Baltic
InteGrid
Integrated Baltic Offshore
Wind Electricity Grid Development

Weighing Costs and Benefits of a meshed grid in the Baltic Sea.

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DEUTSCHE WINDGUARD

IKEM

EU STRATEGY FOR THE BALTIC SEA REGION FLAGSHIP

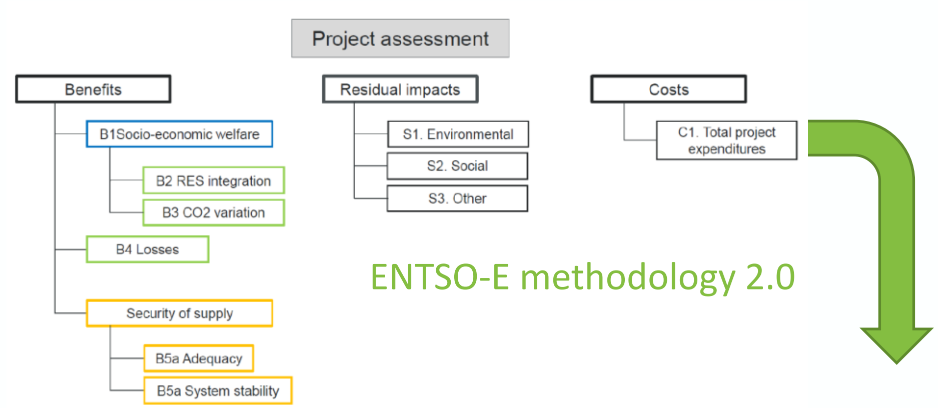
Interreg
Baltic Sea Region

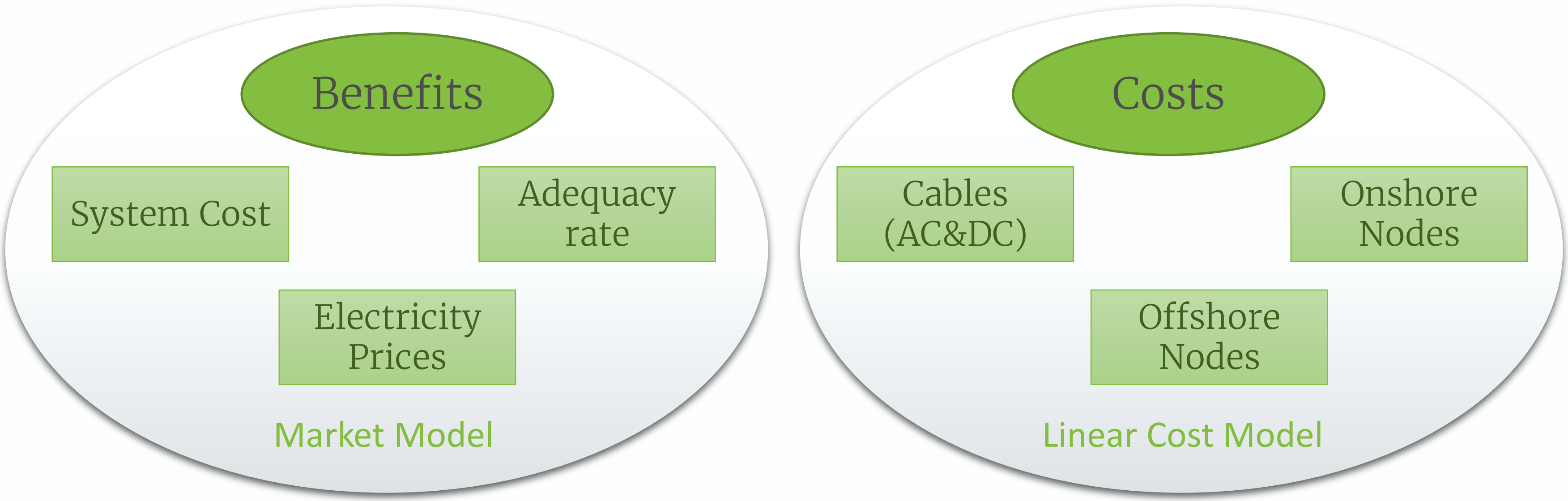
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Agenda

