Value of Additional Norwegian Hydropower to the European Electricity System

- Introduction
- Methodology & Scenario
- Results

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

Simulation and optimization of energy systems – focusing on electrical energy

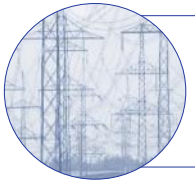
Analysis and evaluation of current and future concepts of energy supply

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

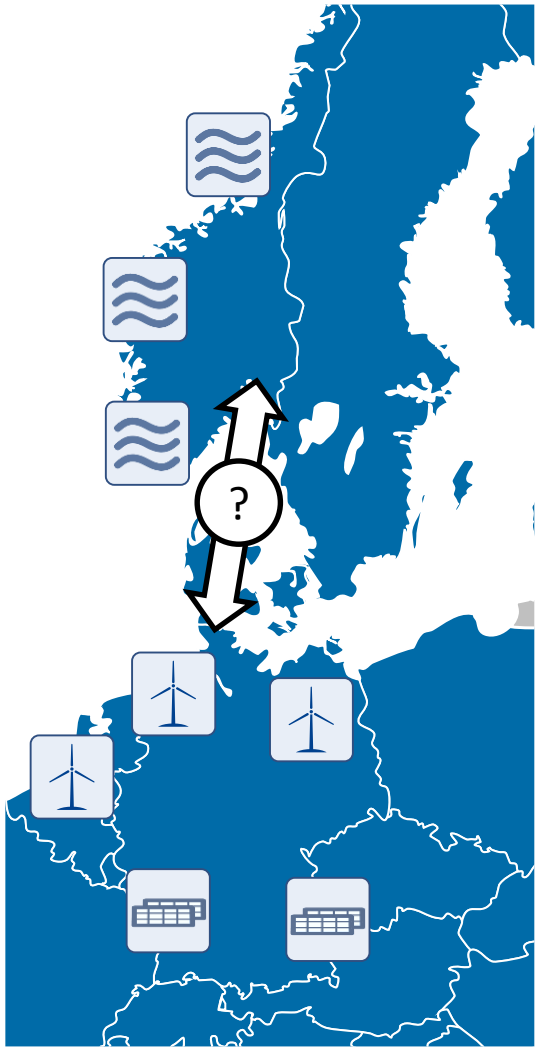
- Network security and reliability of supply
- Voltage and frequency stability
- Regulation

