Value of Additional Norwegian Hydropower to the European Electricity System

- Introduction
- Methodology & Scenario
- Results

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Introduction of the Institute

Institute of Power Systems and Power Economics (IAEW) – Fields of Research

Simulation and optimization of energy systems – focusing on electrical energy
Analysis and evaluation of current and future concepts of energy supply
Integration of renewables in markets and grids

Research Focus

Power Generation & Energy Markets
- European market simulation (scheduled, reserve, capacity)
- Storage technologies, VPP and demand side management
- Power-to-gas

Network Planning & Network Operation
- Network development and simulation of network operation
- Overlay grid
- Smart grids

System Stability & Security of Supply
- Network security and reliability of supply
- Voltage and frequency stability
- Regulation
Advantages of operating Norwegian storages in different markets

Central question:

“What are the advantages from having access to Norwegian hydropower flexibility? What business models can incorporate these?”

Regarding balancing, system costs as well as supply side (utilities) can benefit from the access to flexible generation

- Benefit from cross boarder trading of flexible storages
- Cost reduction from cross boarder provision and activation of balancing power

→ Cross-border balancing markets

- Marketing opportunities of Norwegian hydropower for utilities on (balancing) markets in Europe

→ Long term contracts enable access to hydropower plants
# Main Differences between Scenario B and C

- Scenario for 2050 mainly based upon the EU Trends study and the ENTSO-E TYNDP with increased RES feed-in and reduced nuclear power capacity

<table>
<thead>
<tr>
<th></th>
<th>Scenario B „Big Hydro“</th>
<th>Scenario C „Niche Storage“</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>• Reduced fossil/nuclear capacity by 10%</td>
<td>• Increased hydro capacity by 10%</td>
</tr>
<tr>
<td>generation</td>
<td>• 60 GW of hydro power in Norway</td>
<td>• 50 GW of hydro power in Norway</td>
</tr>
<tr>
<td></td>
<td>• Secured peak load in Europe</td>
<td>• Secured peak load for each country</td>
</tr>
<tr>
<td>Alternative</td>
<td>• Little DSM and inflexible CHP</td>
<td>• Increased DSM and flexible CHP</td>
</tr>
<tr>
<td>flexibilities</td>
<td>• No PtG storages</td>
<td>• 20 GW of PtG storages in Europe</td>
</tr>
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<td></td>
<td>• Passive operation of distributed storages</td>
<td>• Market-orientated operation of distributed storages</td>
</tr>
<tr>
<td>Transmission</td>
<td>• Up to 30 GW cable capacity from and to Norway necessary for export</td>
<td>• Up to 20 GW cable capacity from and to Norway necessary for export</td>
</tr>
<tr>
<td>capacities</td>
<td>• Increased transmission capacities by 50%</td>
<td></td>
</tr>
<tr>
<td>Integration of</td>
<td>• Cross-border reserve markets</td>
<td>• National reserve markets</td>
</tr>
<tr>
<td>Markets</td>
<td>→ Optimal allocation of resources</td>
<td></td>
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</tbody>
</table>
Strong increase in RES generation in comparison to 2013 data
Increase in thermal generation in Scenario C, especially nuclear and lignite
Lower prices in Scenario C
  - More generation from hydro and nuclear power in Scenario C leading to lower price level in all countries
  - Scandinavian price level lower due to less transfer capacities to mainland market areas

Alignment of prices in Scenario B
Benefit of Norwegian Hydro Power to the Generation System

To what extend can increased generation and storage capacity in Norway reduce system wide generation costs?

Comparison of Scenario B and C with Scenario without additional hydro power

High increase of transfer capacity necessary to integrate hydro power into the system

Difference of system costs is benefit of additional hydro power that is to be compared to investment costs for storages and cable connections

<table>
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<tr>
<th>No Additional Hydro</th>
<th>B (Big Hydro)</th>
<th>C (Niche Storage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 30 GW NO hydro generation capacity</td>
<td>• 60 GW NO hydro generation capacity</td>
<td>• 50 GW NO hydro generation capacity</td>
</tr>
<tr>
<td>• 7 GW cable capacity from and to Norway</td>
<td>• Up to 30 GW cable capacity from and to Norway</td>
<td>• Up to 20 GW cable capacity from and to Norway</td>
</tr>
</tbody>
</table>
Cost Reduction from Additional Hydro Power

- Annual cost reduction between 130 and 148 €/kWa (per Turbine Capacity)
- When considering reduction over lifetime of cable and storage (i.e. 40 years at 5%) total benefit between 2.300 and 2.500 €/kW
- Comparison to investment costs of about 500 €/kW for storage expansion and 1.000 €/kW for necessary cable yields high economic benefit

Variable System Costs

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Without Expansion</th>
<th>With Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>0</td>
<td>130</td>
</tr>
<tr>
<td>C</td>
<td>148</td>
<td>0</td>
</tr>
</tbody>
</table>

Results – Benefit from Access to Norwegian Hydro
Reserve Exchange Variations

- **No Reserve Exchange**
  - Transfer capacity reserved for import and export of energy

- **Optimal**
  - Utilization of NTC both for energy and reserve provision
  - Cost based optimization of NTC reserve share for each hour

- Difference of system costs is benefit of integrated European balancing markets

<table>
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<tr>
<th>Scenario B &amp; C</th>
<th>No Reserve Exchange</th>
<th>Optimal Allocation</th>
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<td></td>
<td>No cross-border balancing</td>
<td>Optimization of NTC utilization for scheduled energy and balancing</td>
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Legend: scheduled energy, reserve
Optimal allocation of transfer capacities leads to slightly reduced variable system costs.

Cost reduction in Scenario C lower due to higher hydro capacity (except NO).

Cost reduction only marginal (between 0.08% and 0.43% of total costs) since reserve provision is no subject to scarcity.
Thank you for your attention!

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