1. Methodology
2. Benefits
3. Costs
4. Balance and Conclusion

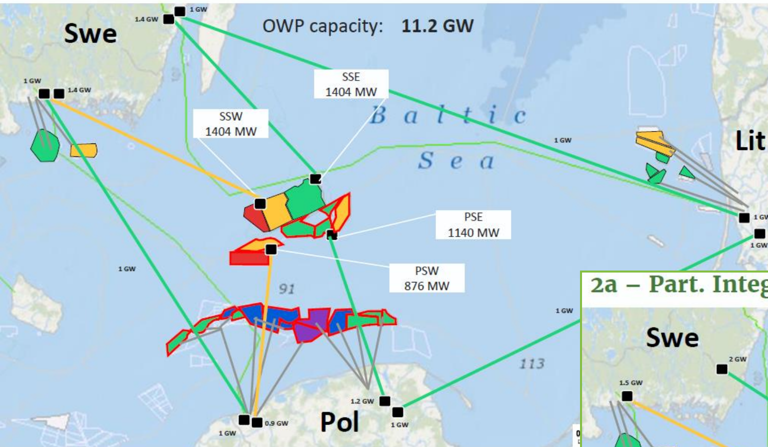
CBA Methodology





Scenario Comparison

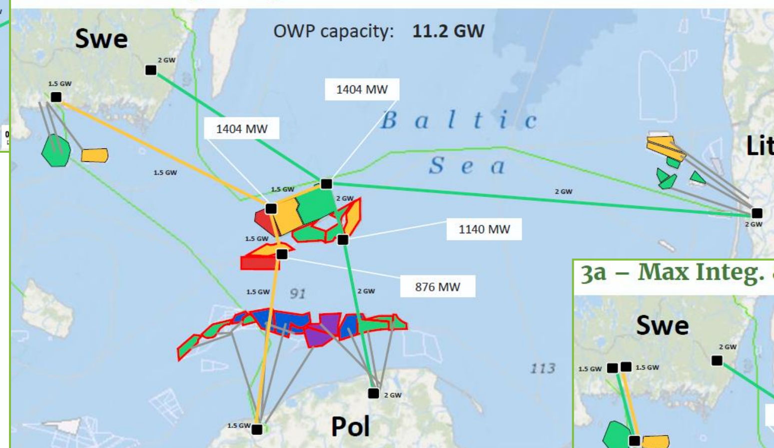
1a – Zero Integ. & High OWP



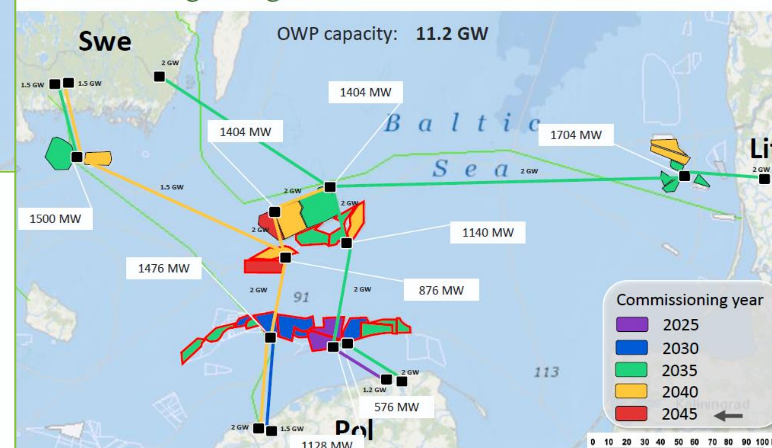
Baseline Scenario

Cost and Benefit Differences

2a – Part. Integ. & High OWP



3a – Max Integ. & High OWP



Benefits

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Model Overview

Model dynELMOD:

Linear program to determine cost-effective development pathways in the European electricity sector

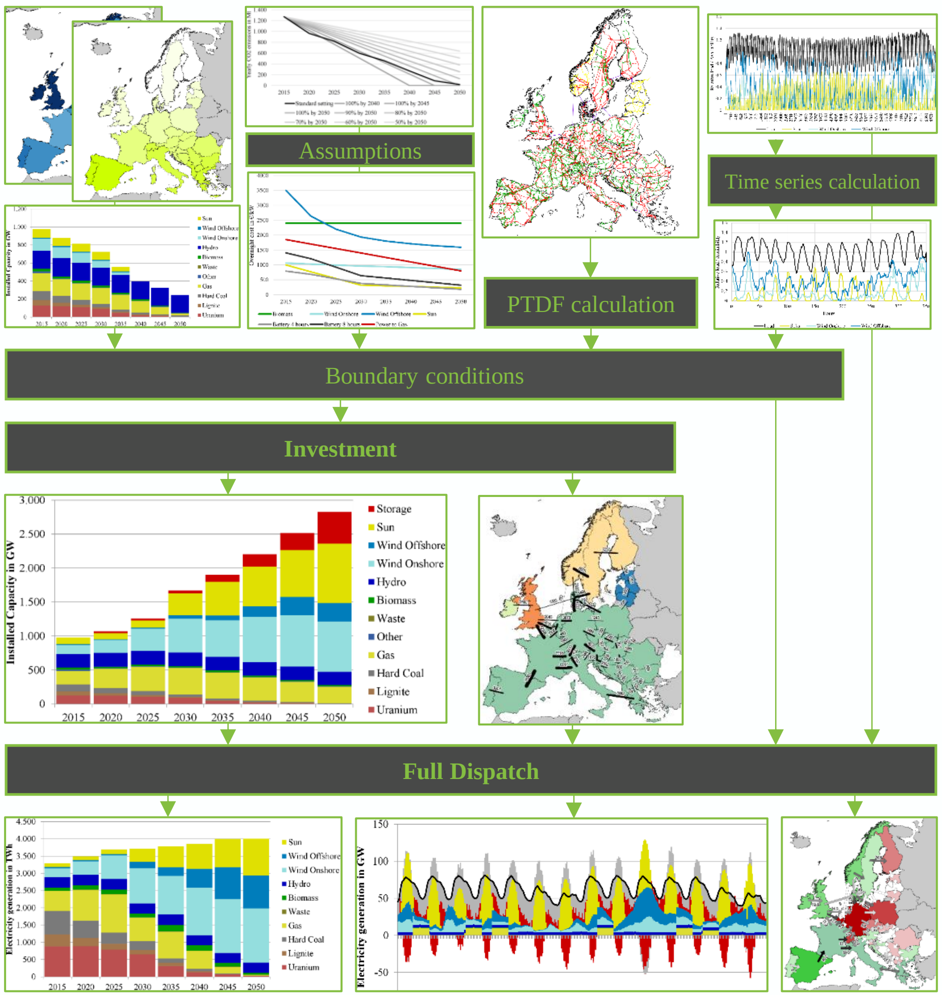
Calculation Steps

1. **Investment**
   - Investment into Conventional and renewable generation, cross-border capacities
   - Reduced time series used
2. **Dispatch**
   - Investment result from step 1 fixed
   - Time series with 8760 hours

Model:
33 European countries
31 conventional or renewable generation and storage technologies
9 investment periods, five-year steps 2020 – 2050

Outputs

- Investment into generation capacities, storage, transmission capacities
- Generation and storage dispatch
- Emissions by fuel
- Flows, imports, exports



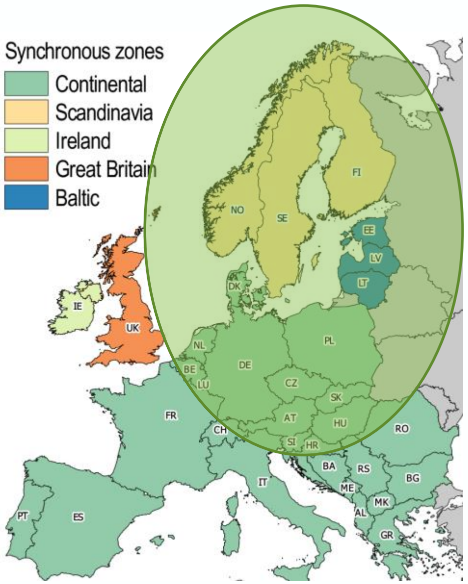
Application in BIG Model Context

Cost benefit analysis: Focus on Baltic countries (but calculate full dispatch for all countries)

Relevant Inputs

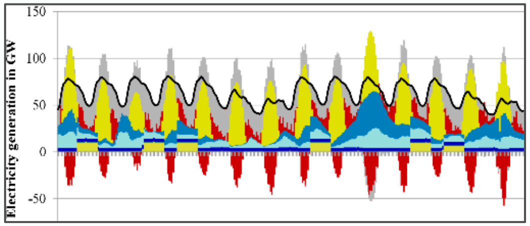
Installed Capacities, Fuel Costs, Emission limits/prices
Scenario-specific data:

