



Baltic  
InteGrid

Integrated Baltic Offshore  
Wind Electricity Grid Development

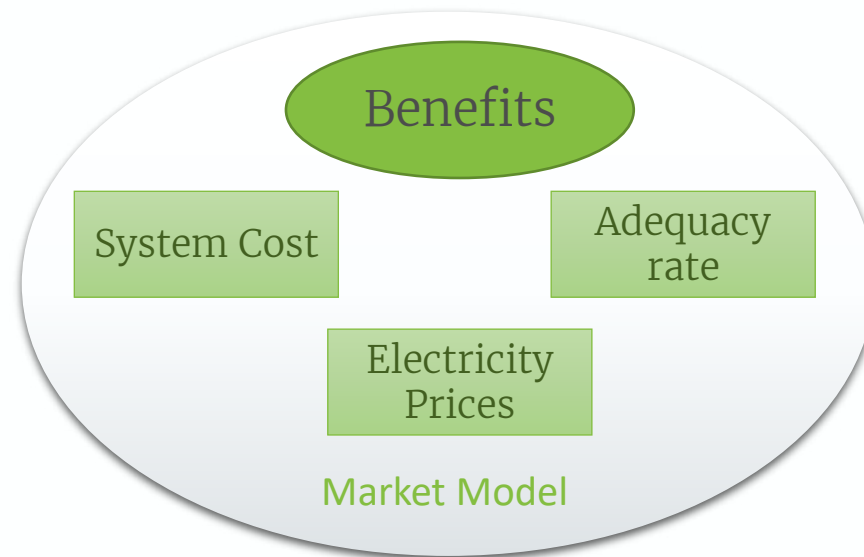
## Benefits of a meshed grid in the Baltic Sea: Design and result of the regional market model

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Espoo, 15 March 2018



EUROPEAN  
REGIONAL  
DEVELOPMENT  
FUND



## 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

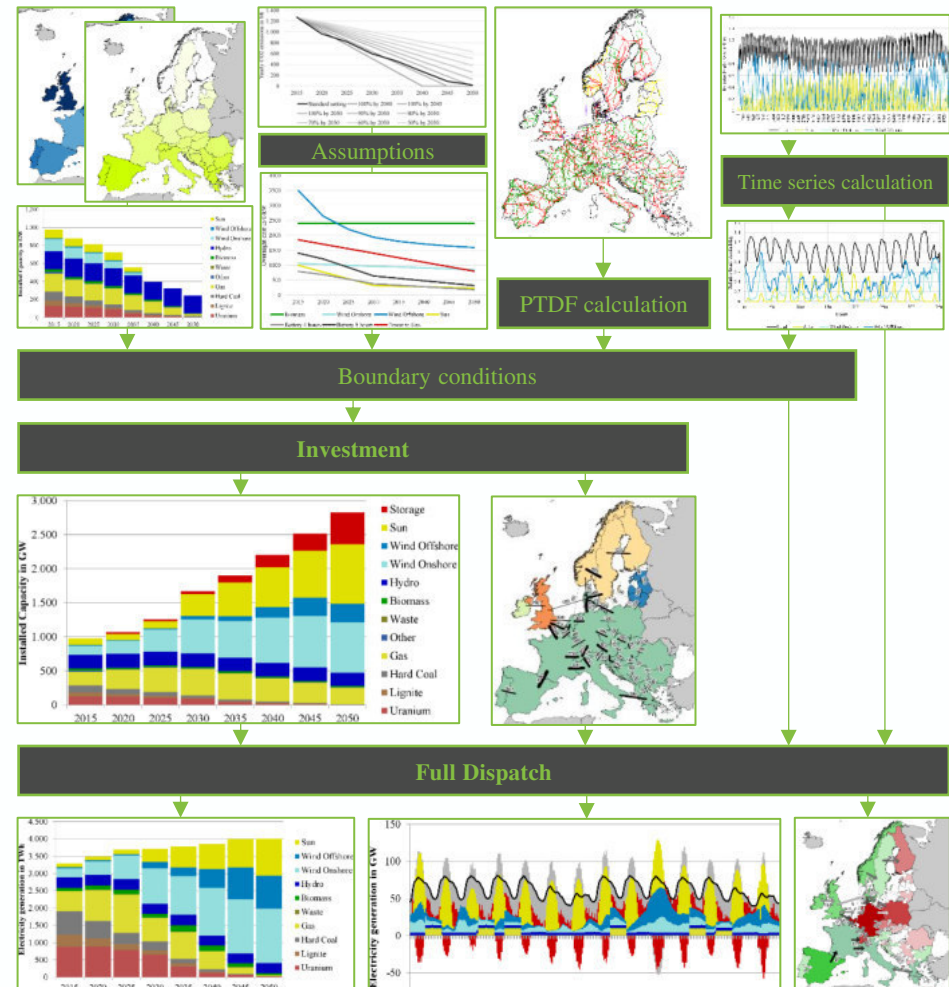
- Investment result from step 1 fixed
- Time series with 8760 hours

### 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



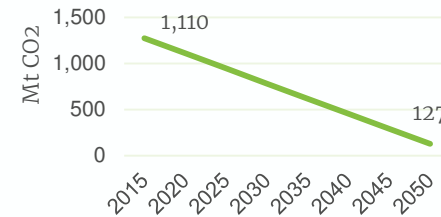


## Electricity generation capacities

- 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

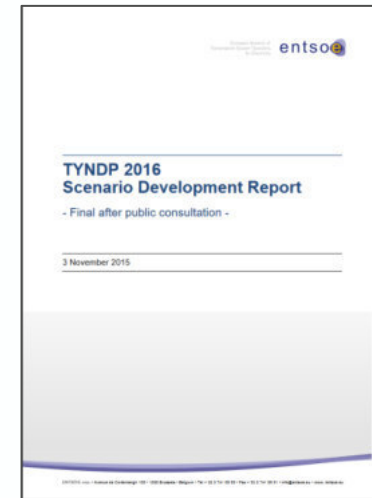
## CO2 decarbonization target:

- 90% CO2 emission reduction until 2050

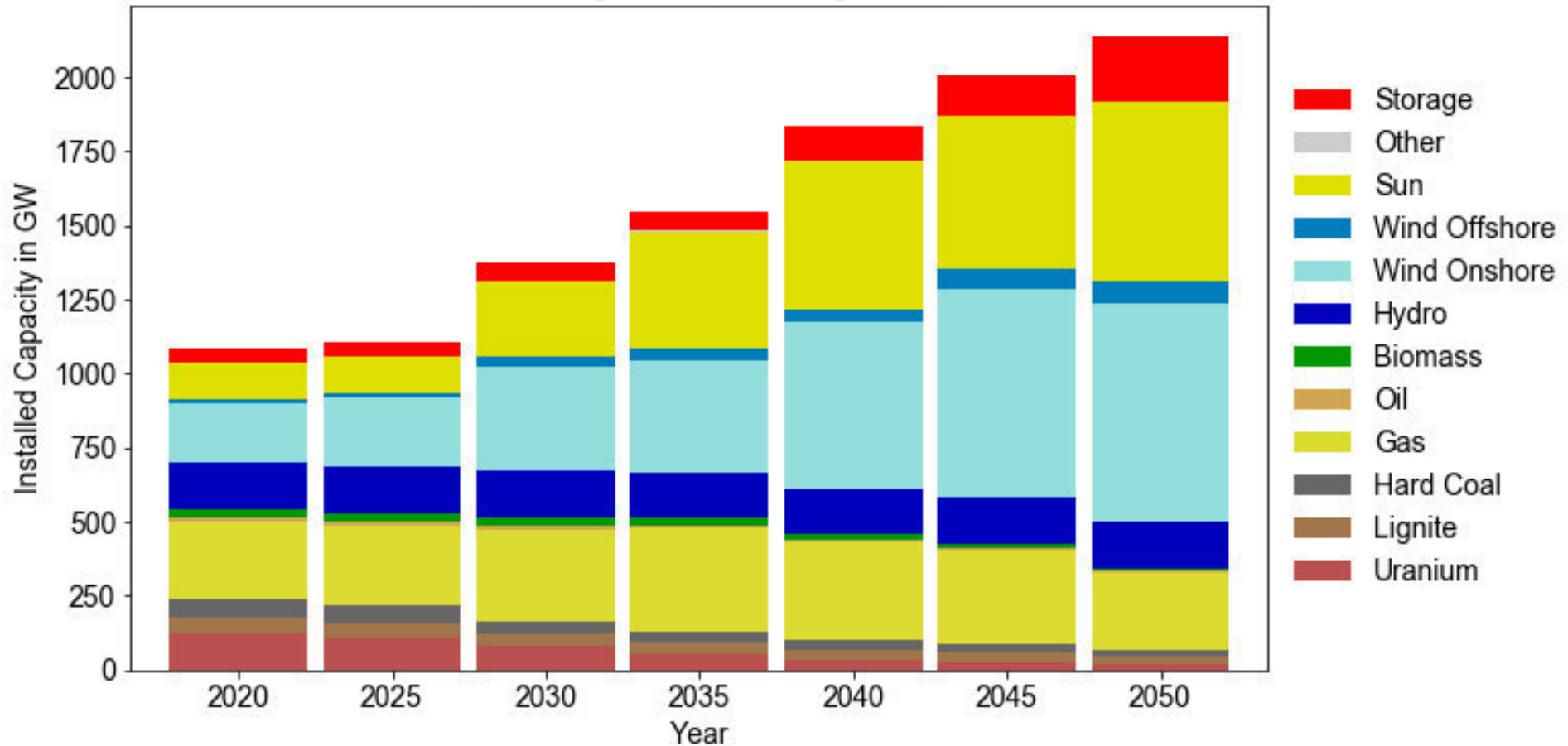


## Other assumptions

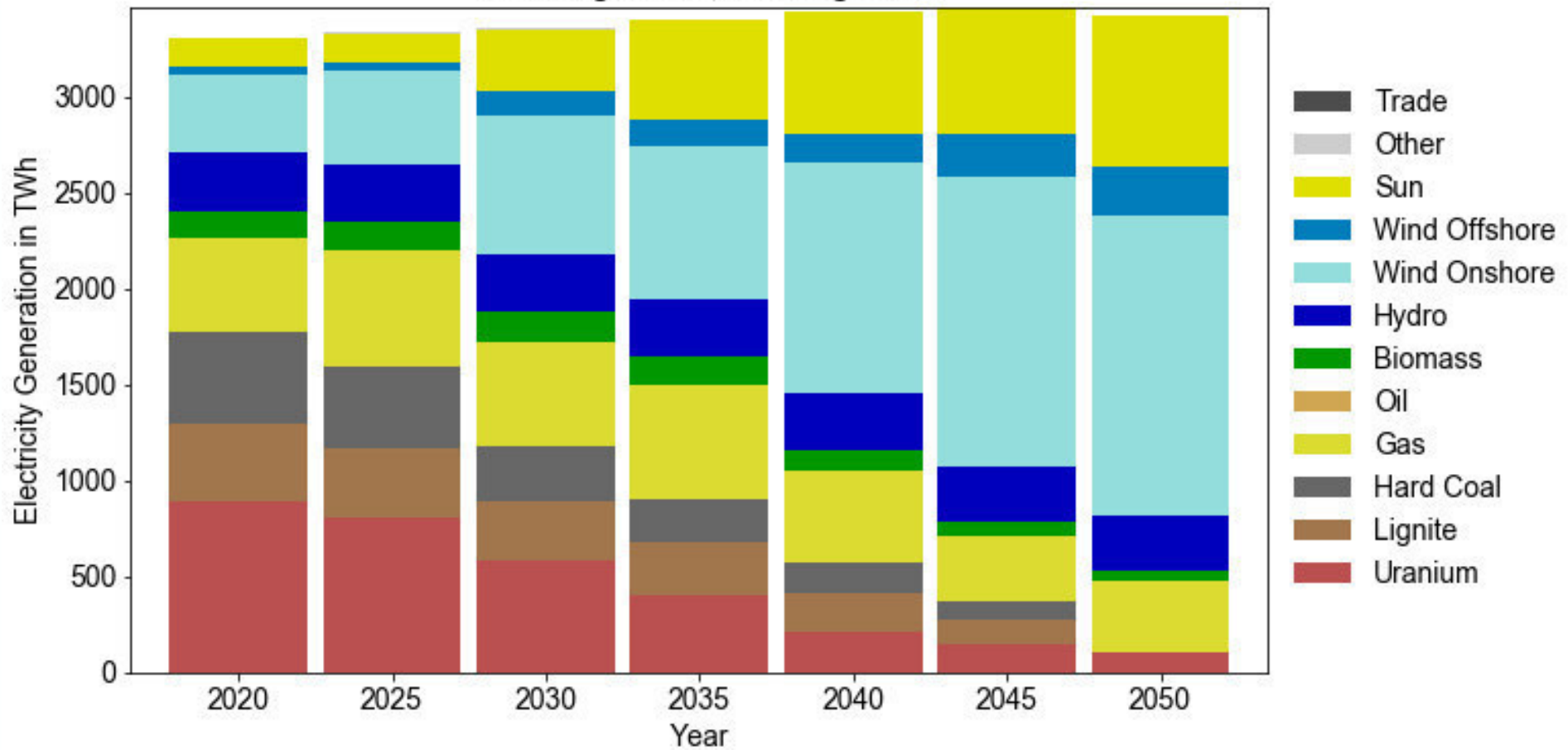
- Prices for fuels etc. are based on the European Commission's Reference Scenario 2016
- Time series: structure based on year 2013, full load hours are scaled to meet projections



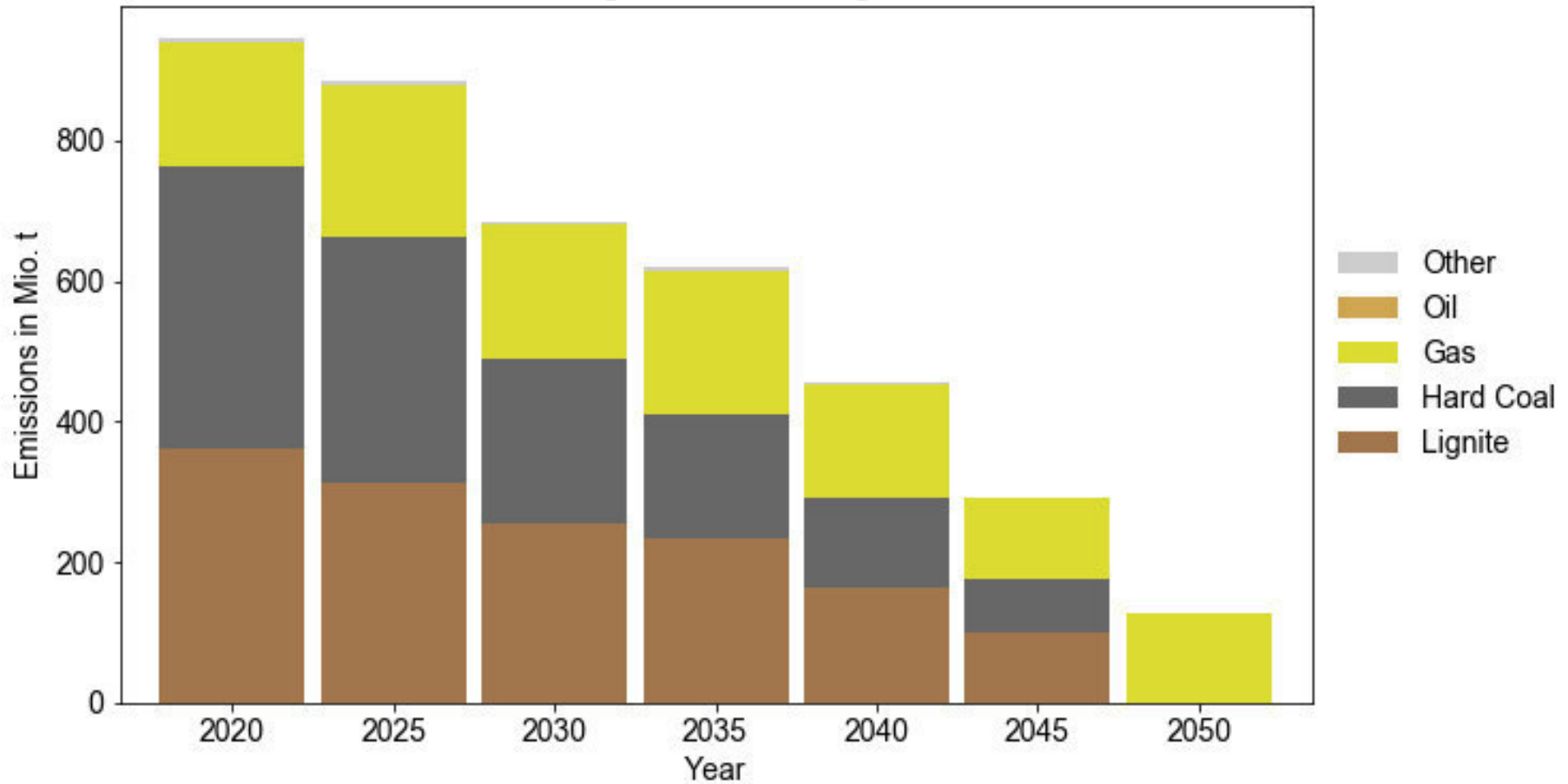
Installed capacity in Europe  
CS1: High wind, no integration



