Power system in Europe and its influence in Norway: Preliminary results from EMPIRE

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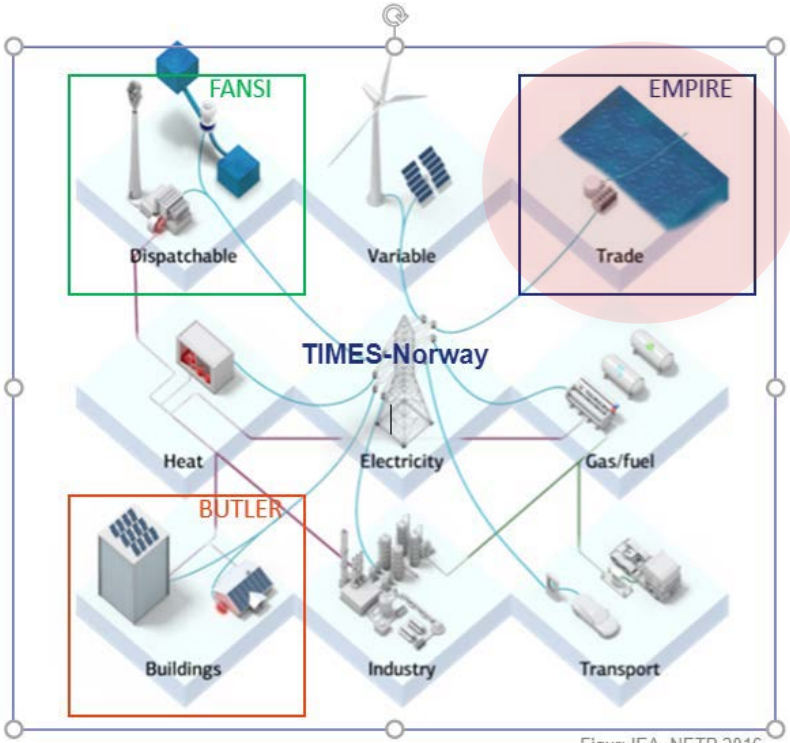
Outline

- Introduction to EMPIRE
- Storylines for Europe
- Results - Energy Nation
  - Capacity and generation in Europe
  - Price developments
  - Trade with Norway
- Conclusion and future work

Introduction to EMPIRE



Figur: IEA, NETP 2016

Introduction to EMPIRE

Input

- **Economic parameters**
  - Discount factors
  - Generation and transmission costs (operation and investment)
  - Load shedding costs
  - Upper bound investments in capacity and transmission
- **Technology features**
  - Aggregated loads and capacities by country
  - Seasonal capacities
  - Exchange losses
  - Pump efficiencies
  - Generator heat rates
- **Stochastic scenarios**
  - Wind and solar production

Multi-horizon stochastic optimization model

Objective function: Minimize total system costs

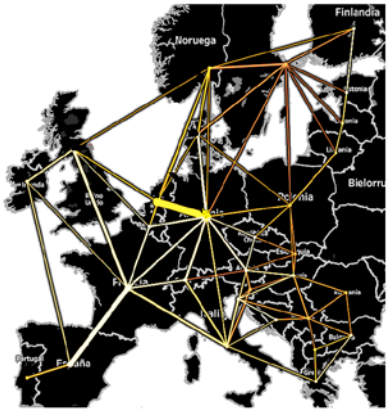
Model constraints:

- Annual investments in capacity installation and transmission expansions
- Power balance
- Generation capacity
- Ramp-up constraints for thermal generators
- Power flow between nodes
- Generation of hydropower technologies (seasonal)
- Pump storage generators

Planning Horizon of 35 years (2020-2055).
Hourly dispatch.
Investment windows of 5 years

Output

- Generation and line capacities
- Hourly system operation
  - Dispatch schedules
  - Power flows between nodes
  - Energy used for pumping
  - Load shedding
- Total system costs
- Dual prices