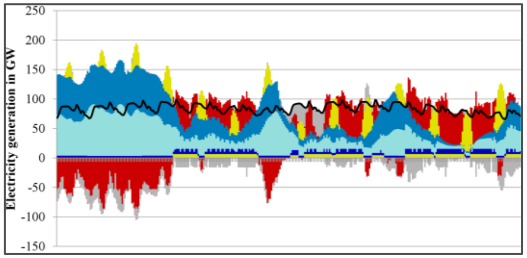
- Connections between countries
- Wind farm integrations

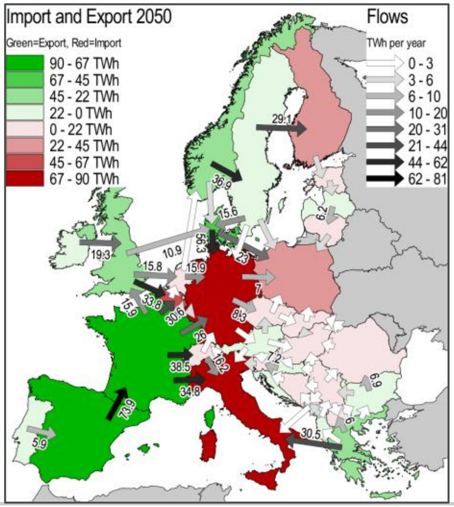


Outputs relevant for CBA

- ➢ Security of supply → hourly adequacy margin
- ➢ Electricity generation costs and prices.
  - ➢ Relevant stakeholders for welfare implications: Consumers, Producers (conventional and renewable), TSOs
- ➢ Hourly generation & storage dispatch
- ➢ Cross-border flows
- ➢ RES Integration factor (rate of curtailment)
- ➢ Generation and storage dispatch
- ➢ Emissions by country and fuel



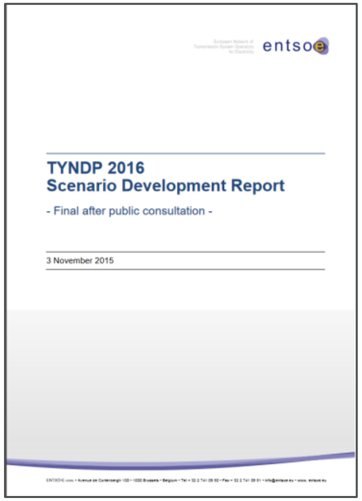




Modeling Assumptions

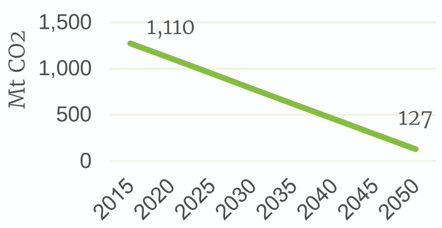
Electricity generation capacities

- Entsoe TYNDP 2016 Market Modeling Data for 2020 and 2030 Scenario Vision 3
- **Offshore wind** capacities for the baltic sea region are set within consortium and differ by scenario



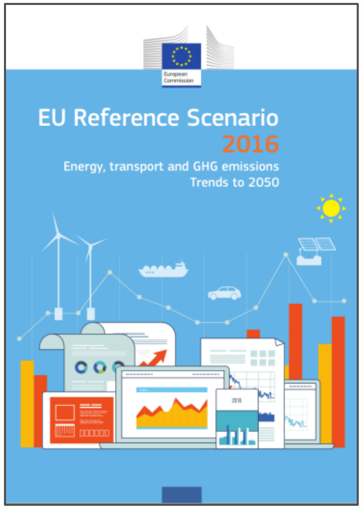
CO_2 decarbonization target:

- 90% CO_2 emission reduction until 2050



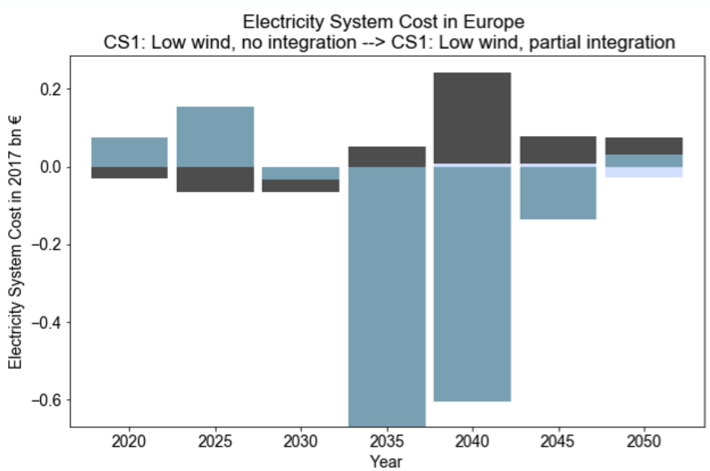
Other assumptions

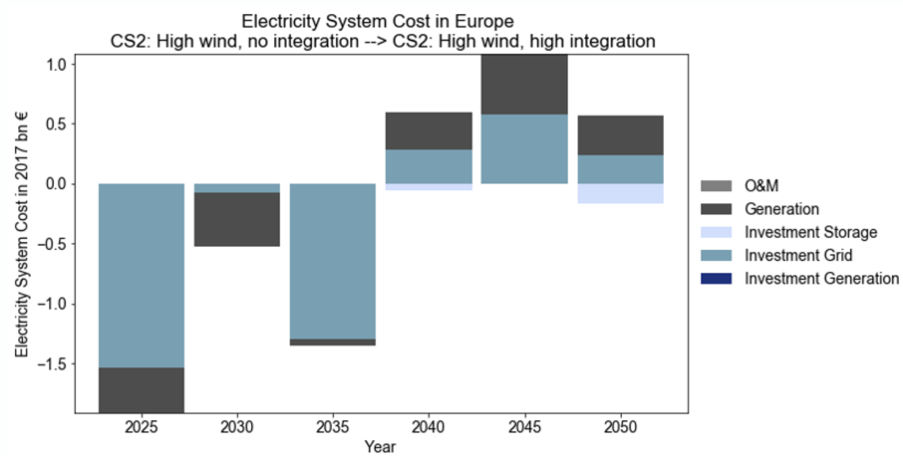
- Prices for fuels etc. are based on the European Commission's Reference Scenario 2016
- Time series: structure based on year 2013, full load hours are scaled to meet projections



