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Why geographical balancing decreases electricity storage needs: a model-based illustration for Europe

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MODEZEEN

Modellierung (De-)Zentraler Energiewenden: Wechselwirkungen, Koordination und Lösungsansätze aus systemorientierter Perspektive

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Background

- Decarbonization of the economy requires a decarbonization of the energy system

  → fossil sources are replaced by renewable energy sources
- Main sources of (variable) renewable energy: solar (photovoltaic) and wind

  → Defining characteristic is their **variability**
- How to guarantee power supply in times of no wind and no sun?

  (1) Imports from an area that has excess energy

  (2) Storage

  (3) Demand management

- Previous studies came to different conclusions on future storage requirements in Germany and Europe

Reference	Region	RES share	Conclusions on storage requirements
VDE (2012)	Germany	up to 100%	36 GW / 184 GWh short-term, 68 GW / 26 TWh long-term
Jägemann et al. (2013)	Europe	up to 85%	50 - 178 GW | 5 - 223 TWh
Fürsch et al. (2013)	Europe	up to 80%	Energy and power ratings of around 10% and 15% of generation capacity
Pape et al. (2014)	Germany & Europe	up to 80%	0 - 20 GW in Germany depending on scenario
Bussar et al. (2014-2016)	Europe & MENA	100%	Up to 320 GW / 1.6 TWh NaS, 190 GW / 2.7 TWh PHS, 900(550) GW / 800 TWh H2

… and many more

- **General notion:** larger balancing area decreases electricity storage needs

  → unclear: <u>what exactly is driving this finding?</u>

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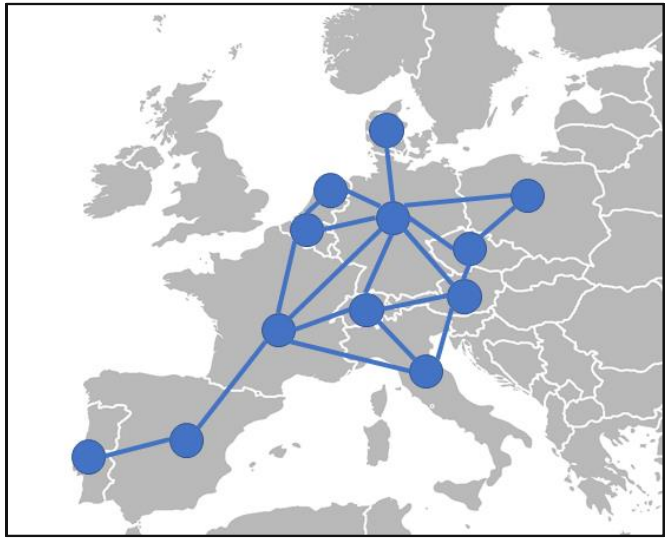
1 Research question

To what extent does geographical balancing mitigate storage needs in Europe and what are the drivers?

The model DIETER

- Dispatch and Investment Evaluation Tool with Endogenous Renewables (DIETER)
  - Open-source tool, used in various previous publications: www.diw.de/dieter
- Cost minimizing, linear dispatch and investment model
- Country-specific renewable energy constraint, relative to demand
- Endogenous variables:
  - Installed capacities (power plants, electricity storage)
  - Hourly generation, curtailment, storage (dis-)charging, NTC flows
- Covers 12 countries (nodes)
  - Net transfer capacity model between nodes
  - No grid modelled within node ("copper plate")
- Focus on electricity market, no sector coupling



Input data

- General idea: lean on established scenarios
- Main source: Sustainable transition scenario of ten-year network development plan (TYNDP) from ENTSO-E (2018):
  - Limits on generation capacities
  - Net transfer capacities (fixed)
  - Hourly load profiles
  - Fuel and CO_2 costs
- Additional data from other sources:
  - Renewable energy generation profiles (renewables.ninja)
  - Investment costs
  - Efficiency of generators and storage

Capacity expansion

- *Lower, but no upper limit* on investment in renewable energy sources (RES)
  - PV, wind onshore and offshore
- *Upper limit* on investment in conventional and nuclear generation given by TYNDP (2018)

Electricity storage

- Two storage technologies assumed:
  - Short-term: li-ion batteries
  - Long-term: power-to-gas-to-power (P2G2P)
  - Pumped-hydro storage deactivated (to allow for better identification of effects)
- Hydro reservoirs fixed as given by TYNDP (2018)

2 Drivers

Driver	Description
• Demand effect	→ Different demand patters (profile & level)
• Renewable availability effect	
• Profile effect	→ Different sun & wind patterns
• Level effect	→ Different total full load hours of sun & wind
• Capacity portfolio effect	
• Storage	→ Different legacy storage portfolios (e.g., reservoirs)
• Power plants	→ Different legacy power plant portfolios (e.g., nuclear)