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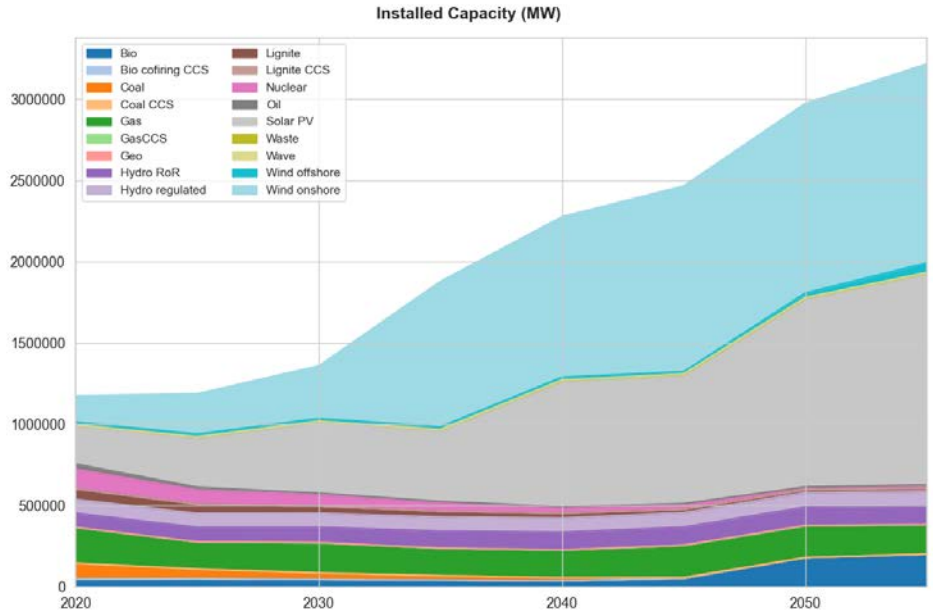
Scenarios – Interpretation of scenarios in Europe

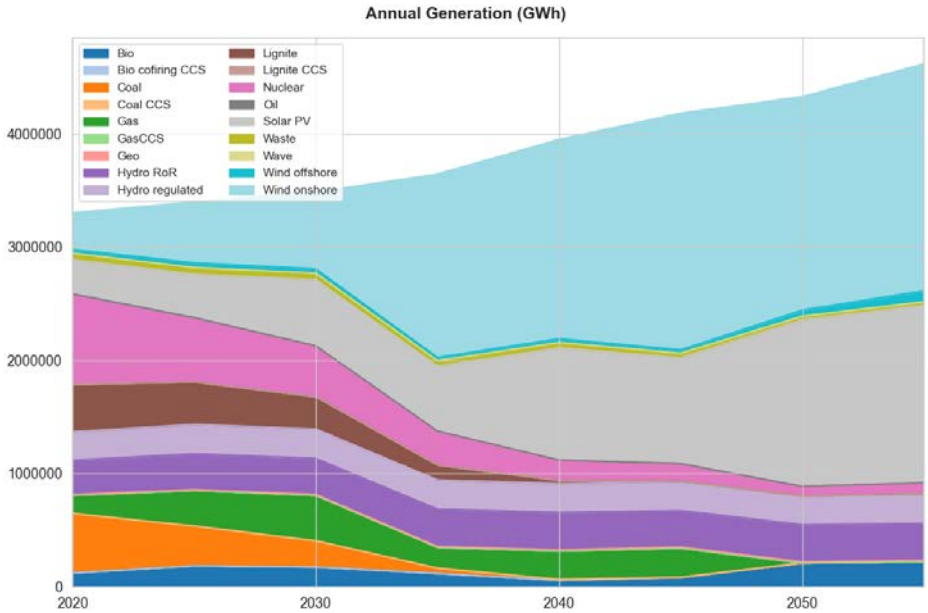
Scenario	CCS	Transmission	Technology learning curves	Gas/oil phased out
Energy Nation	NO	+20% ENTSO-E limits	High	2050 phase out
Nature Nation	YES	ENTSO-E limits	Moderate	2050 phase out
Petroleum Nation	YES	Higher than ENTSO-E	High	No phase out
Climate Panic Nation	NO	ENTSO-E limits	High	2030 phase out