Overall system cost differences in 2017 bn €

	Low Wind		High Wind	
	CS1	CS2	CS1	CS2
no integration -> high integration	-0.99	0,01	-0.09	-1.76
no integration --> partial integration	-0.92	0.03	-0.06	-1.83





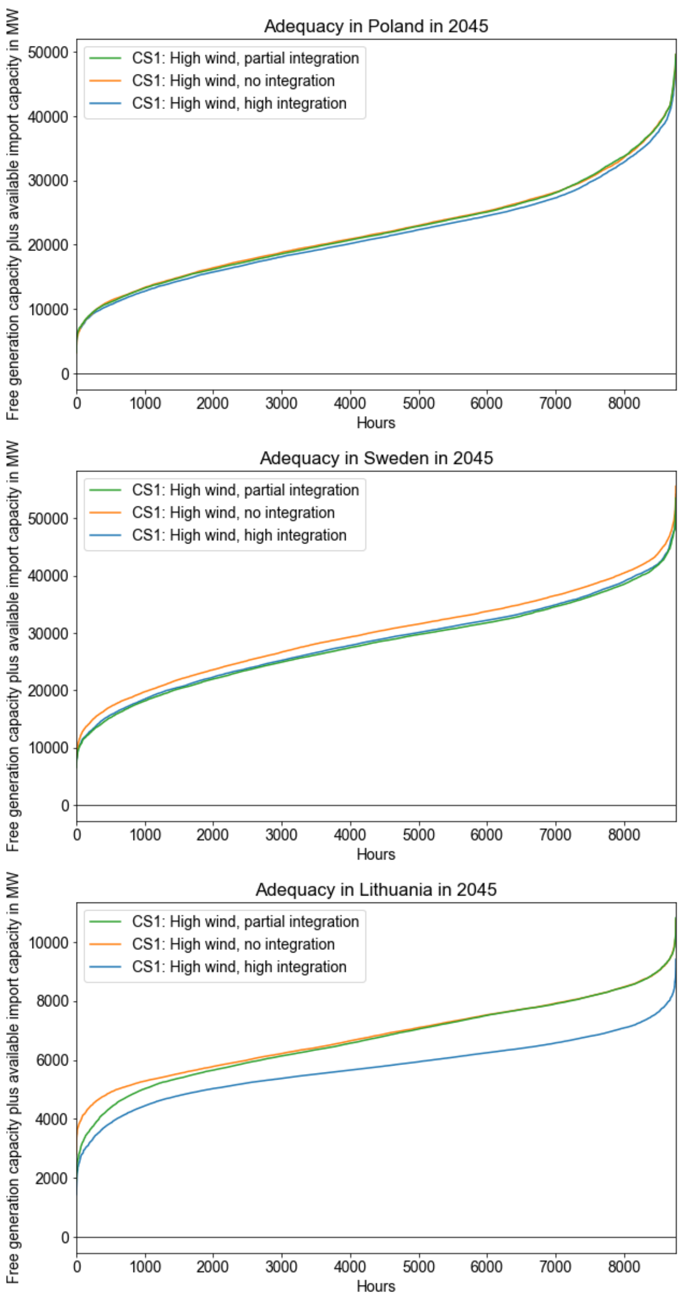
- Overall, the difference is relatively small but differences appear in different wind scenarios
- Cost changes occur due to reduced grid expansion need in case of higher offshore interconnection
- In CS1: Mainly in Sweden, Poland, and Lithuania. Other Countries less affected
- In CS2: Mainly in the scenario-relevant countries Germany, Sweden, and Denmark

System Adequacy / Security of Supply

System Adequacy depends on:

- Unused generation and available capacity in each country
- State of network: flows and flow directions, which determines the available import capacity

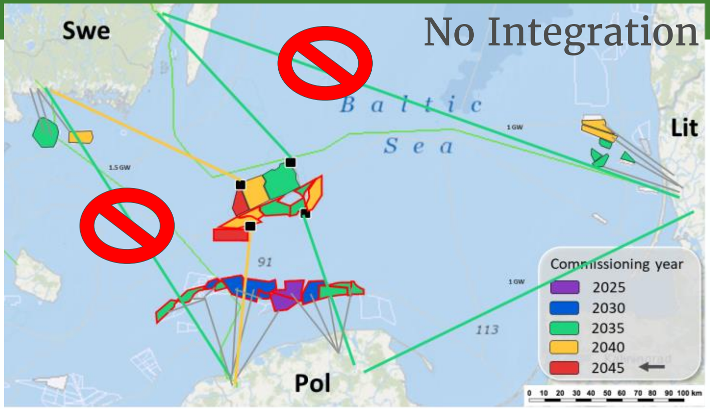
➢ Derive System Adequacy Margin for each hour in each country

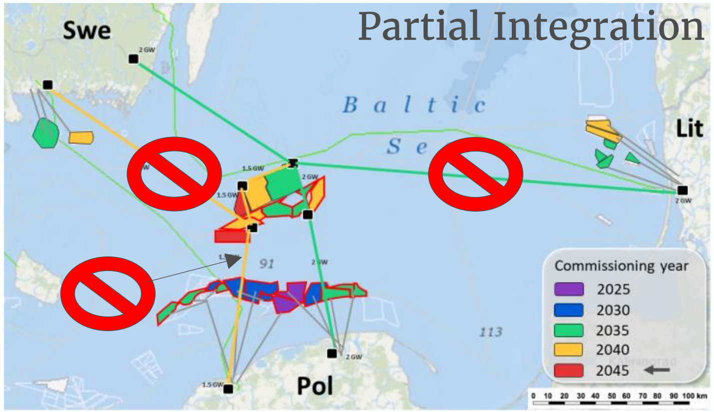


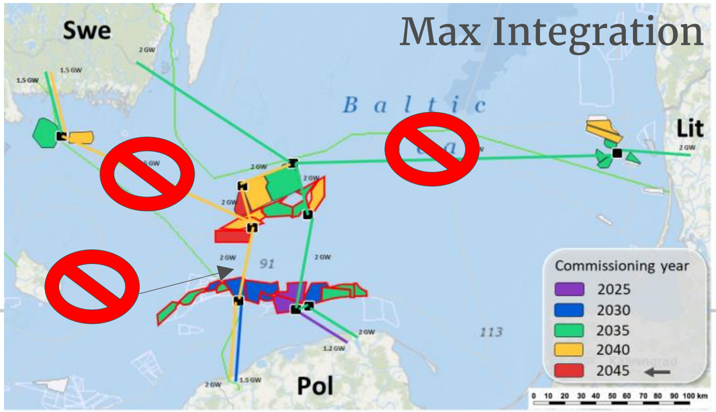
System Adequacy

- ➢ In all scenarios the system configuration is adequate
- ➢ Adequacy is similar in all scenarios
- ➢ For Lithuania the system adequacy is lower in the High Integration scenarios

Adequacy in case of line outages







Question:

Do scenarios with higher connectivity provide higher adequacy in case of a line outage?

