Institut für Elektrische Anlagen
und Energiewirtschaft
Univ.-Prof. Dr.-Ing. Albert Moser

RWTH AACHEN UNIVERSITY

IAEW
Institute of Power Systems and Power Economics

Schinkelstraße 6
52056 Aachen

Phone +49 241 80-97653
Telefax +49 241 80-92197
E-Mail post@iaew.rwth-aachen.de

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

Simulation and optimization of energy systems – focusing on electrical energy

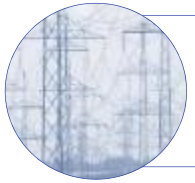
Analysis and evaluation of current and future concepts of energy supply

Integration of renewables in markets and grids

Research Focus

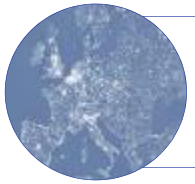
Power Generation & Energy Markets

- 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

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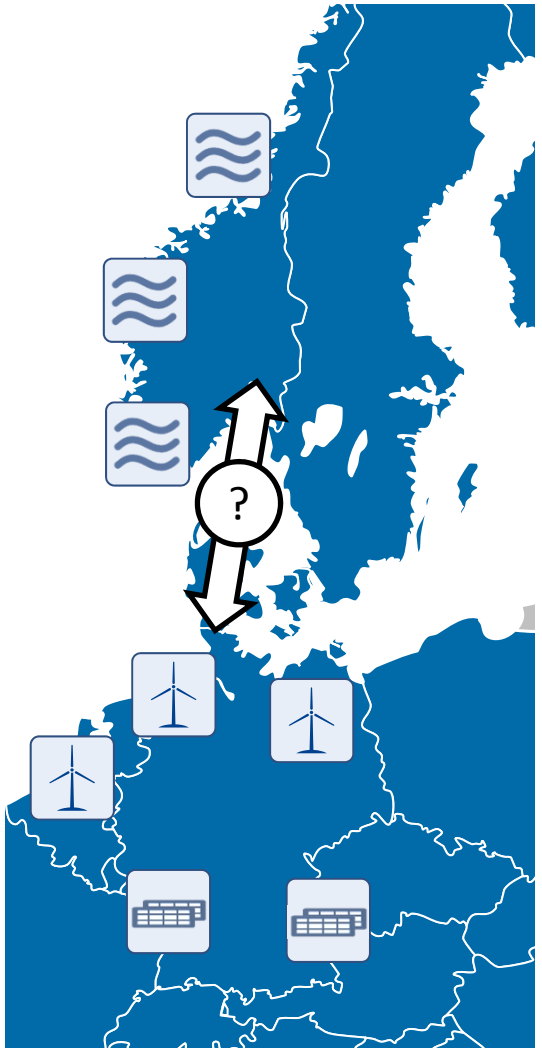
Possible business models for operating storages in different markets

- Central question:

"What are the advantages from having access to Norwegian hydropower flexibility and what business models can incorporate these?"

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



Overview of the Work Packages

Aim

- Quantification of benefits from
  - Cross-border purchasing and activation of balancing power
  - Participation of Norwegian storage on German market for different generation portfolios

Work Package 1 – Macroeconomic Investigations

- Simulation of system with and without optimization of cross-border reserve provision

➔ System benefit of cross-border balancing markets

- Simulation of spot prices for different weather years
- Simulation of German ¼-hourly prices and prices for reserve power and energy

Work Package 2 – Microeconomic Investigations

- Optimization of portfolio dispatch and trading based on simulated market prices

➔ Contribution margin of storage and portfolio effect in different generation portfolios

➔ Impact of forecast errors on benefit from additional storage

Investigation Approach

European Market Simulation

- Simulation of European system with coverage of load and reserve constraints
- Determination of cross border flows between market areas
- Simulation of different weather years

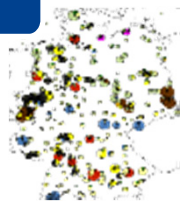
Results

- Cross-border exchanges
- Participation of Norwegian storages on German market

Detailed Simulation German System

- Detailed data on reserve markets
- Add. technical constraints for generation units

- Consideration of load coverage, provision of reserve power and reserve energy in different products
- Identification of price indicators