Energy Nation – Assumptions input data

Parameter	Assumption	Qualitative storylines
CO2 Cap	1.5°C scenario – A Clean Planet for all (EU strategy) → 95% reduction	“There is wide political will to tackle the climate crisis”
Fossil fuel costs	20% reduction – 2°C base scenario	“Norwegian oil and gas phased out by 2050”. Assumed also in Europe. This produce the oil and gas demand decrease and fuel prices drop.
CCS assumption	No CCS	“CCS technology never becomes commercial”
Demand	From GENeSYS-MOD → high electrification rates	High electrification of industry and transport sector
Conventional technologies costs	95% of 2°C base scenario	Improvements compare to business-as-usual scenario.
RES costs	85% of 2°C base scenario	

Energy Nation – Capacity and generation in Europe





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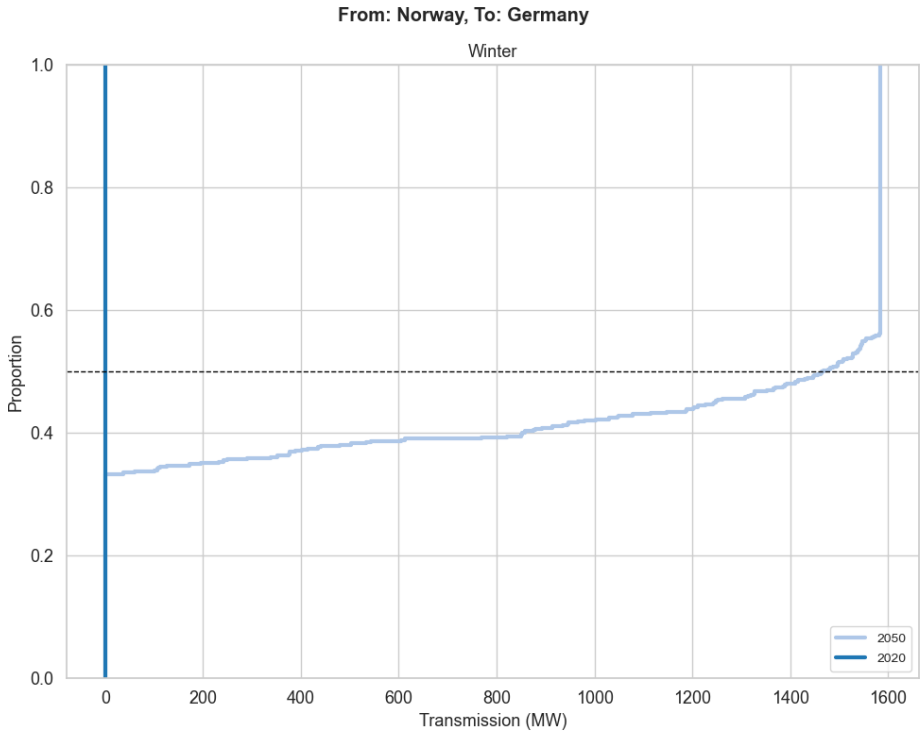
Energy Nation – Exports and transmission capacities