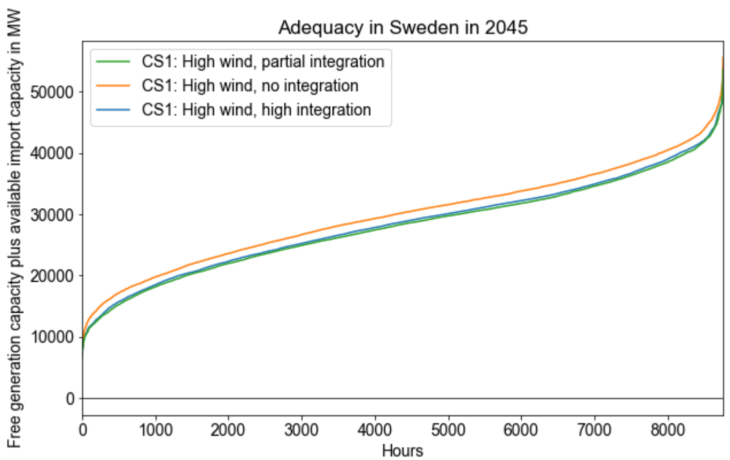
Comparison: Hourly Adequacy with and without lines.

Lines excluded for system adequacy comparison:

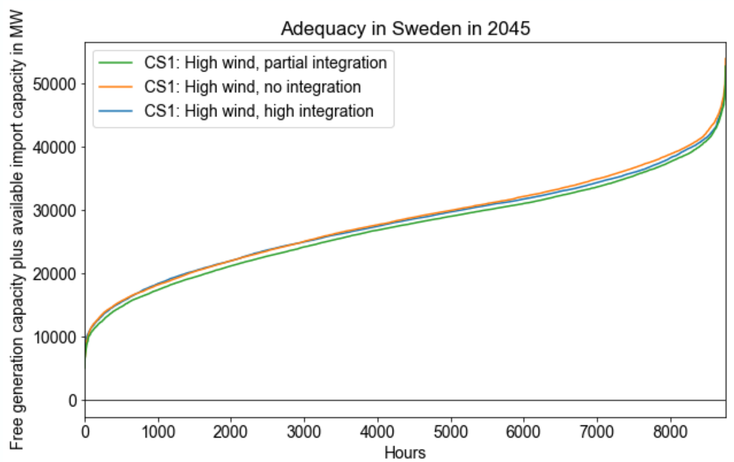
- No Integration: Main Interconnectors
- Partial Integration: Lines to Central Point
- Max Integration: Lines between Wind farms

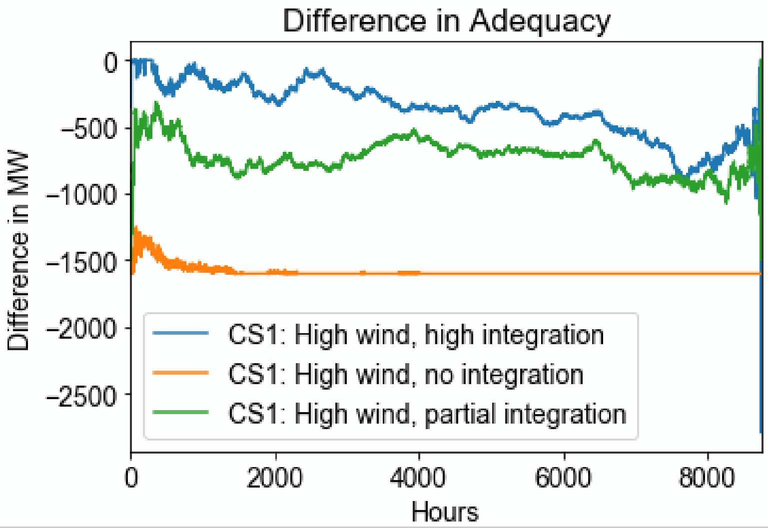
Adequacy in case of line outages – Sweden

Before



After line outage



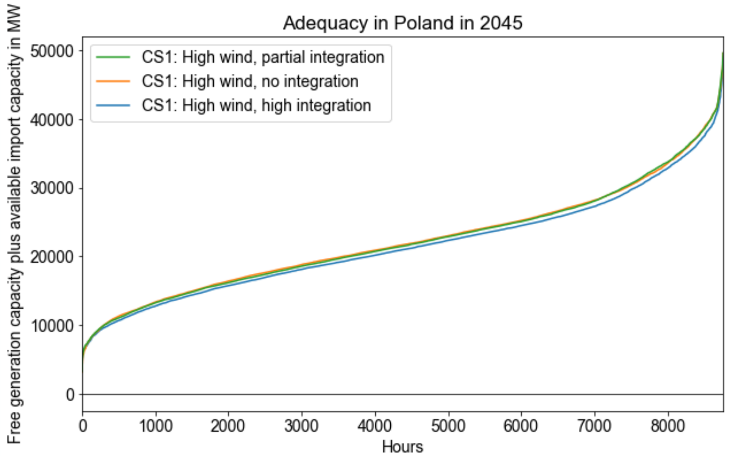


Adequacy after line outage

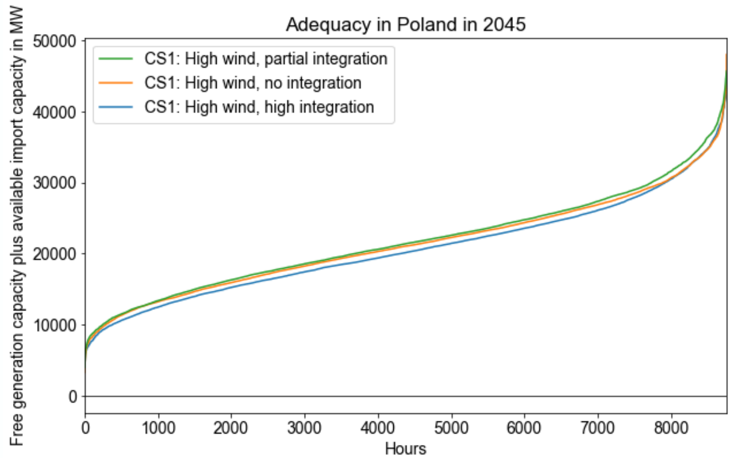
- Adequacy is reduced as expected, but no threat to system adequacy overall
- No Integration scenario mostly affected
- Similar adequacy reduction in partial and high integration scenarios.