Results

- Market prices for energy, reserve power and reserve energy

WP3.2 Portfolio Dispatch & Trading

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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

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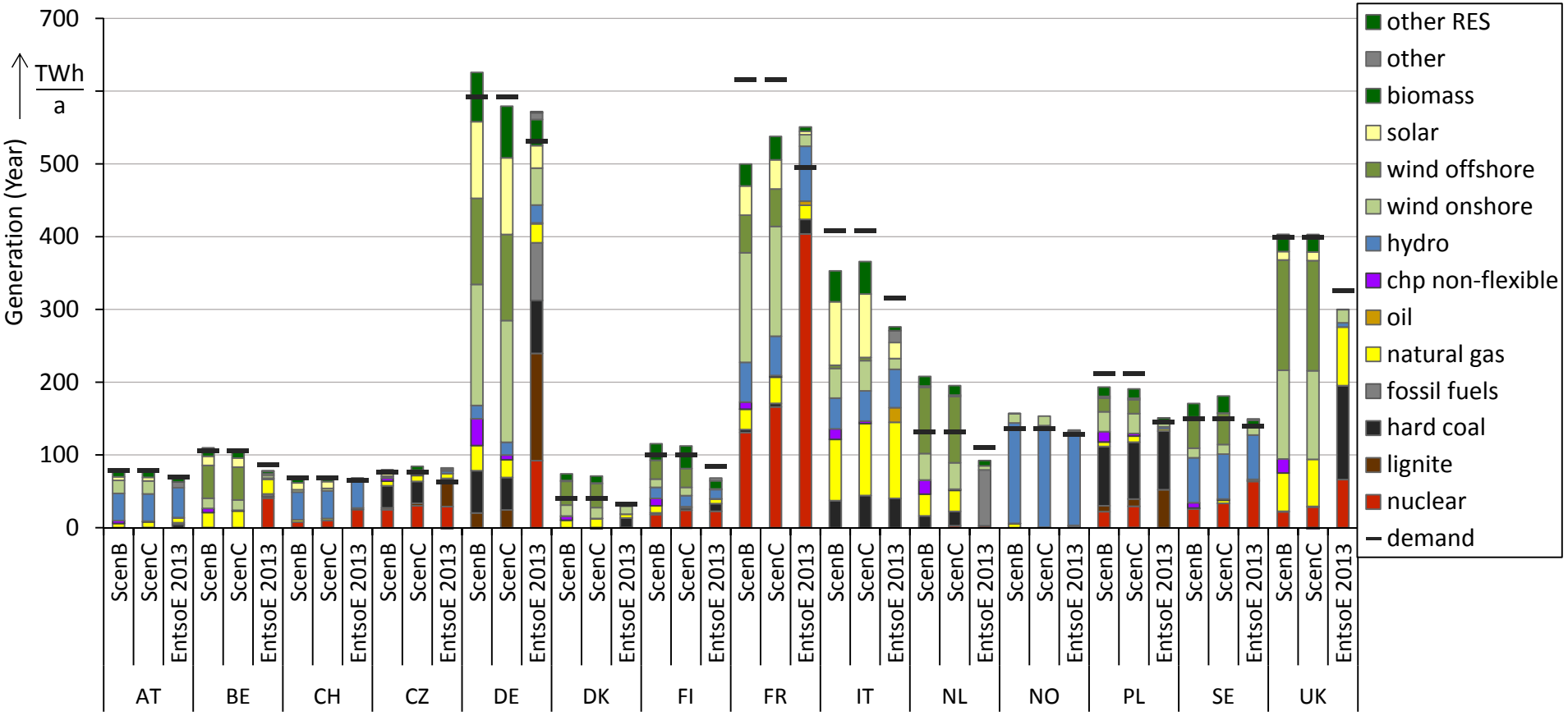
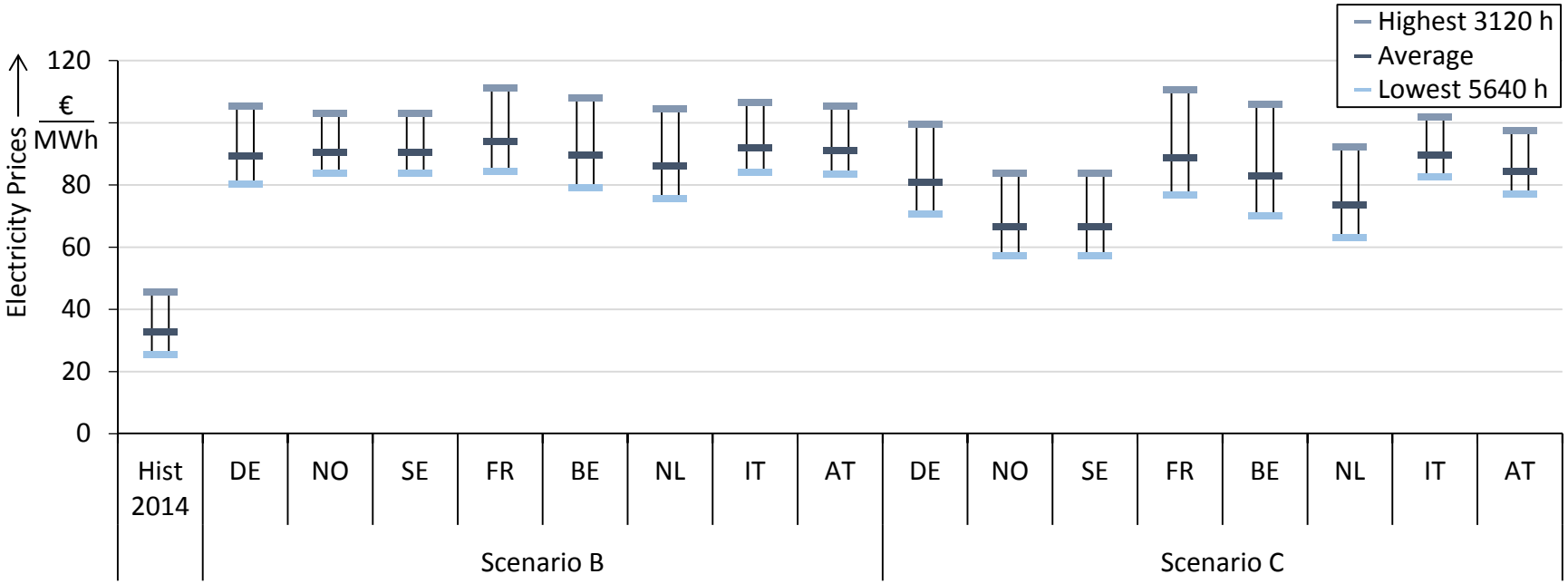
Power Generation



