in New Installed Capacity

Difference in New Installed Capacity [GW]

-400 -300 -200 -100 0 100 200 300

Pessimistic S  Pessimistic D  Conservative S  Conservative D

2050

Geothermal
Storage
PSP
Reservoir
Sun
Wind
RoR
Biomass
Waste
Oil
Gas
Hard Coal
Lignite
Uran
Results: Balancing Cost

![Bar chart showing Balancing Cost in Billion € for different scenarios: Pessimistic S, Pessimistic D, Conservative S, and Conservative D. The chart indicates the cost breakdown by categories: Investment Storage, Investment Generation, Investment Grid, Generation, and Fix O&M.](chart.png)
Result: Positive Reserves
Result: Negative Reserves
Conclusion & Outlook

- Balancing reserves only have a large impact on the optimal long term electricity infrastructure when pessimistic assumptions regarding technology and market development are made.

- The effect is already reduced with conservative assumptions regarding the provision of balancing reserves (underestimation due to aggregate model type).

- (Battery) Storage is playing a major role for future positive balancing reserves.

- Dynamic reserve sizing can lower the cost and the influence of balancing reserves dramatically.

- Determination of additional balancing demand from renewables is still too complicated in a long term model due to non-lineairities and therefore sensitives are a better option.

- Reserve provision from transport and heat sector is still unclear.
Questions for you!

• How realistic is an 80 % share of storages for the provision of positive reserves?
• What is a realistic time horizon for storage capacity withholding for the provision of reserves?
• Is it realistic that those storages can recharge in that time period if the market is very short during long term shortage?

• Would the provision by reducing fluctuating RES be cheaper?
  • Li-Ion: 35 € per kW and 188€ per kWh in 2050
  • PV: 230 € per kW and FLH 1752
  • For 1 kW of (positive) reserves we need four times storage capacity and five times PV capacity
  • Result: 787 € / kW for Li-Ion vs 1150 € / kW for PV
  • This neglects:
    – Positive side effects of storages
    – Non-spinning OCGT can not provide FCR and aFRR
    – No cost for reserve provision during curtailment of RES


Thank You for Your Attention!

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