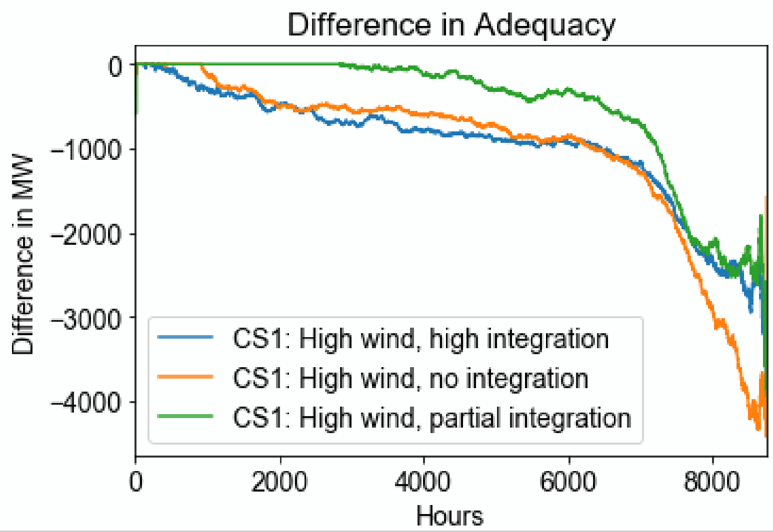
Adequacy in case of line outages – Poland

Before



After Line outage



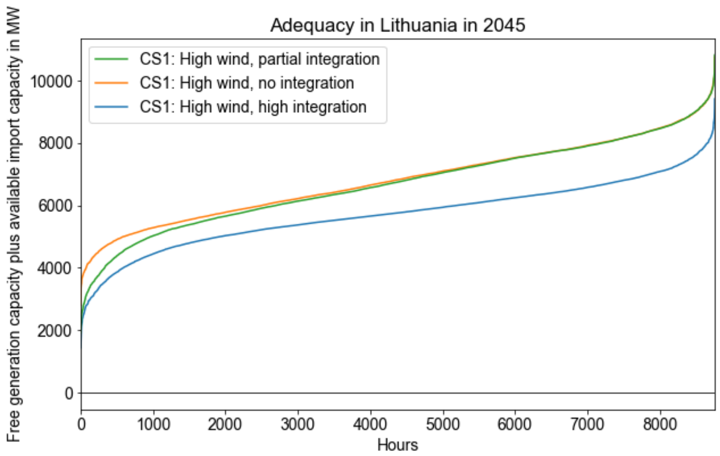


Adequacy after line outage

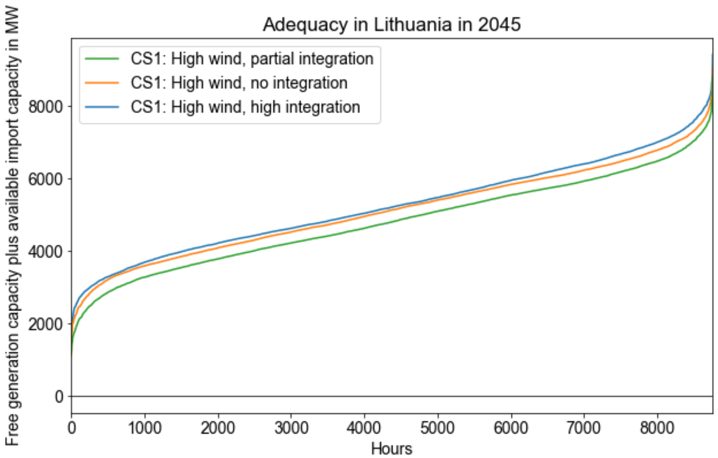
- Differences between scenarios are smaller
- In case of lowest adequacy the decrease due to line outage is smallest
- Partial Integration is most resilient against the modeled line outage

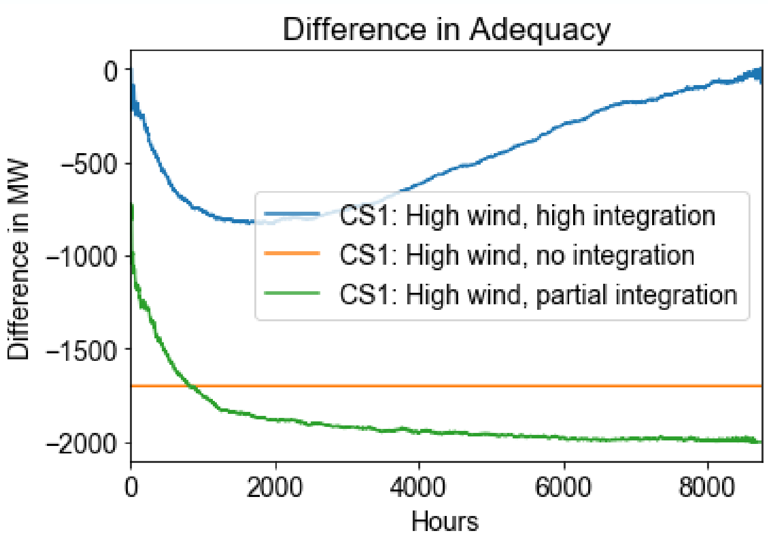
Adequacy in case of line outages – Lithuania

Before



After Line outage





Adequacy after line outage

- Differences relative to total generation capacity largest in Lithuania
- High integration scenario is most robust against line outage
  - Especially in case of already low adequacy

Conclusions

Conclusions Benefits Part

- Expectation previous to model runs: Small overall system cost differences between levels of integration in the baltic sea region
- Results: Depending on Wind installation, the need for grid expansion can be reduced by increased offshore integration across countries
- Increased integration also helps to improve system reliability

Next:

- Combination of Benefits results with the Costs part in the following presentation

Costs

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Linear Cost Model

Cable Cost
(Cable + Installation)

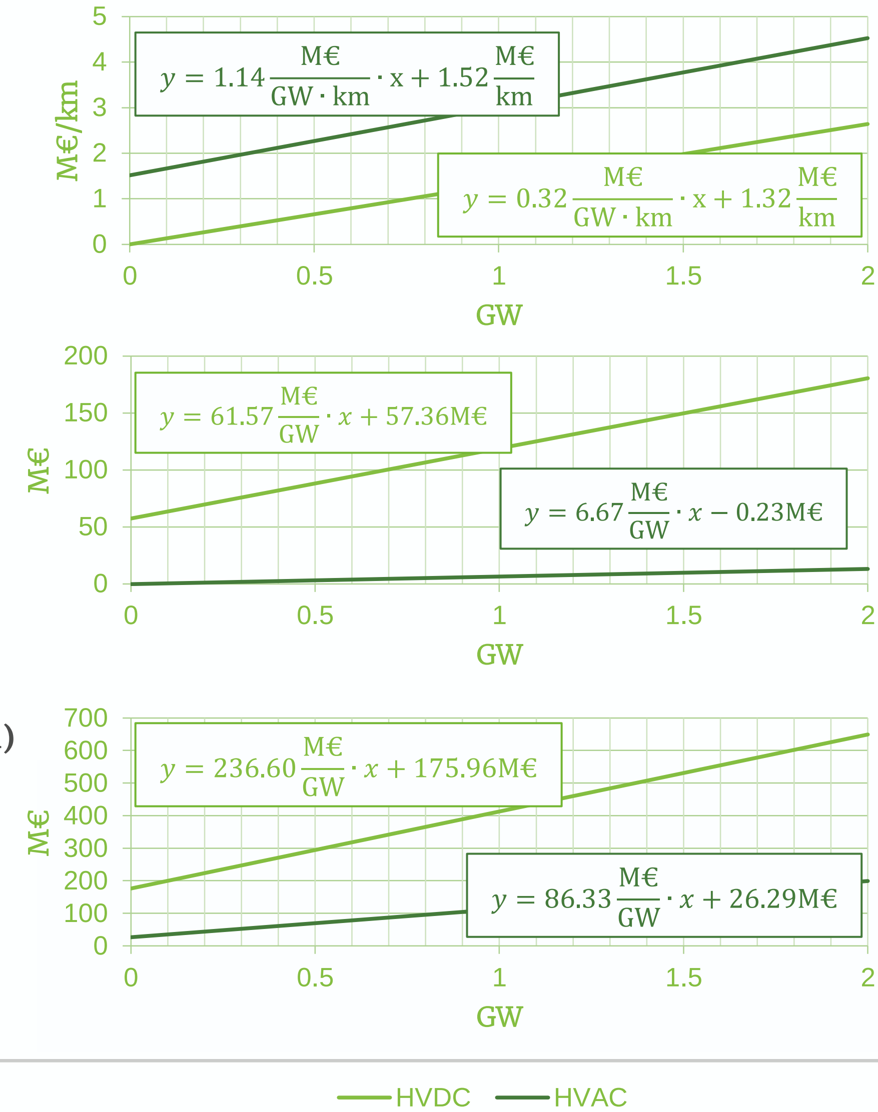
- length- and power dependent cost
- length-dependent cost

Onshore Node Cost
(Converter/Transformer + Installation)

- power-dependent cost
- fixed cost

Offshore Node Cost
(Converter/Transformer + Platform + Installation)

- power-dependent cost
- fixed cost



[Linear Cost Model, cf. Härtel et al. 2017]

CS1 (SE/PO/LT)

High Offshore Wind power

-0.30 bn €	+0.24 bn €

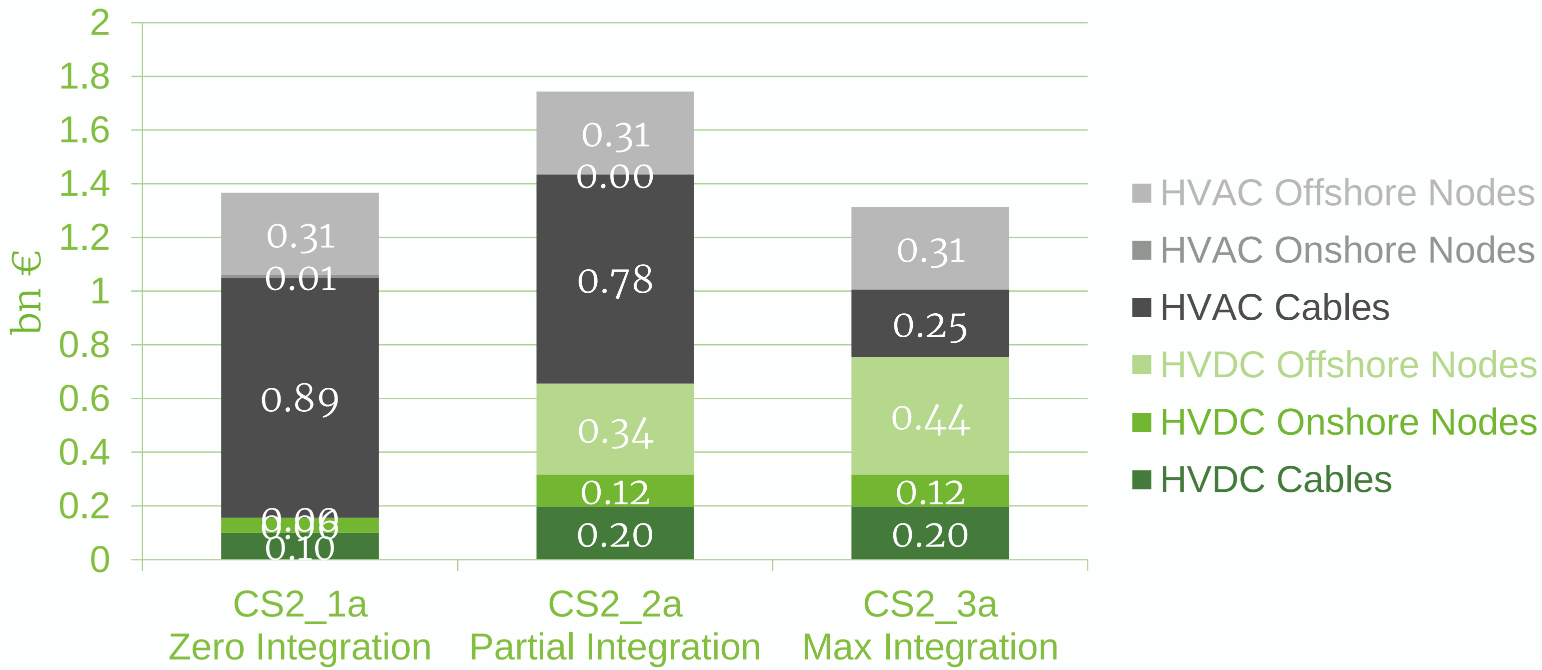
CS1 (SE/PO/LT)