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

Electricity Prices

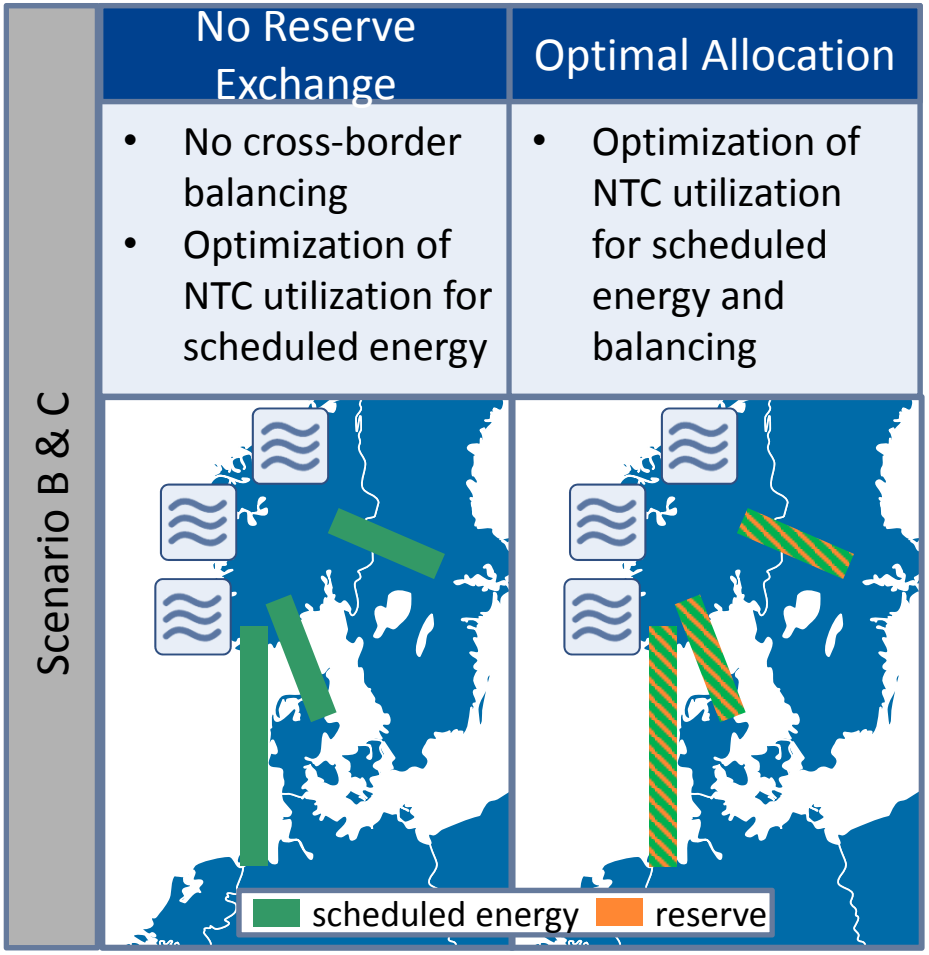


- Lower prices in Scenario C
  - More generation from hydro and nuclear power in Scenario C leading to lower price level in all countries
  - Scandinavian price level lower due to less transfer capacities to mainland market areas
- Alignment of prices in Scenario B