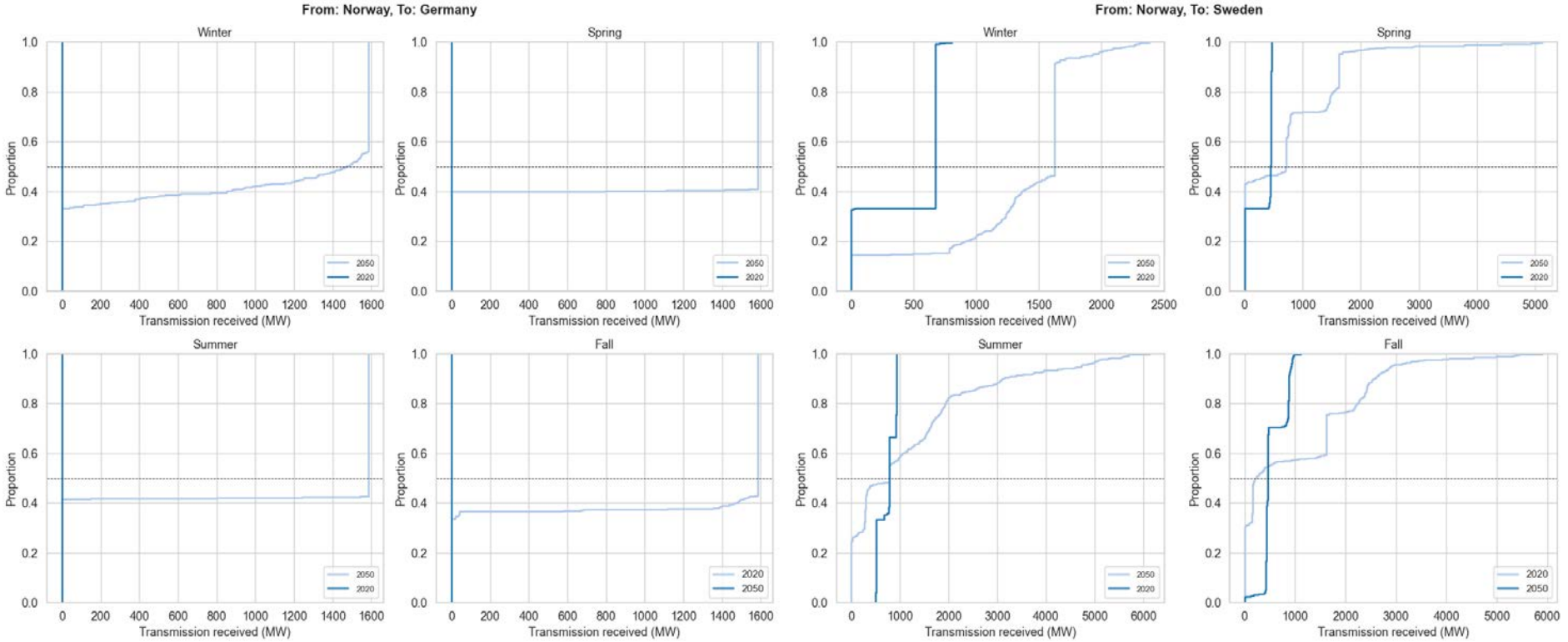
Estimator of Cumulative Distribution Function

It shows *the probability that a data value is less than or equal to a certain value.*