Electricity generation in Europe  
CS1: High wind, no integration



Emissions from electricity generation in Europe  
CS1: High wind, no integration

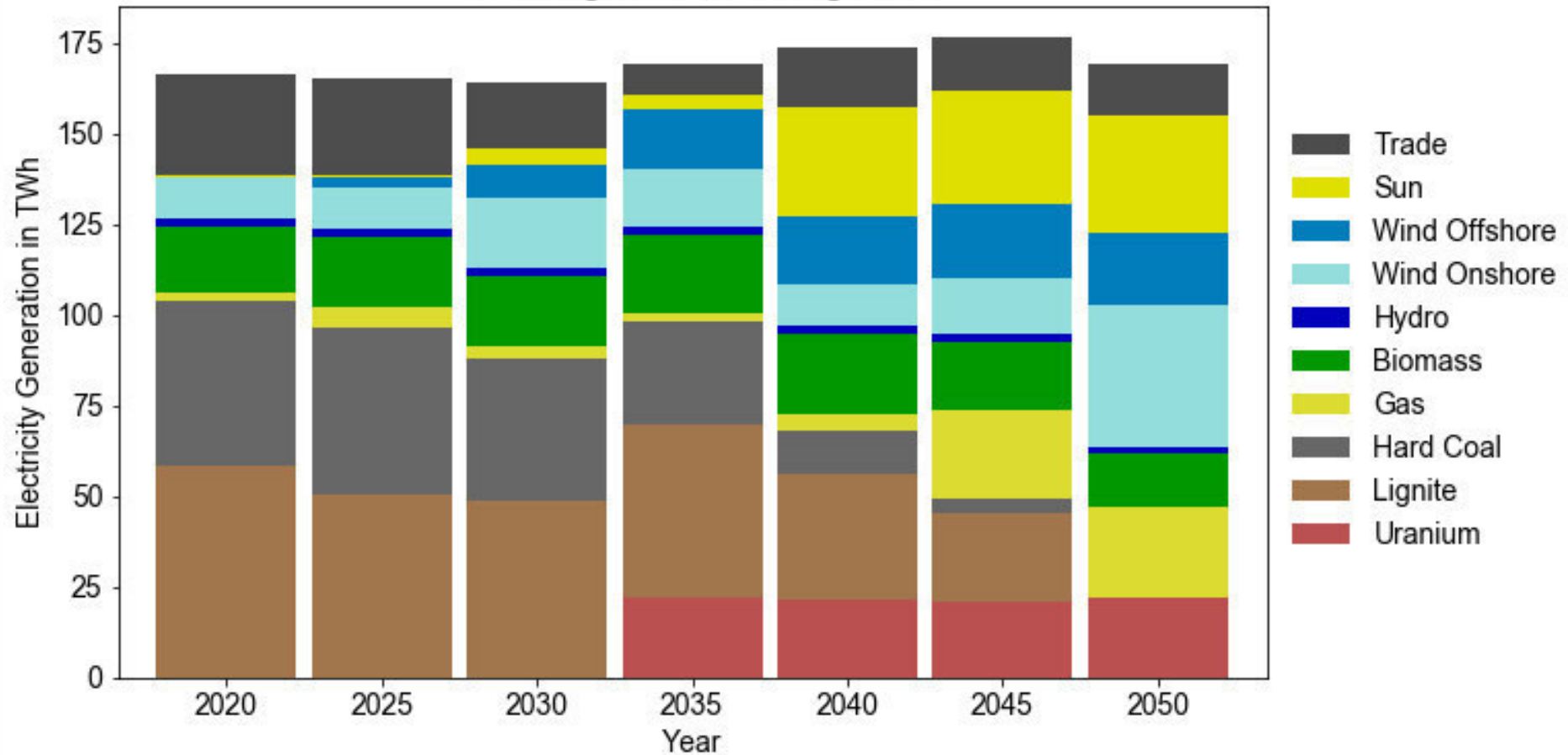


## Pre-Feasibility Analysis 1:

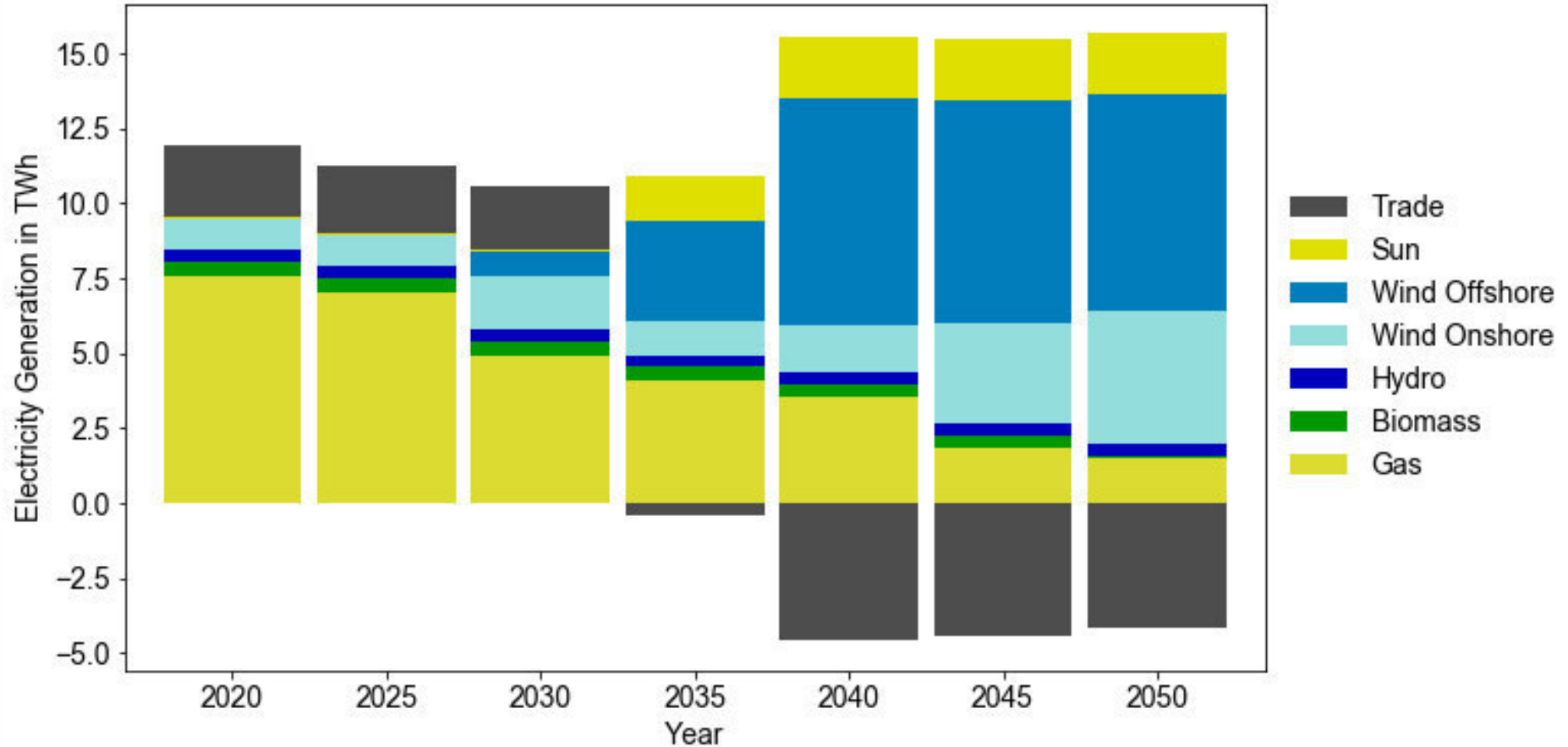
Sweden – Poland – Lithuania

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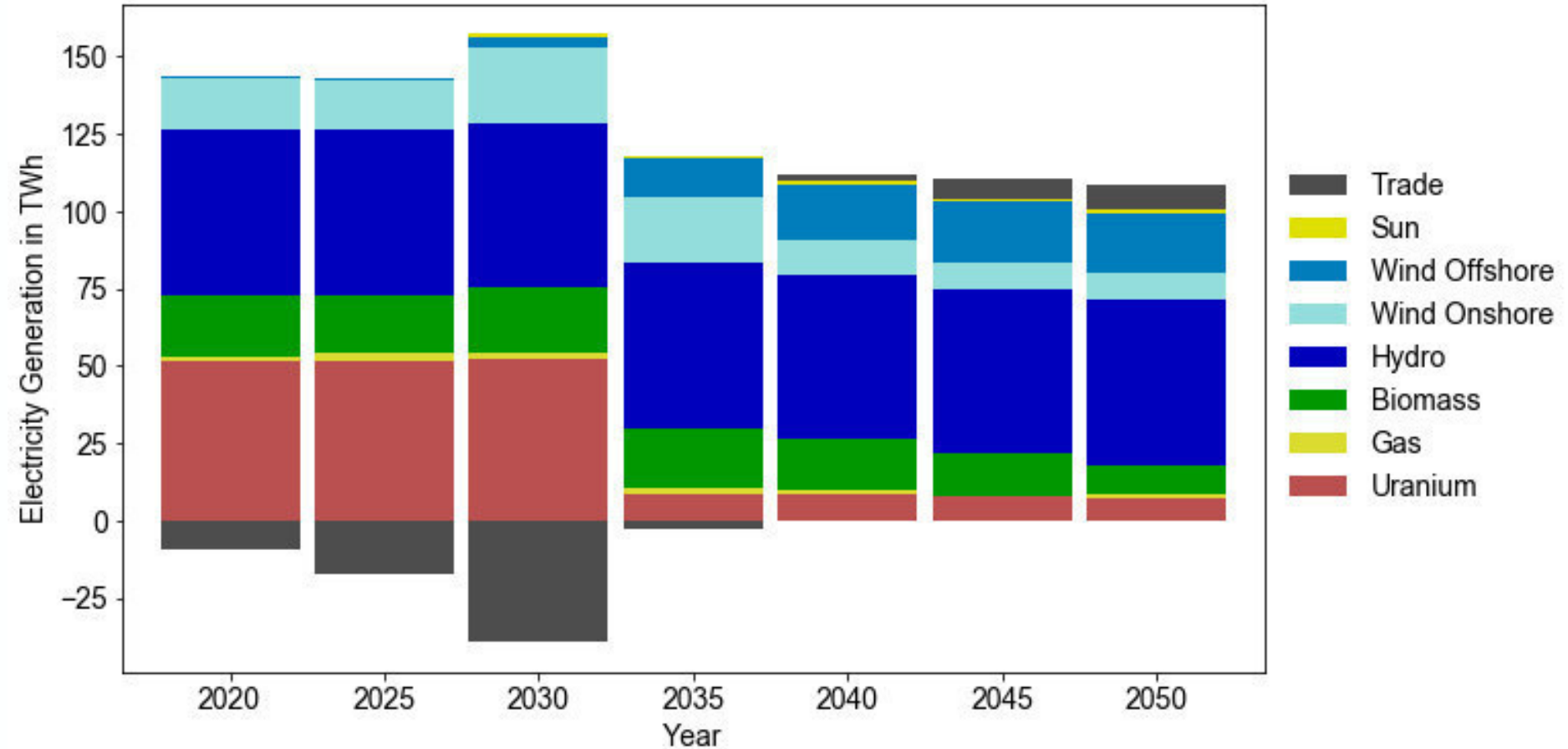
Electricity generation in Poland  
CS1: High wind, no integration