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

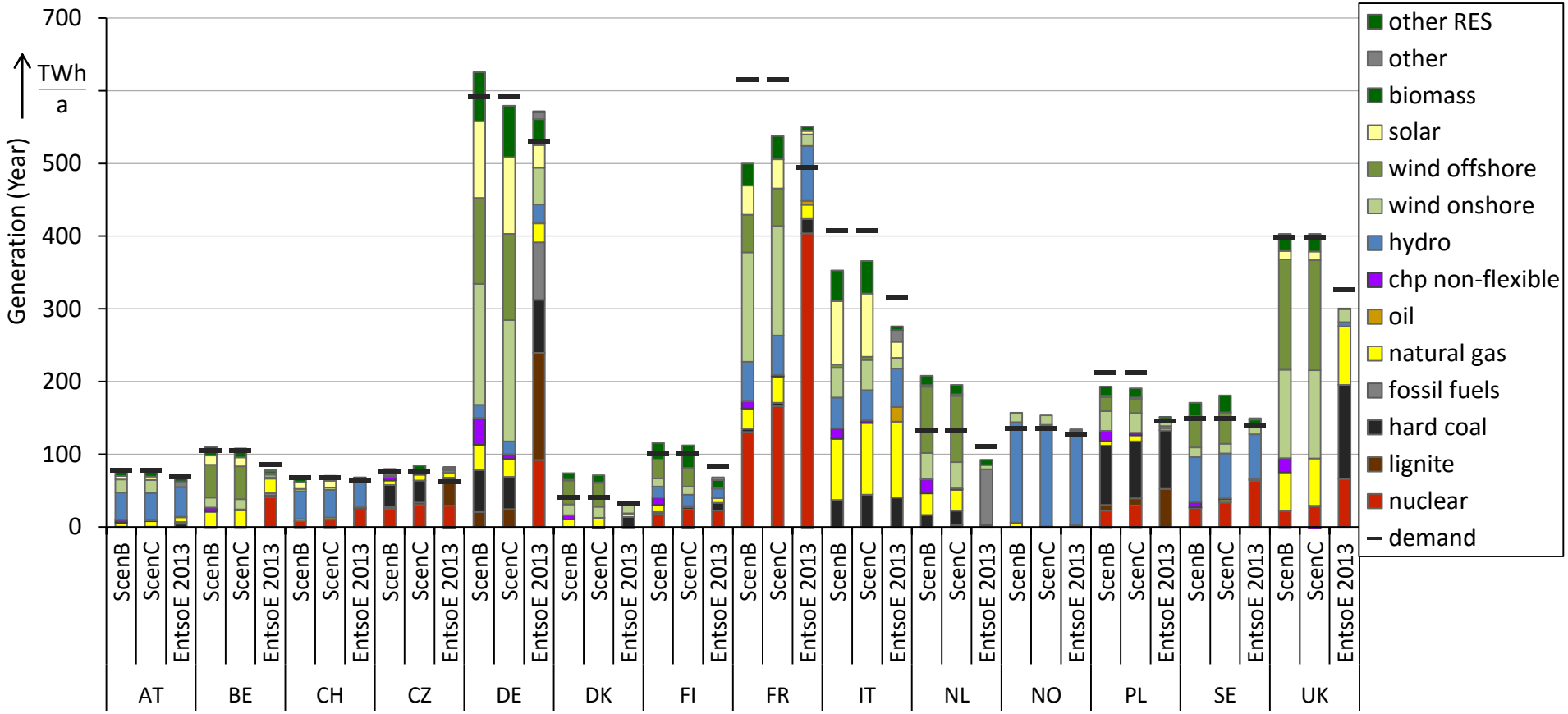


Main Differences between Scenario B and C

- 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

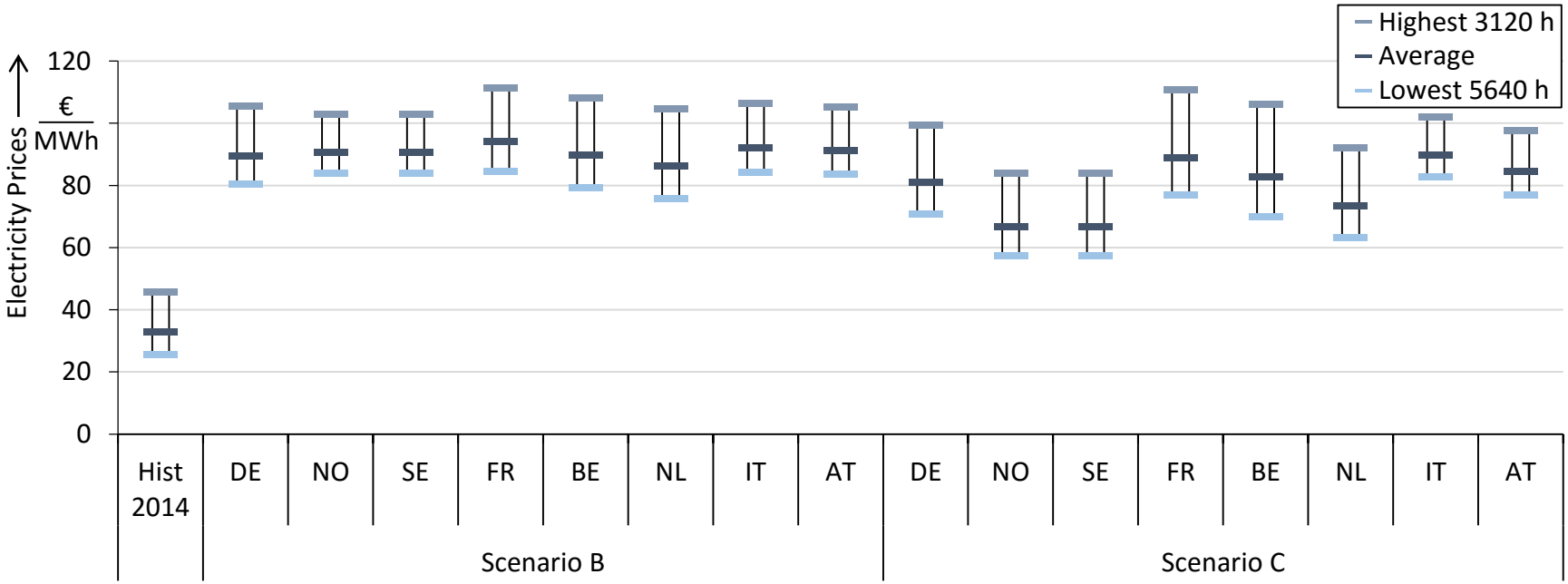
	Scenario B „Big Hydro“	Scenario C „Niche Storage“
Conventional generation	• Reduced fossil/nuclear capacity by 10% • 60 GW of hydro power in Norway • Secured peak load in Europe	• Increased hydro capacity by 10% • 50 GW of hydro power in Norway • Secured peak load for each country
Alternative flexibilities	• Little DSM and inflexible CHP • No PtG storages • Passive operation of distributed storages	• Increased DSM and flexible CHP • 20 GW of PtG storages in Europe • Market-orientated operation of distributed storages
Transmission capacities	• Up to 30 GW cable capacity from and to Norway necessary for export • Increased transmission capacities by 50%	• Up to 20 GW cable capacity from and to Norway necessary for export
Integration of Markets	• Cross-border reserve markets → Optimal allocation of resources	• National reserve markets