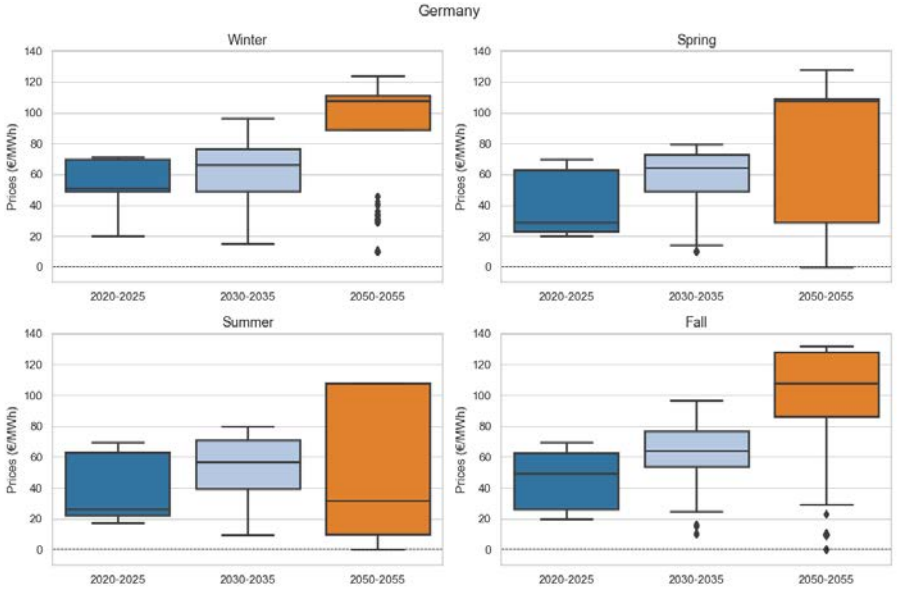
By 2020
No installed capacity

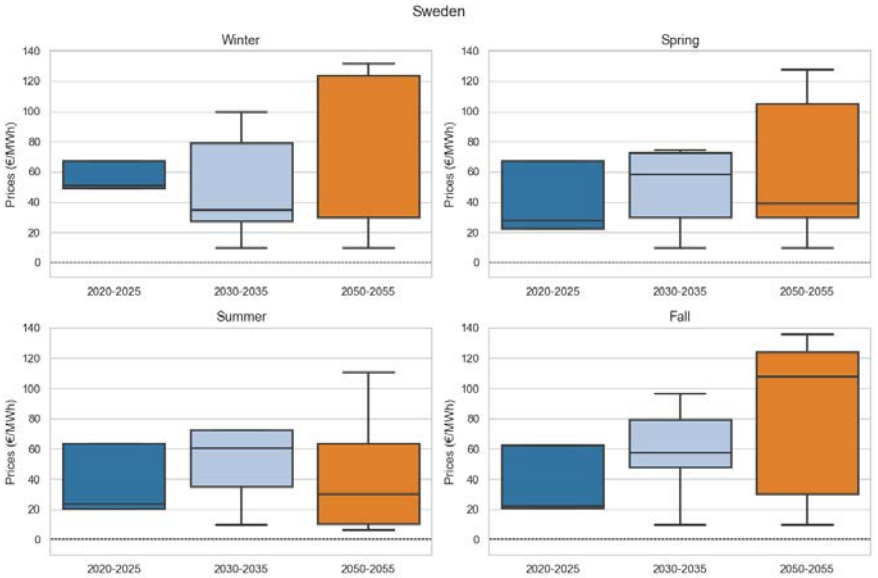
By 2050
55% of the time the capacity is deployed at a lower capacity than its maximum.
45% of the time used at maximum capacity

Energy Nation – Exports and transmission capacities



Energy Nation – Prices in neighbouring countries





Conclusion and future work

- Europe and Norway will be mostly aligned in their objectives
- Storylines have been defined → quantitative work
- CCS and transmission capacities major influence in prices

- Link between TIMES and EMPIRE

Thank you!

Any questions?

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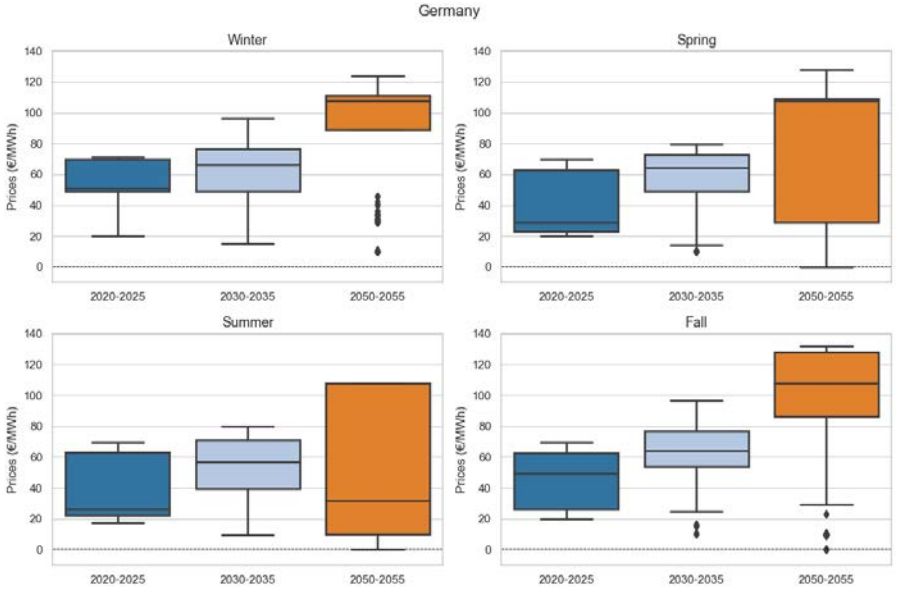
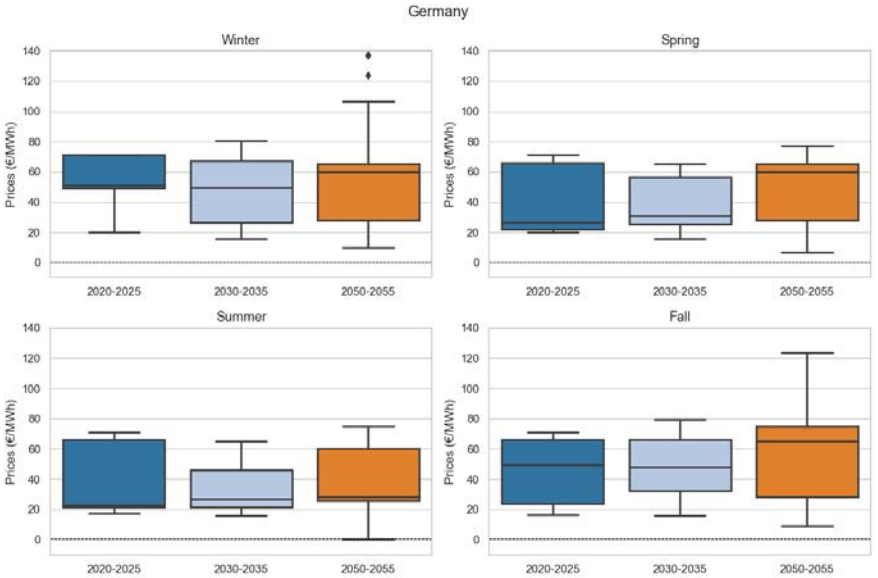
Energy Nation (CCS) – Prices in neighbouring countries