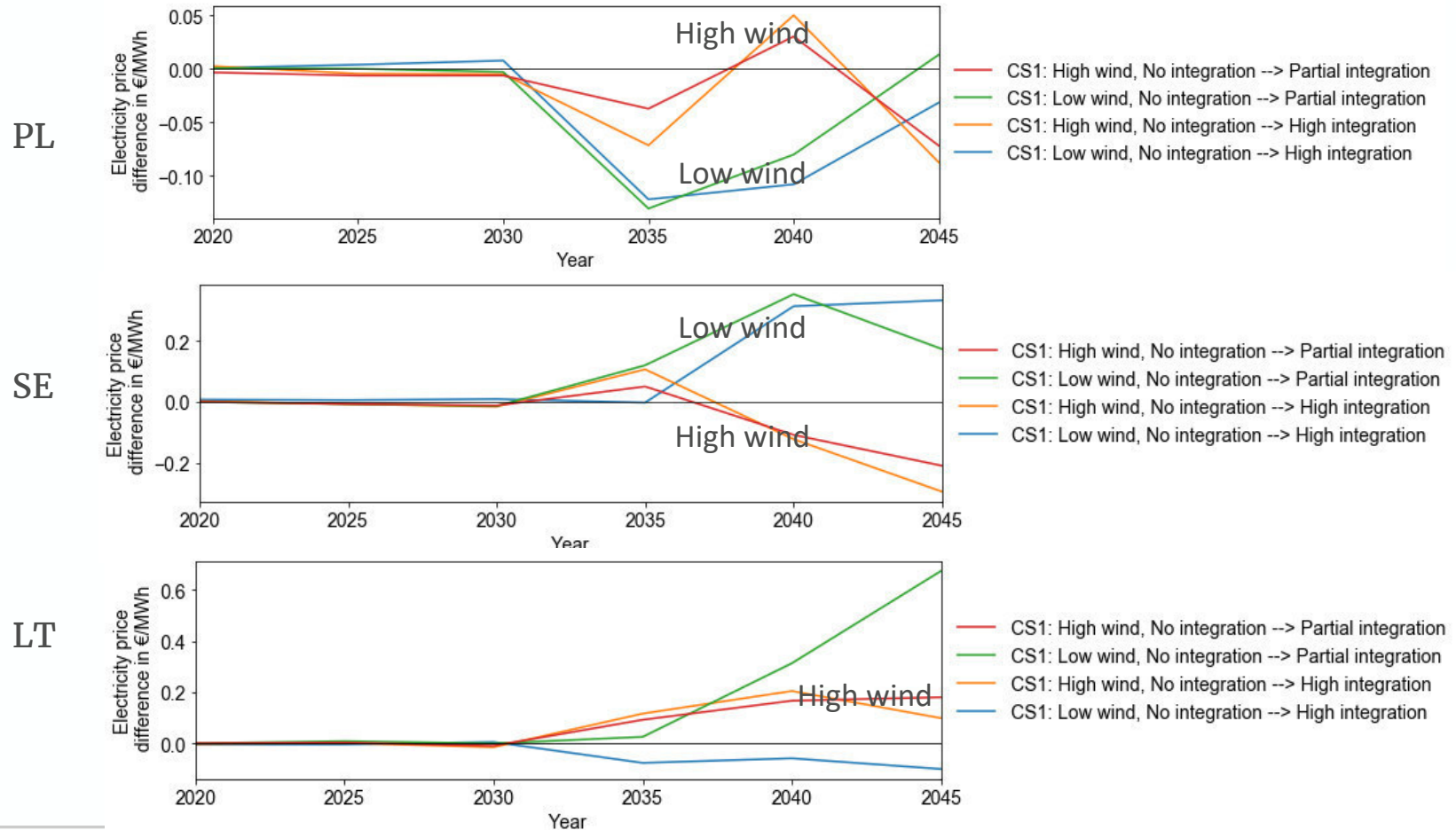
Electricity generation in Lithuania  
CS1: High wind, no integration



Electricity generation in Sweden  
CS1: High wind, no integration

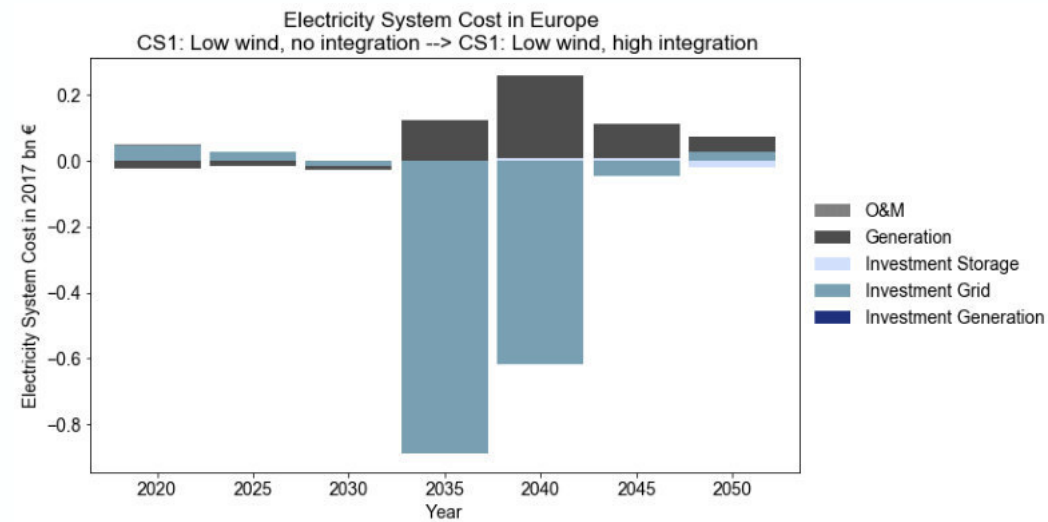
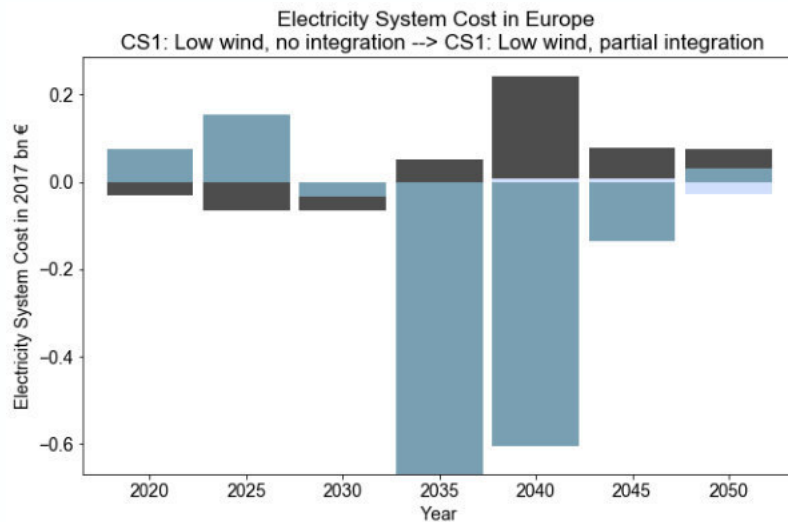


## Average electricity price difference for scenario variations



## Overall system cost differences in 2017 bn €

Scenario	2020	2025	2030	2035	2040	2045	2050	sum
<b>CS1: High wind, no integration --&gt; high integration</b>	0.00	0.00	-0.01	0.03	-0.07	-0.03	-0.02	<b>-0.09</b>
<b>CS1: High wind, no integration --&gt; partial integration</b>	0.00	0.00	-0.01	0.03	-0.06	-0.01	-0.01	<b>-0.06</b>
<b>CS1: Low wind, no integration --&gt; high integration</b>	0.03	0.01	-0.03	-0.76	-0.36	0.07	0.05	<b>-0.99</b>
<b>CS1: Low wind, no integration --&gt; partial integration</b>	0.04	0.09	-0.07	-0.62	-0.36	-0.06	0.05	<b>-0.92</b>



- In the high wind scenarios, the difference is relatively small
- Cost changes occur due to reduced grid expansion need in case of higher offshore interconnection
- Mainly in Sweden, Poland, and Lithuania. Other Countries less affected

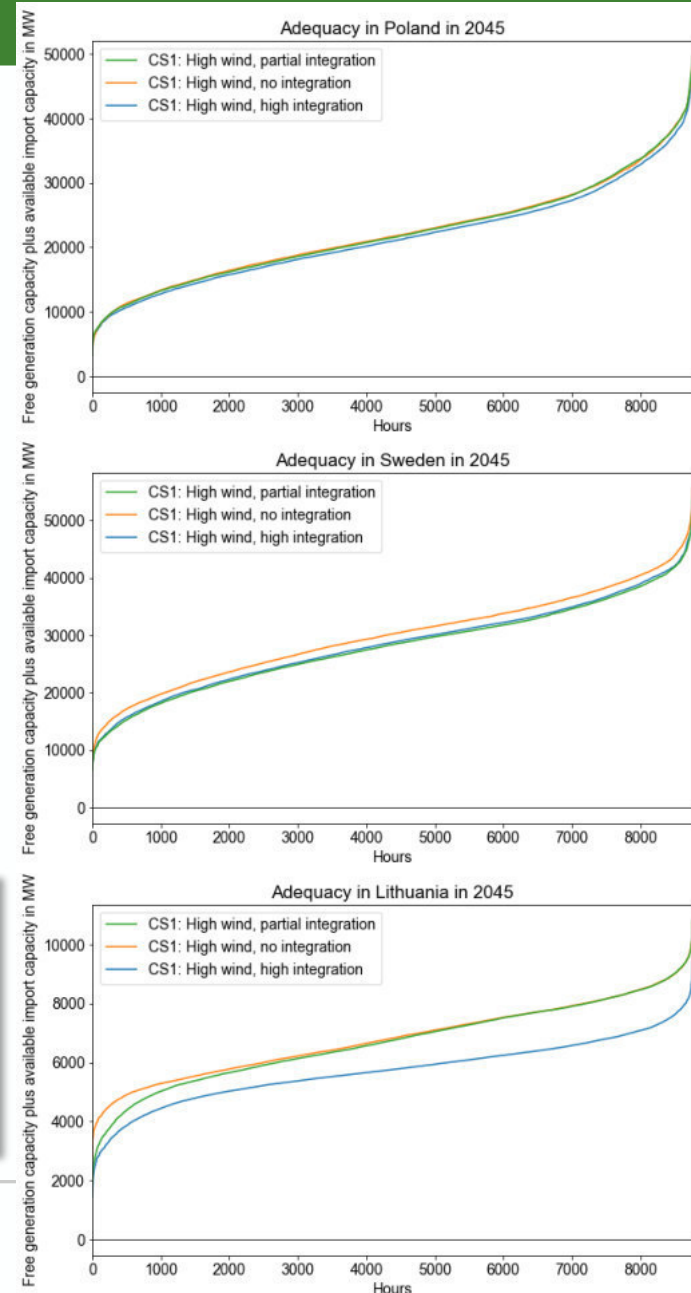
System Adequacy depends on:

- 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



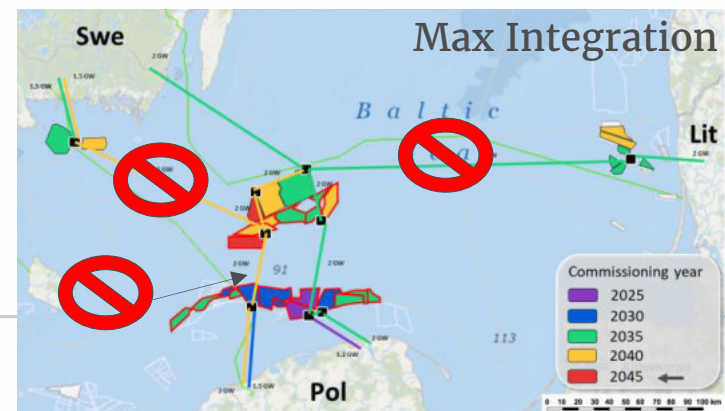
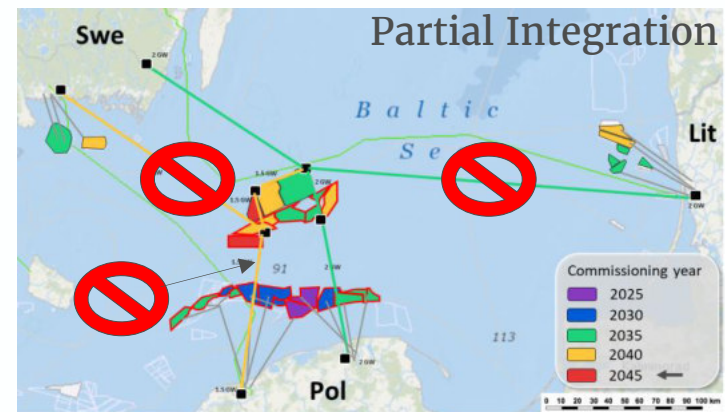
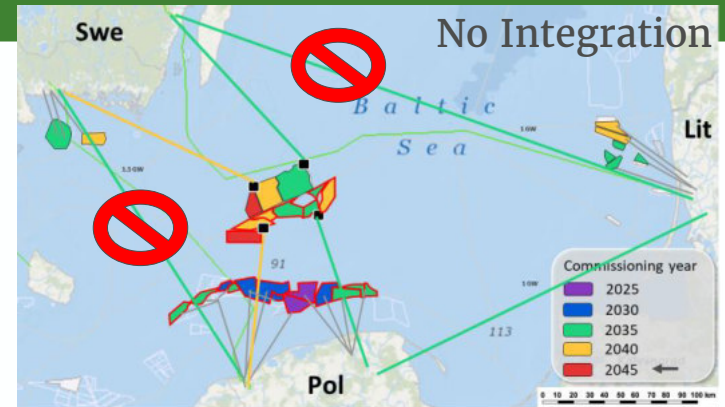
Question:

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

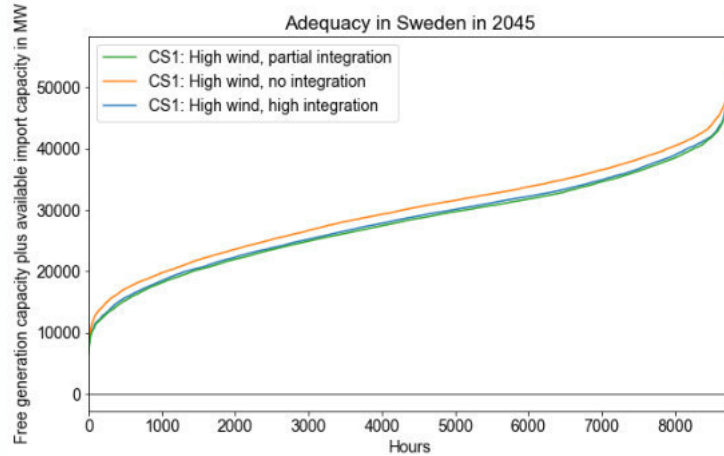
Comparison: Hourly Adequacy with and without lines.

Lines excluded for system adequacy comparison:

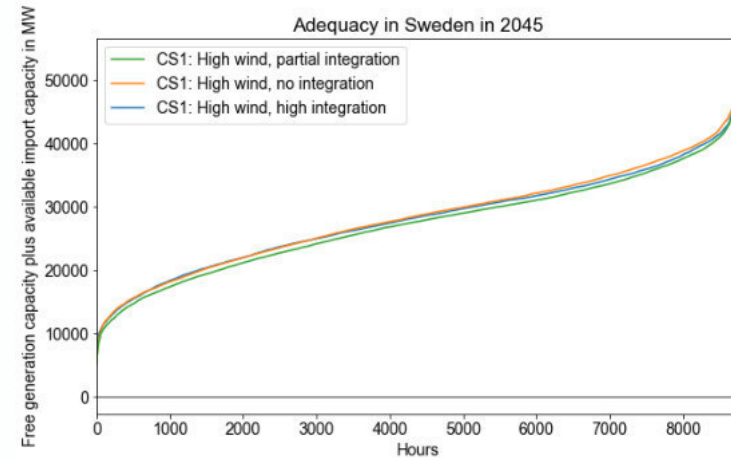
- No Integration: Main Interconnectors
- Partial Integration: Lines to Central Point
- Max Integration: Lines between Wind farms



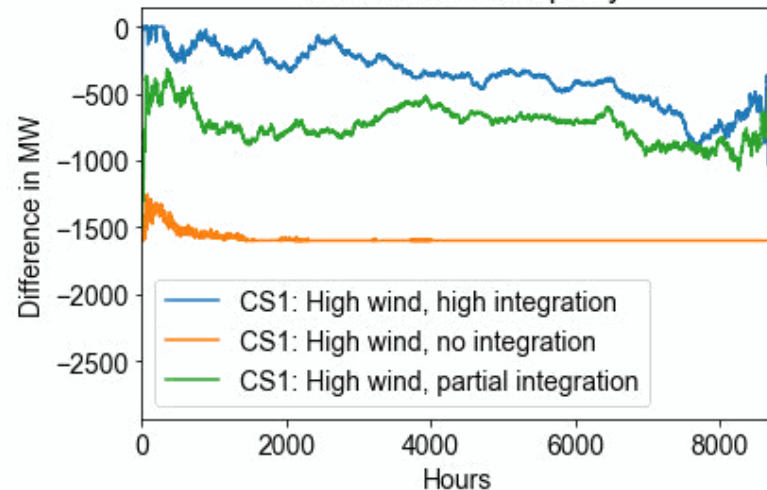
## Before



## After line outage



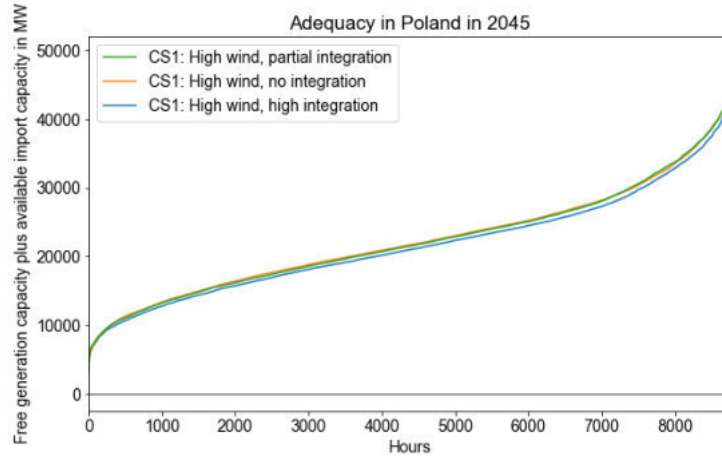
## Difference in Adequacy



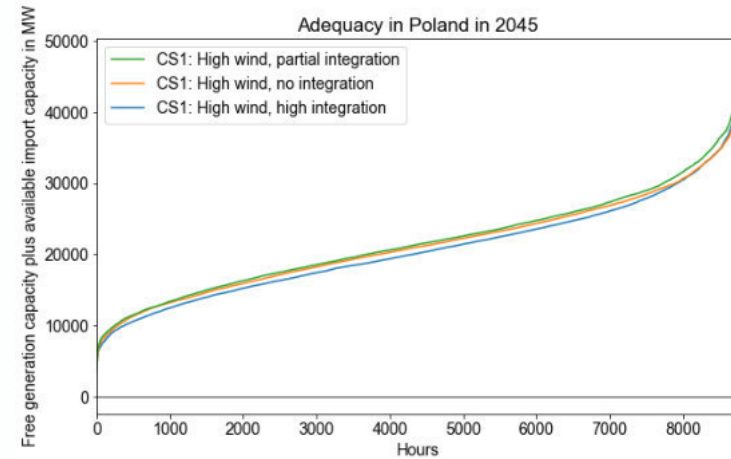
### Adequacy after line outage

- 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.