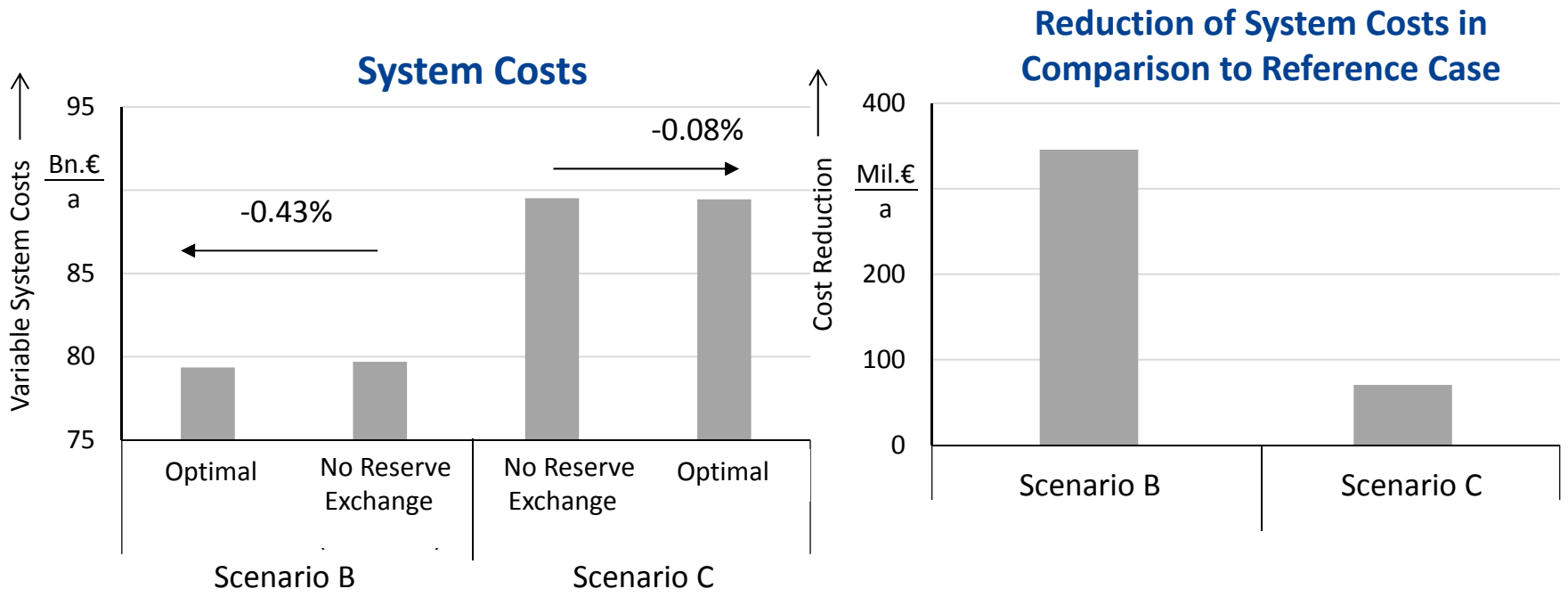
WP 1 – Reserve Exchange Variations

- 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

Regarded Portfolio

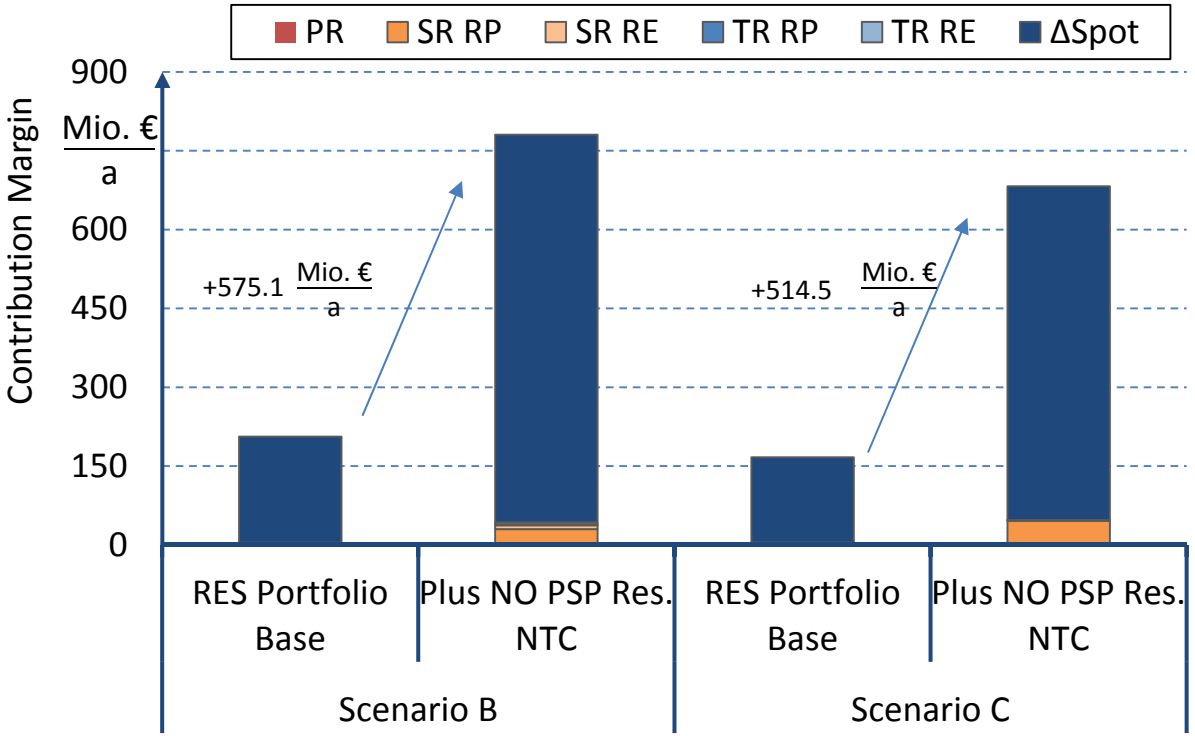
Portfolio „RES“

Technology	Capacity [MW]	Reserve provision
Solar	429	-
Wind	516	TR
Biomass	55	SR, TR

- Portfolio with 1 GW of installed capacity and proportions according to RES share in Germany
- ➔ Potential for flexible hydro power to compensate volatile RES feed-in