Without CCS



With CCS



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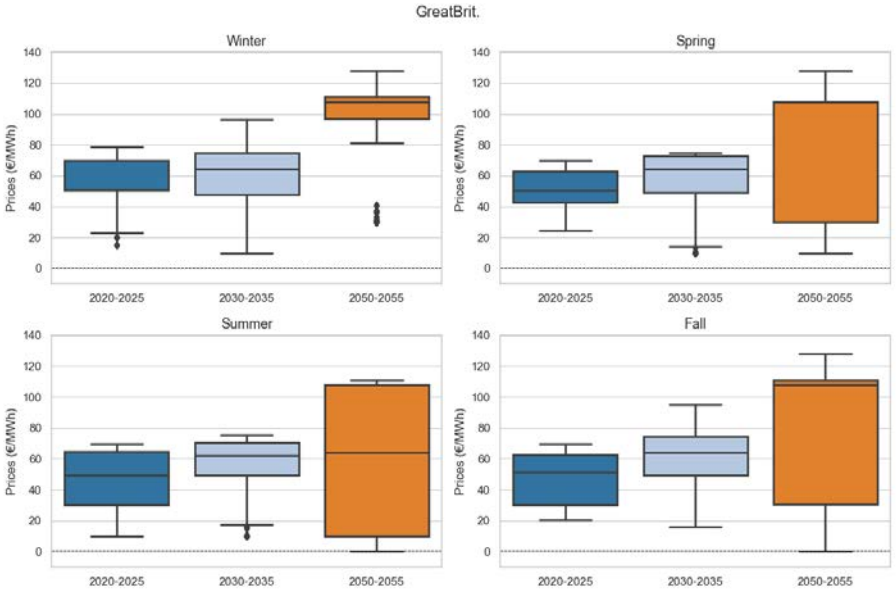