Power Generation



- Strong increase in RES generation in comparison to 2013 data
- Increase in thermal generation in Scenario C, especially nuclear and lignite

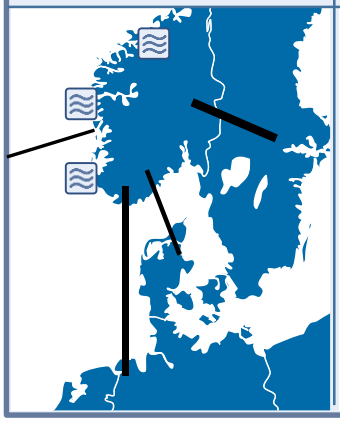
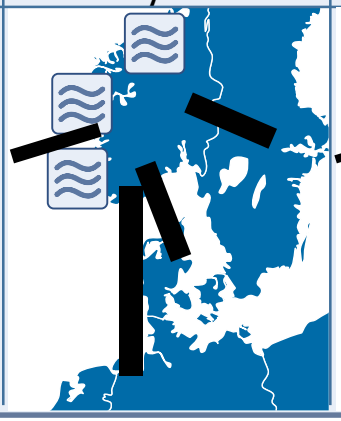
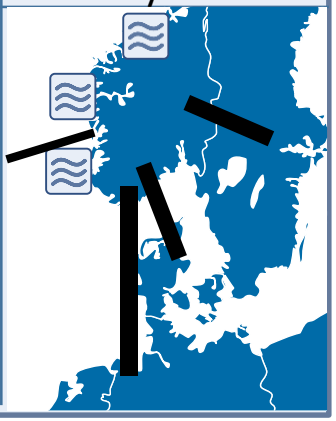
Electricity Prices



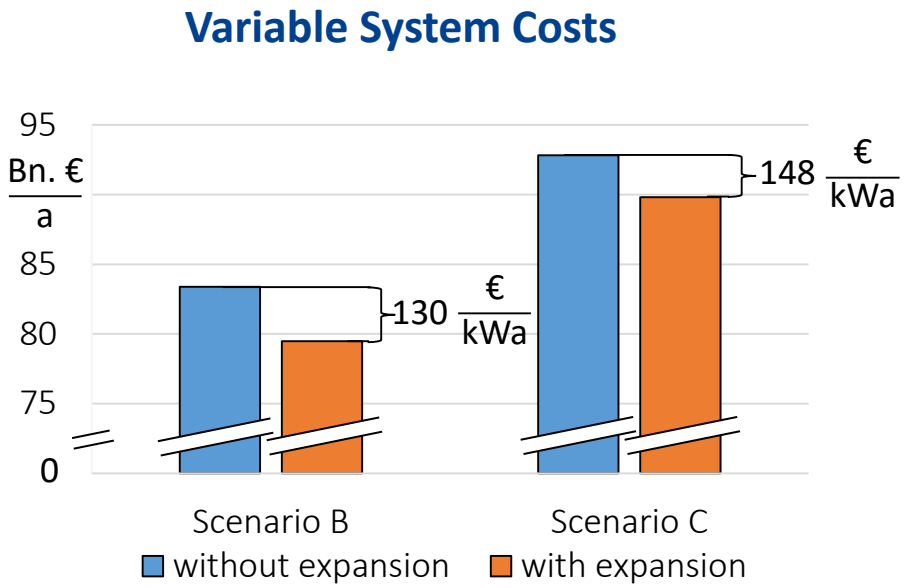
- Lower prices in Scenario C
  - More generation from hydro and nuclear power in Scenario C leading to lower price level in all countries
  - Scandinavian price level lower due to less transfer capacities to mainland market areas
- Alignment of prices in Scenario B