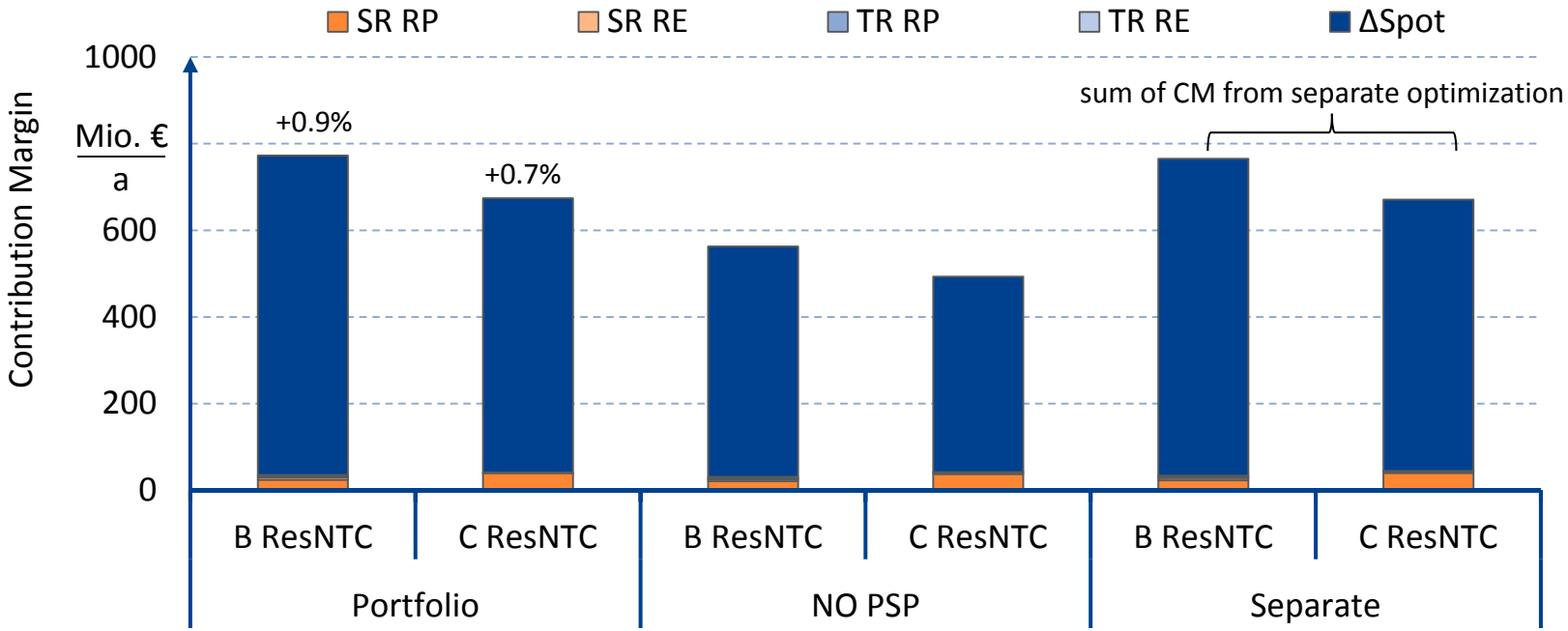
Additional Contribution Margin from Norwegian PSP

- Comparison of portfolio CM compared to market situation without Norwegian PSP taking part in German market



- CM of RES Portfolio slightly higher when NO PSP not in German market
- Highest benefits from additional storage for RES Portfolio and Scenario B (+575.1 Mio.€/a)

RES Portfolio – Portfolio Effect



- Portfolio effect with steady reserve between 0.7% and 0.9%
- ➔ Effect from optimizing reserve provision

Summary

Motivation and Background

- RES development in Europe triggers need for flexibility in the power system
- Possible provision of the needed flexibility from Norwegian hydropower
- Possible benefit from having access to Norwegian hydropower for utilities and TSO to be investigated

Results of Macroeconomic Investigations

- Alignment of prices between Scandinavia and Northern Europe of approx. 100 €/MWh
- Benefit from optimal allocation of transfer capacity to exchange reserve power and scheduled energy amounts to 345 mio. €/a in scenario B and 70 mio. €/a in scenario C
- ➔ Higher additional value on macroeconomic scale from short- and long-term balancing for scenarios with low flexibility in the rest of Europe

Results of Microeconomic Investigations

- Additional pumped storage increases contribution of portfolio
- ➔ Increasing additional value for portfolios with decreasing inherent flexibility (e.g. wind and solar plants), especially considering prognosis errors