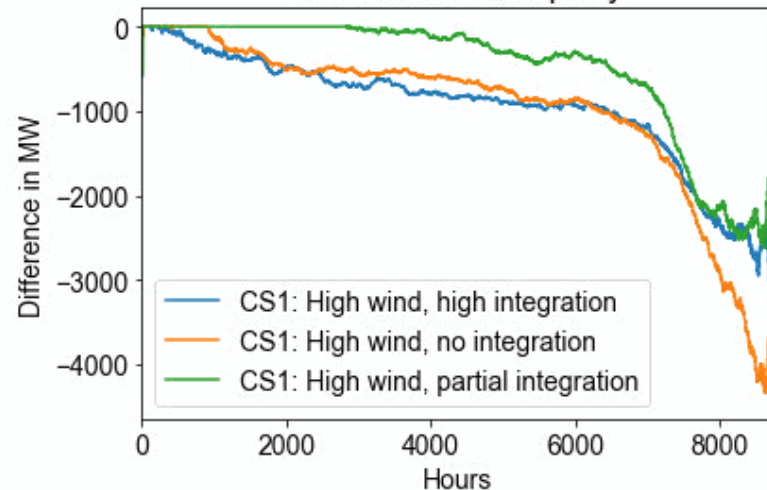
## Before



## After Line outage



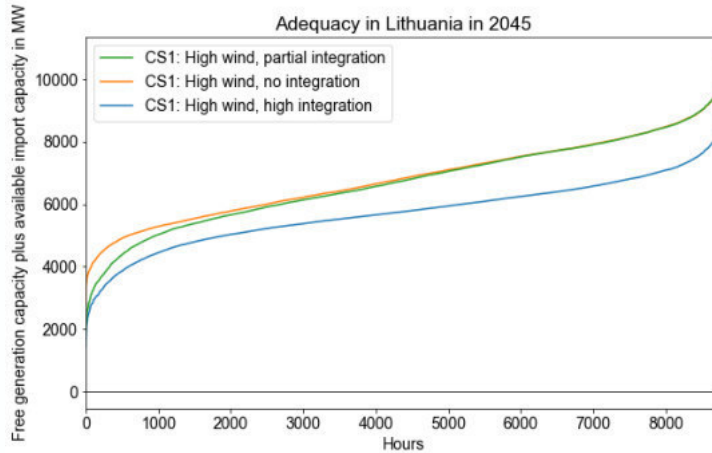
## Difference in Adequacy



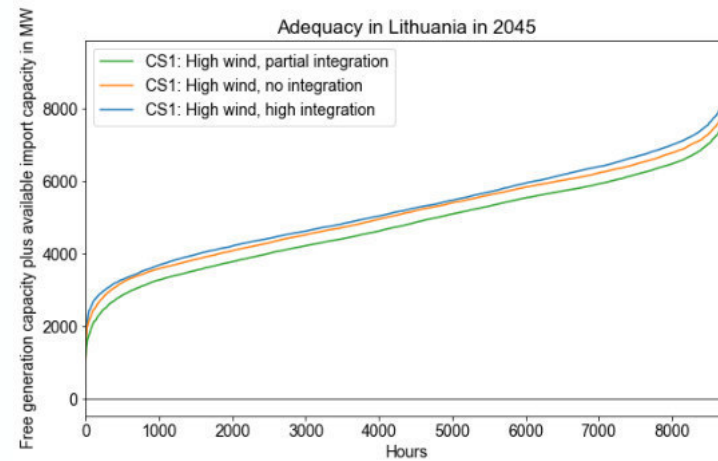
### Adequacy after line outage

- 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

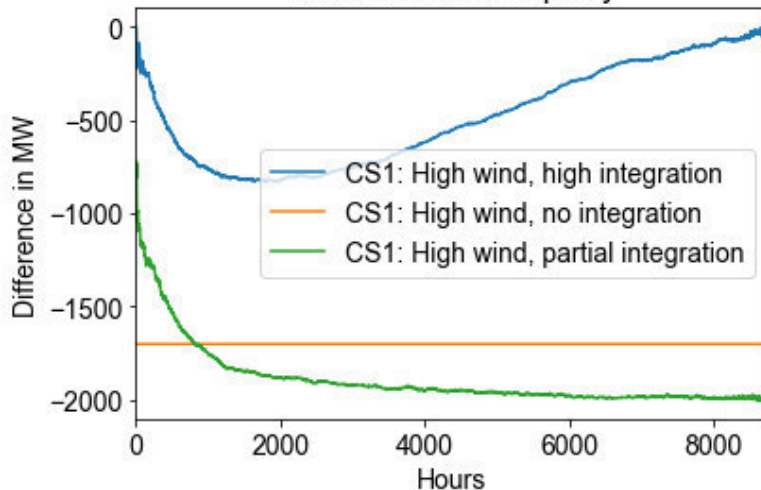
## Before



## After Line outage



## Difference in Adequacy



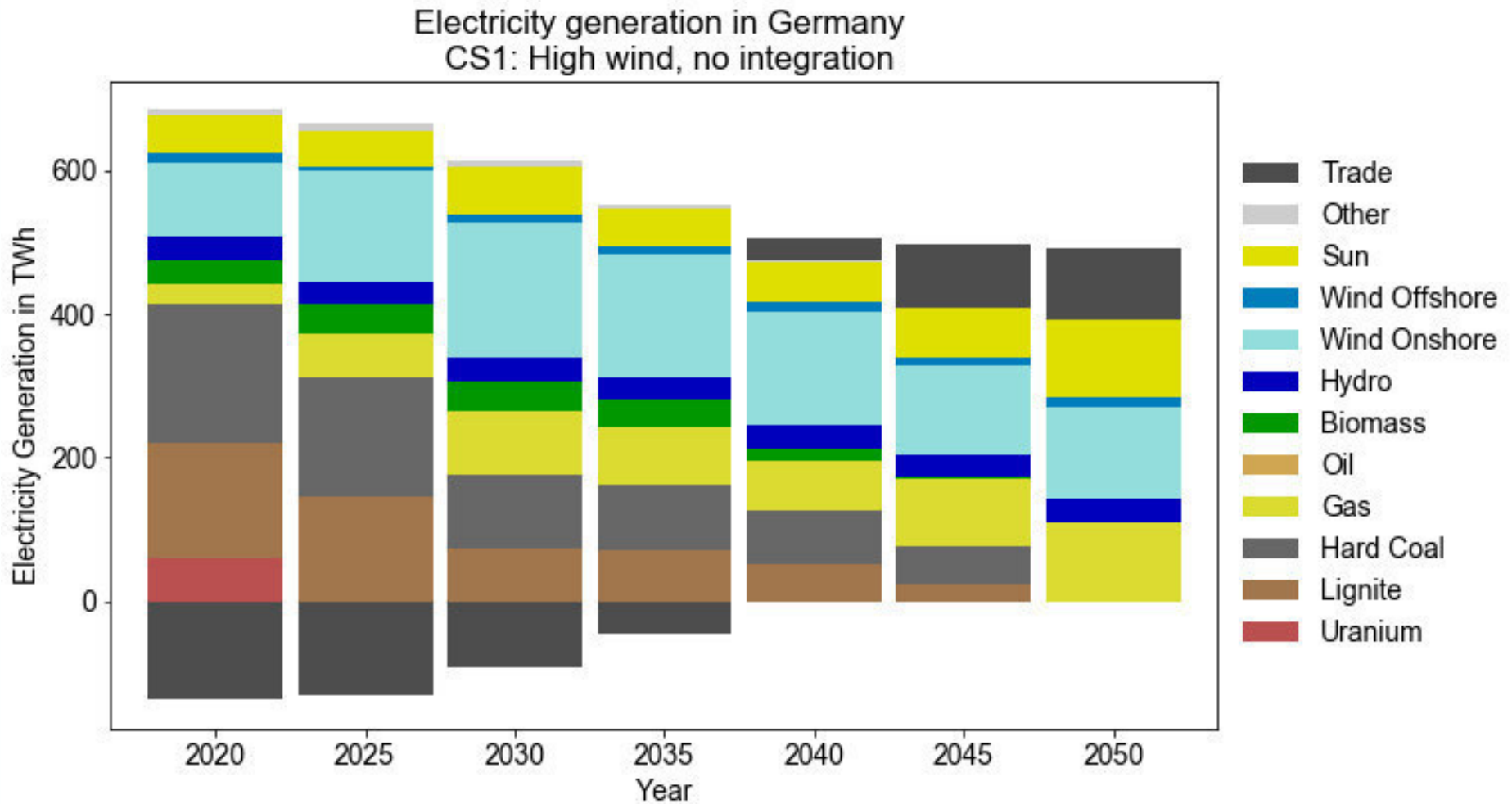
### Adequacy after line outage

- 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

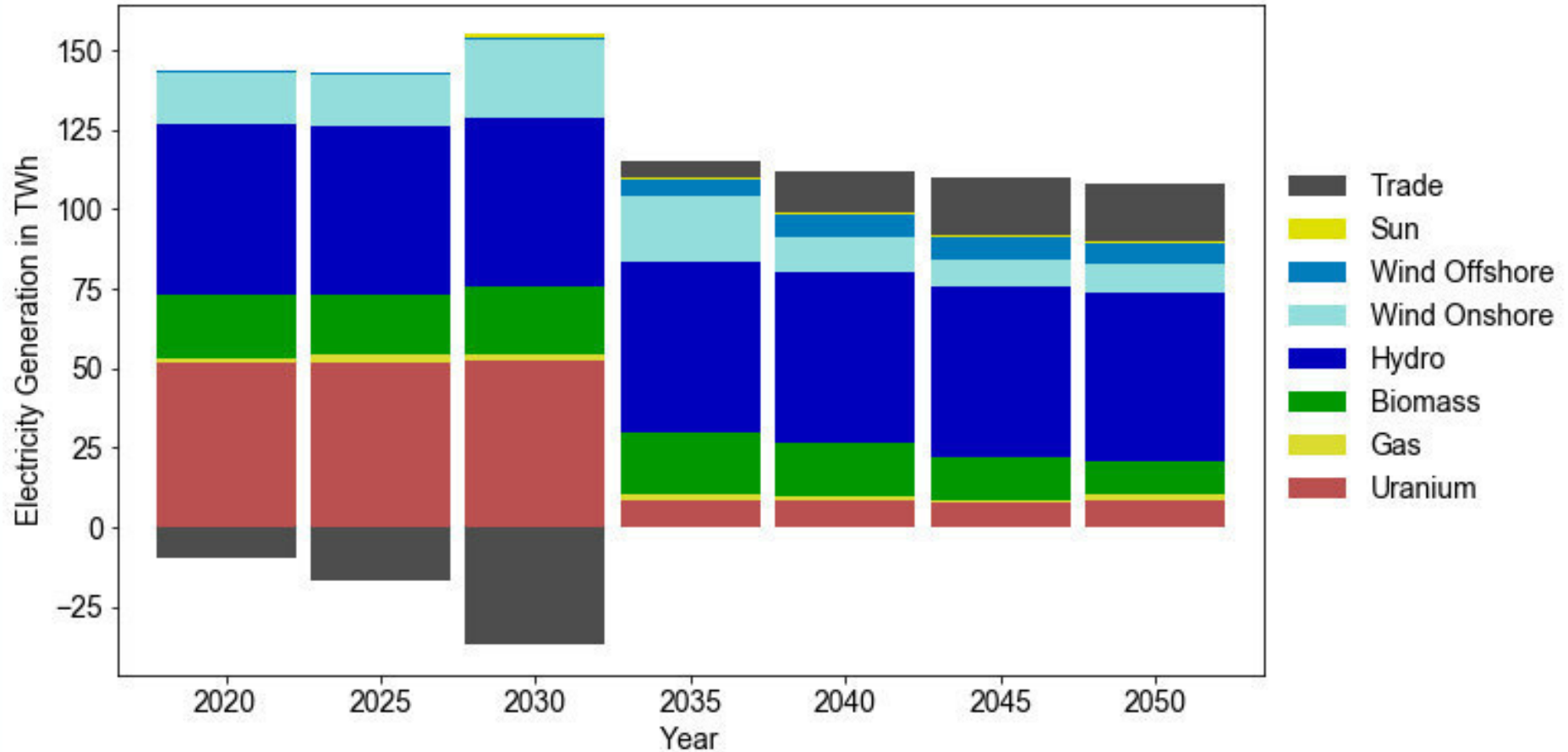
## Pre-Feasibility Analysis 2:

Germany – Sweden – Denmark

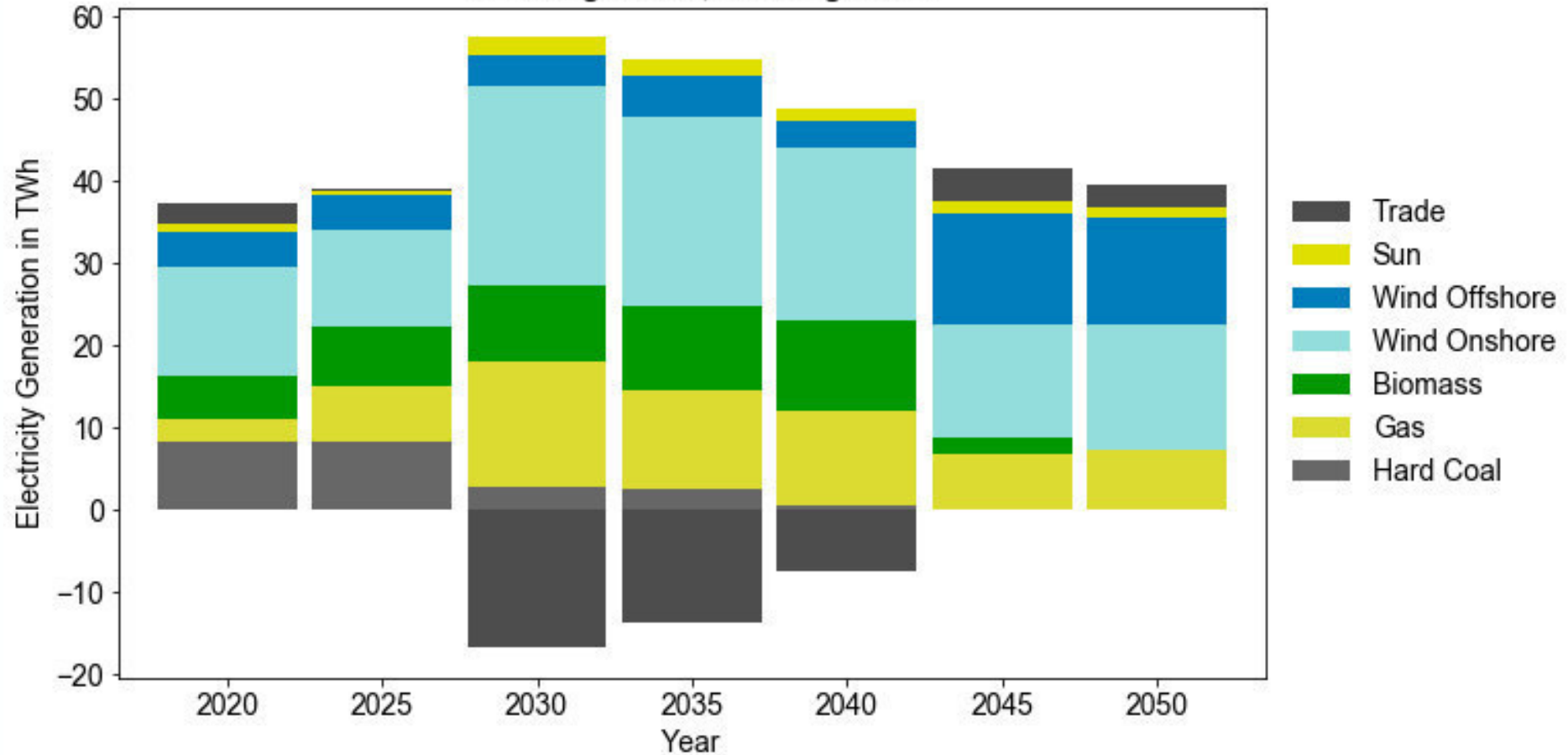
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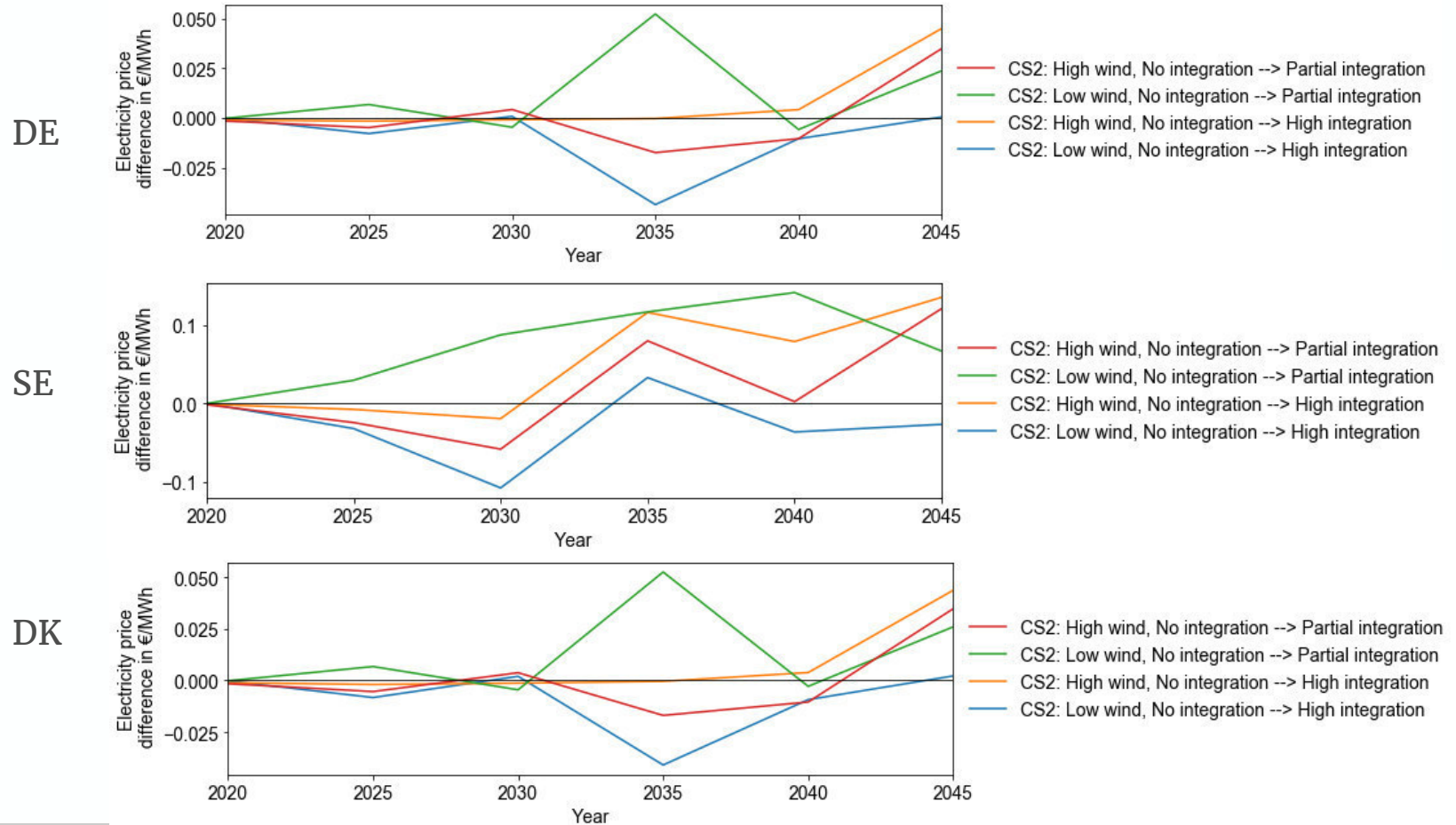
Electricity generation in Sweden  
CS2: High wind, no integration