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

No Additional Hydro	B (Big Hydro)	C (Niche Storage)
•30 GW NO hydro generation capacity •7 GW cable capacity from and to Norway	•60 GW NO hydro generation capacity •Up to 30 GW cable capacity from and to Norway	•50 GW NO hydro generation capacity •Up to 20 GW cable capacity from and to Norway
		

Cost Reduction from Additional Hydro Power

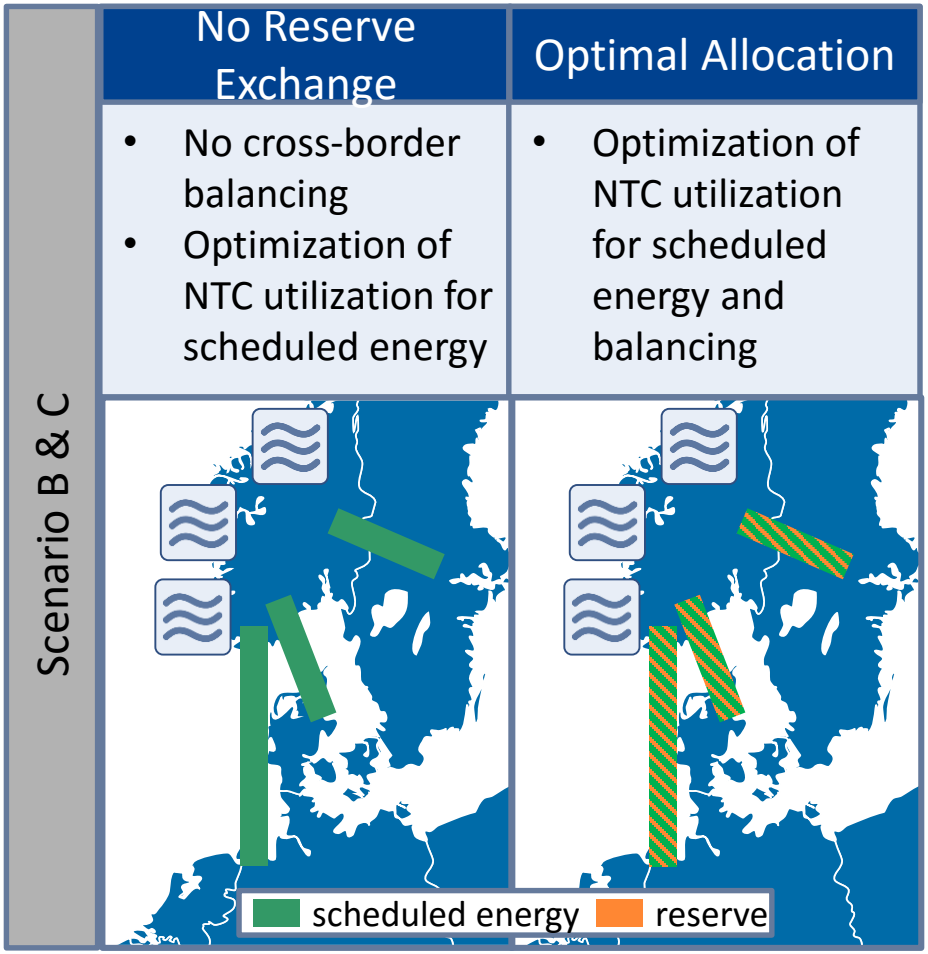


- Annual cost reduction between 130 and 148 €/kWa (per Turbine Capacity)
- When considering reduction over lifetime of cable and storage (i.e. 40 years at 5%) total benefit between 2.300 and 2.500 €/kW
- ➔ Comparison to investment costs of about 500 €/kW for storage expansion and 1.000 €/kW for necessary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