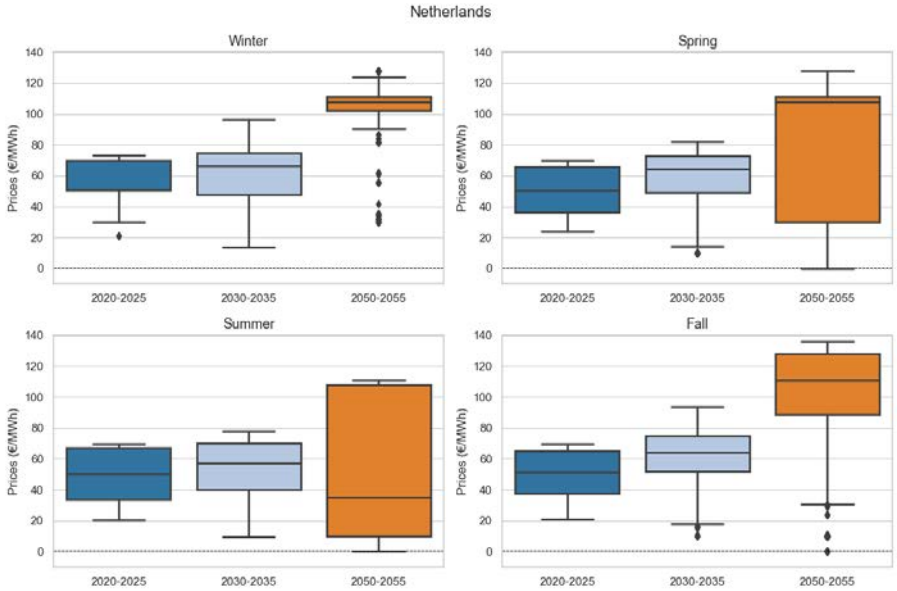

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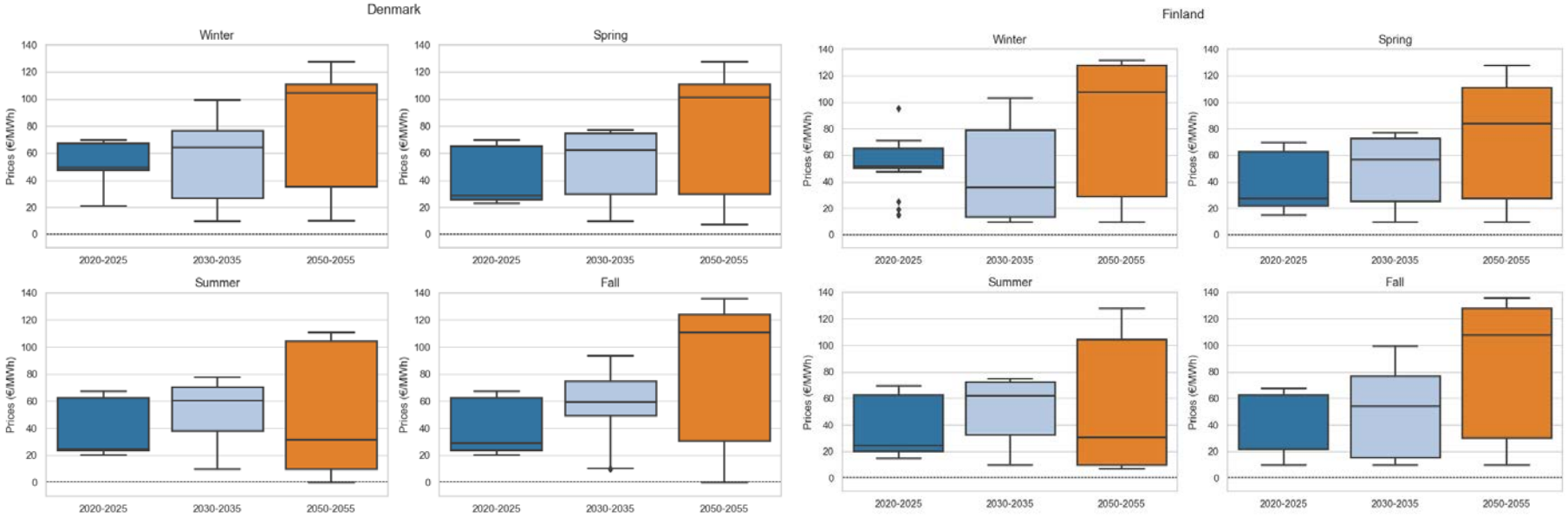