Low Offshore Wind Power

+0.11 bn €	+0.08 bn €

CS2 (DE/SE/DK)

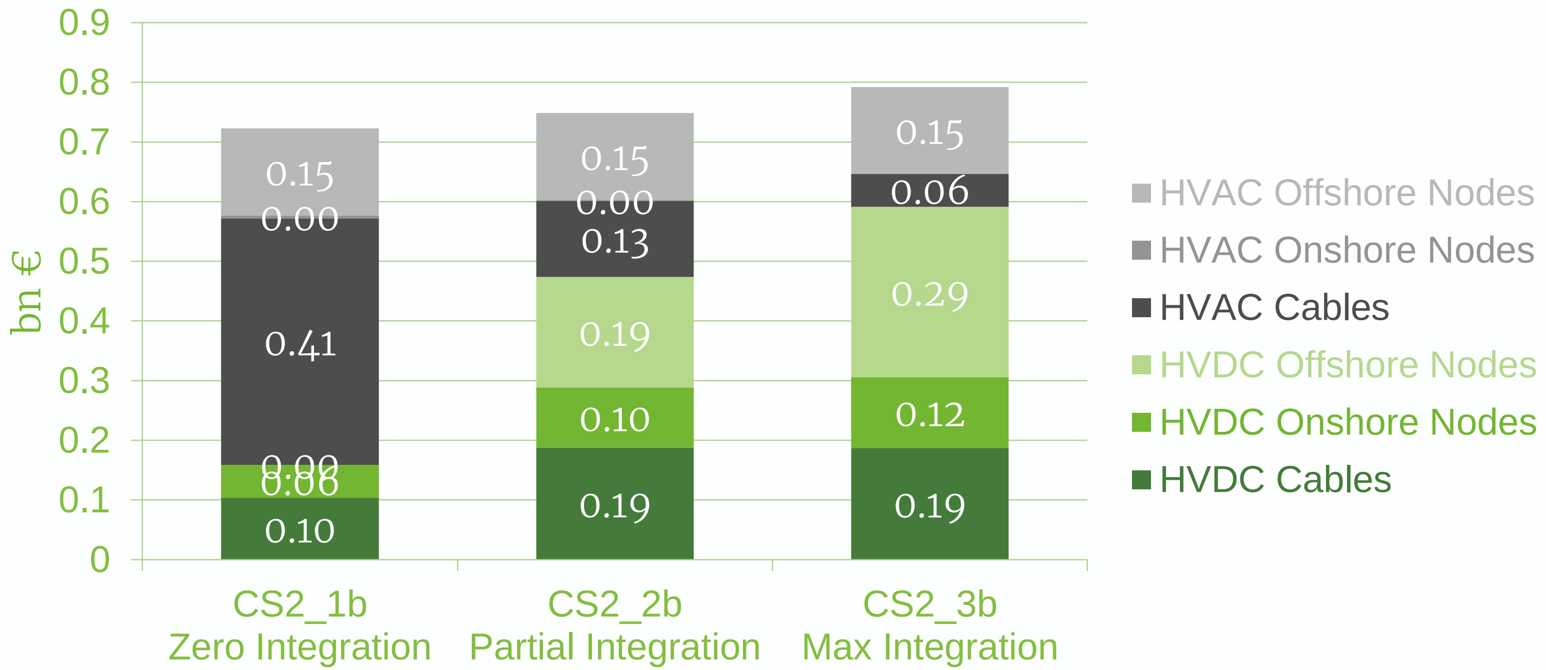
High Offshore Wind Power



+0.38 bn €	-0.05 bn €

CS2 (DE/SE/DK)

Low Offshore Wind Power



+0.03 bn €	+0.07 bn €

Balance

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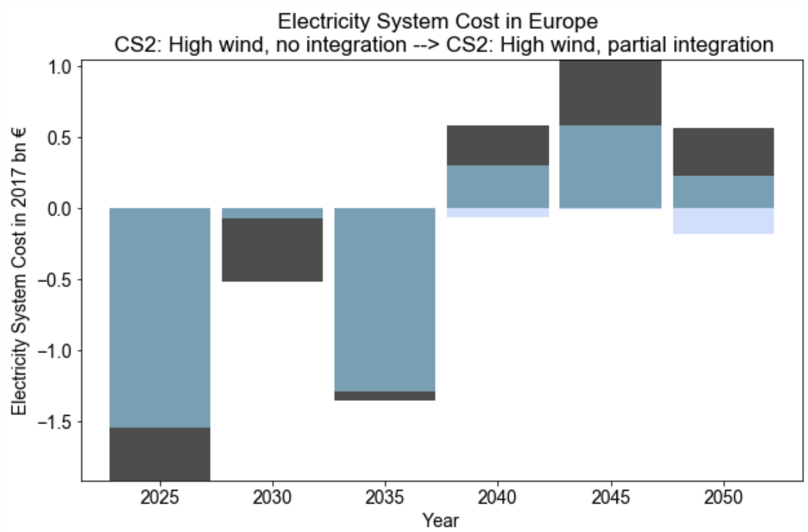
Approach



Net Present Value Difference compared to Base Case

Most favorable scenario:

	Case Study 1 (SE/PO/LT)	Case Study 2 (DE/SE/DK)
High OWP	Partial Integration	Maximum Integration
Low OWP	Maximum Integration	Zero Integration

Conclusions

- No general trend can be seen for an increasing level of integration.
- The main benefit results from the interconnection, which is already part of the base case (zero integration).
- The differences in costs and benefits between the different levels of integration are relatively low compared to overall costs.
- A higher degree of integration seems to makes more sense for scenarios with high offshore wind capacity.
- A higher level of integration supports additional non-monetarized benefits.

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