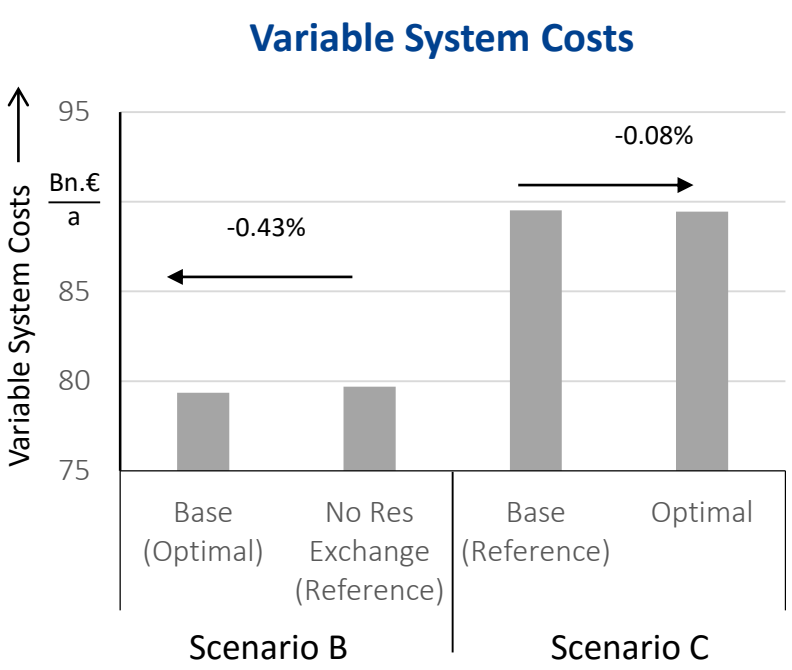
Reserve Exchange Variations

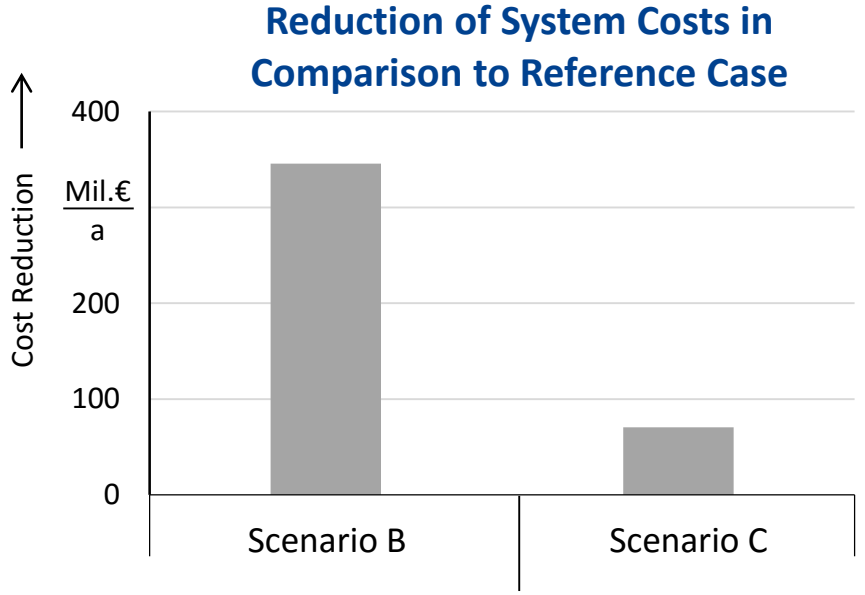
- No Reserve Exchange
  - Transfer capacity reserved for import and export of energy
- Optimal
  - Utilization of NTC both for energy and reserve provision
  - Cost based optimization of NTC reserve share for each hour

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



Cost Reduction from Cross-Border Reserve Provision





- 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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