Electricity generation in Denmark  
CS2: High wind, no integration

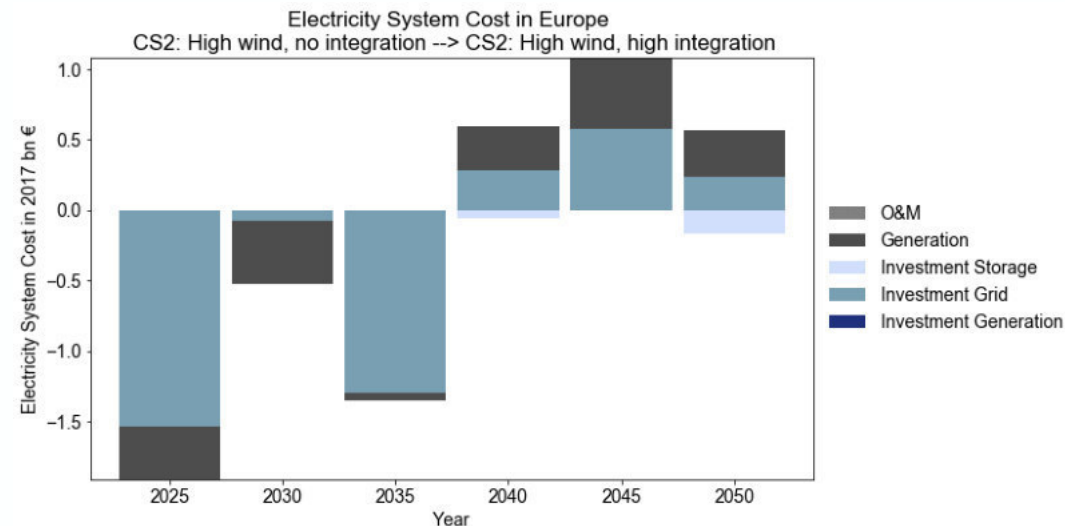
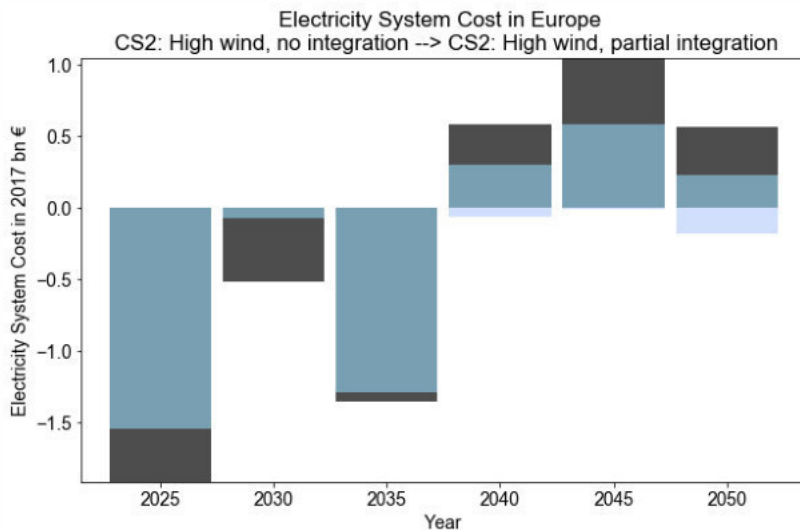


## Average electricity price difference for scenario variations



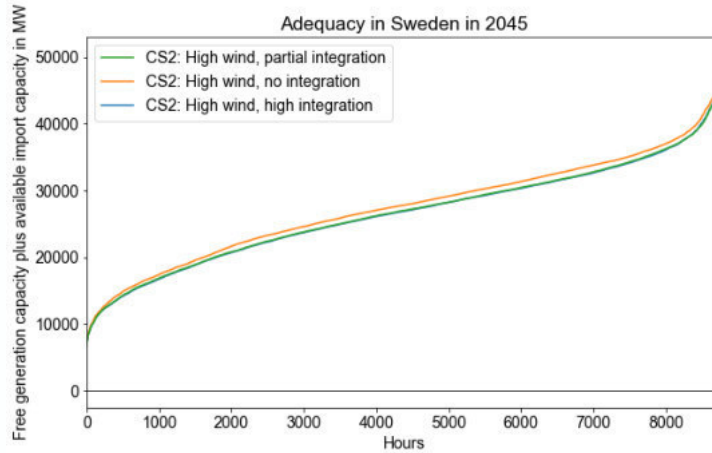
## Overall system cost differences

Scenario	2025	2030	2035	2040	2045	2050	sum
<b>CS2: High wind, no integration --&gt; high integration</b>	-1.91	-0.52	-1.35	0.54	1.09	0.41	-1.76
<b>CS2: High wind, no integration --&gt; partial integration</b>	-1.92	-0.52	-1.35	0.52	1.05	0.38	-1.83
<b>CS2: Low wind, no integration --&gt; high integration</b>	0.00	0.00	0.00	-0.01	0.01	0.01	0.01
<b>CS2: Low wind, no integration --&gt; partial integration</b>	0.01	-0.04	-0.02	0.03	0.03	0.03	0.03

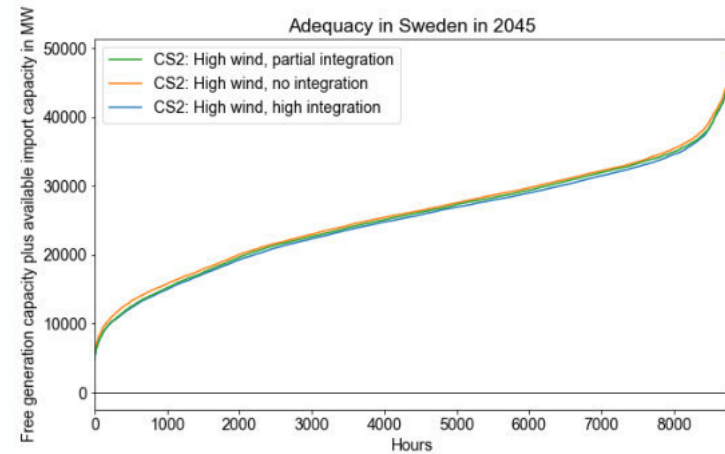


- Cost decreases also here mostly in grid expansion.
- Mainly in the scenario-relevant countries Germany, Sweden, and Denmark

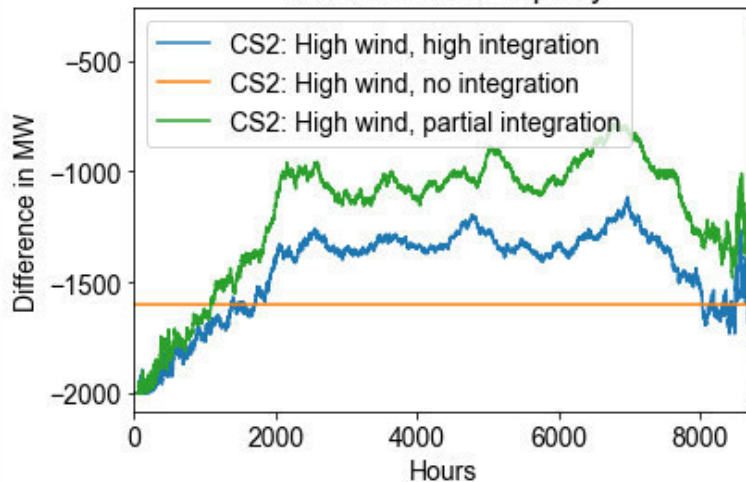
## Before



## After line outage



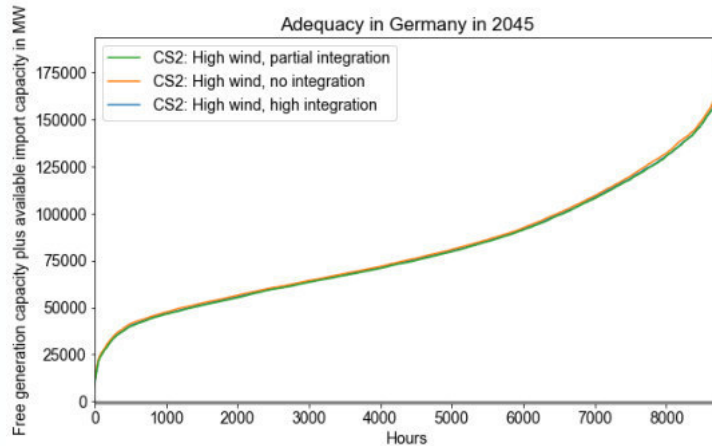
## Difference in Adequacy



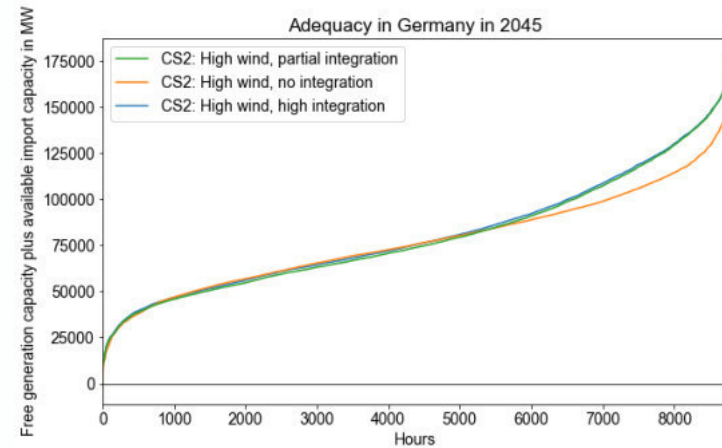
## Adequacy after line outage

- Line outage similar between scenarios in relevant hours
- No integration scenario mostly affected
- Overall reduction mostly less than 2000 MW

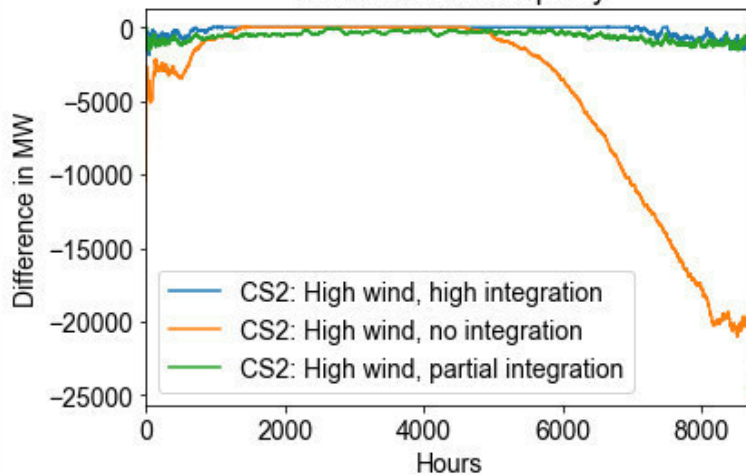
## Before



## After line outage



## Difference in Adequacy



## Adequacy after line outage

- Line outage similar between scenarios in relevant hours
- No integration scenario mostly affected
- Overall reduction mostly less than 2000 MW

## 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