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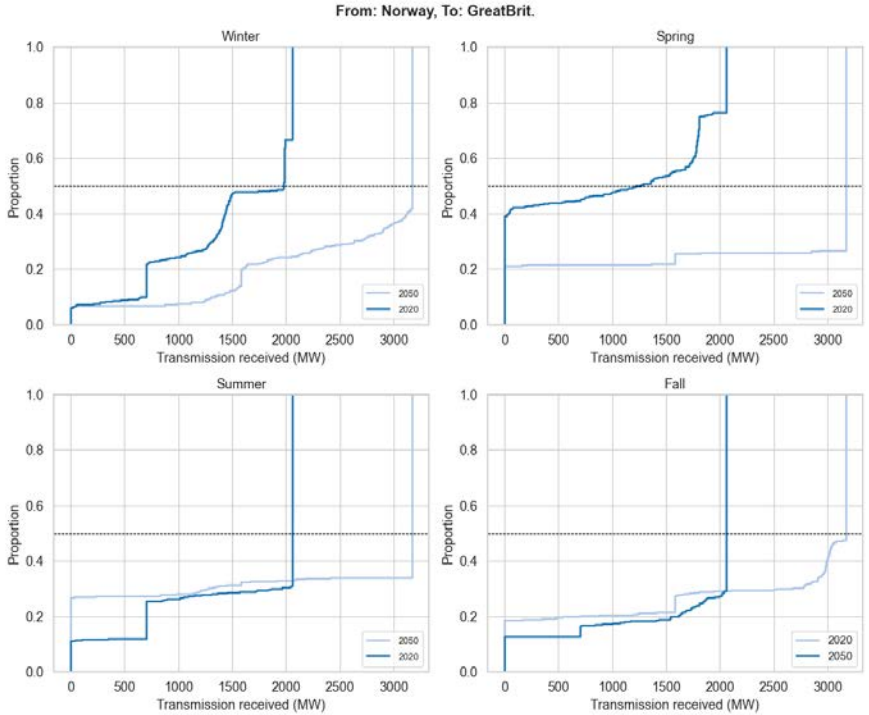
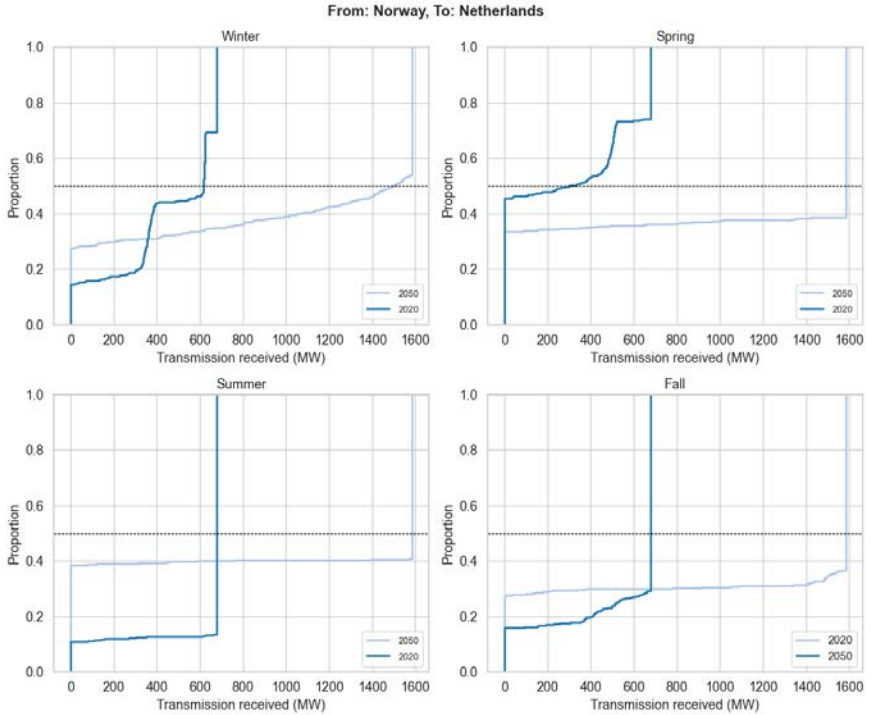
Energy Nation – Power Exports





Energy Nation – Power Exports