Scenario specifications

- **Country effect:**
  → *No cross-country flow of electricity*

- **Demand effect:**
  → *Assume that all countries have Germany's electricity demand, scaled to their level*
- **Renewable availability effect:**
  → *Assume that all countries have Germany's PV / wind capacity factors (not scaled)*

Scenario runs

We conduct the following runs:

Country effect

1. “no NTC” (no cross-country flows allowed):
   a) **Default** time series
   b) **Demand** in all countries as in Germany
   c) **PV profiles** in all countries as in Germany
   d) **Wind profiles** in all countries as in Germany

2. “NTC” (cross-country flows allowed):
   a) **Default** time series
   b) **Demand** in all countries as in Germany
   c) **PV profiles** in all countries as in Germany
   d) **Wind profiles** in all countries as in Germany

Factor separation / driver

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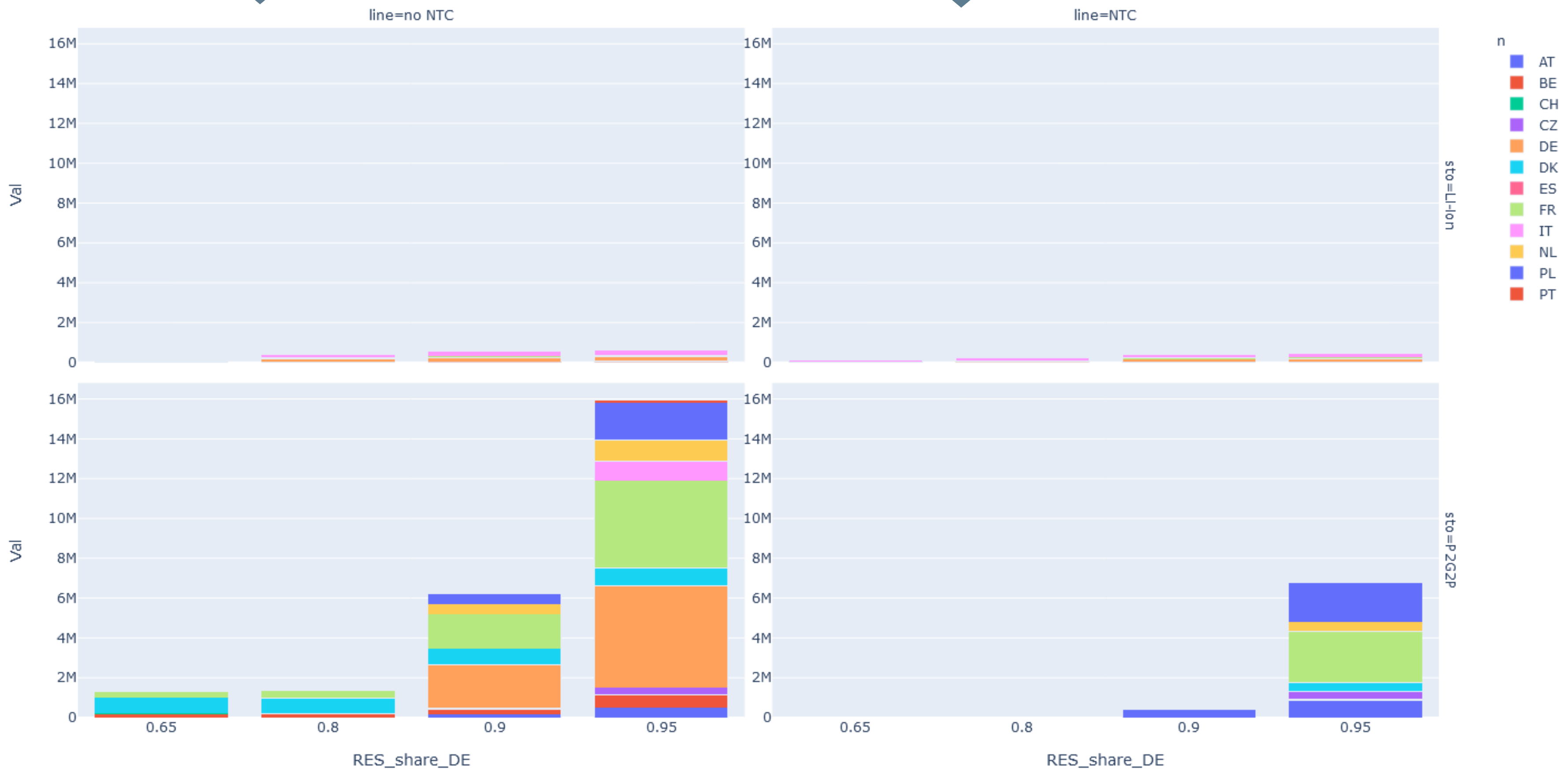
3.1 Country effects - Storage needs (Energy)

Without interconnection | With interconnection

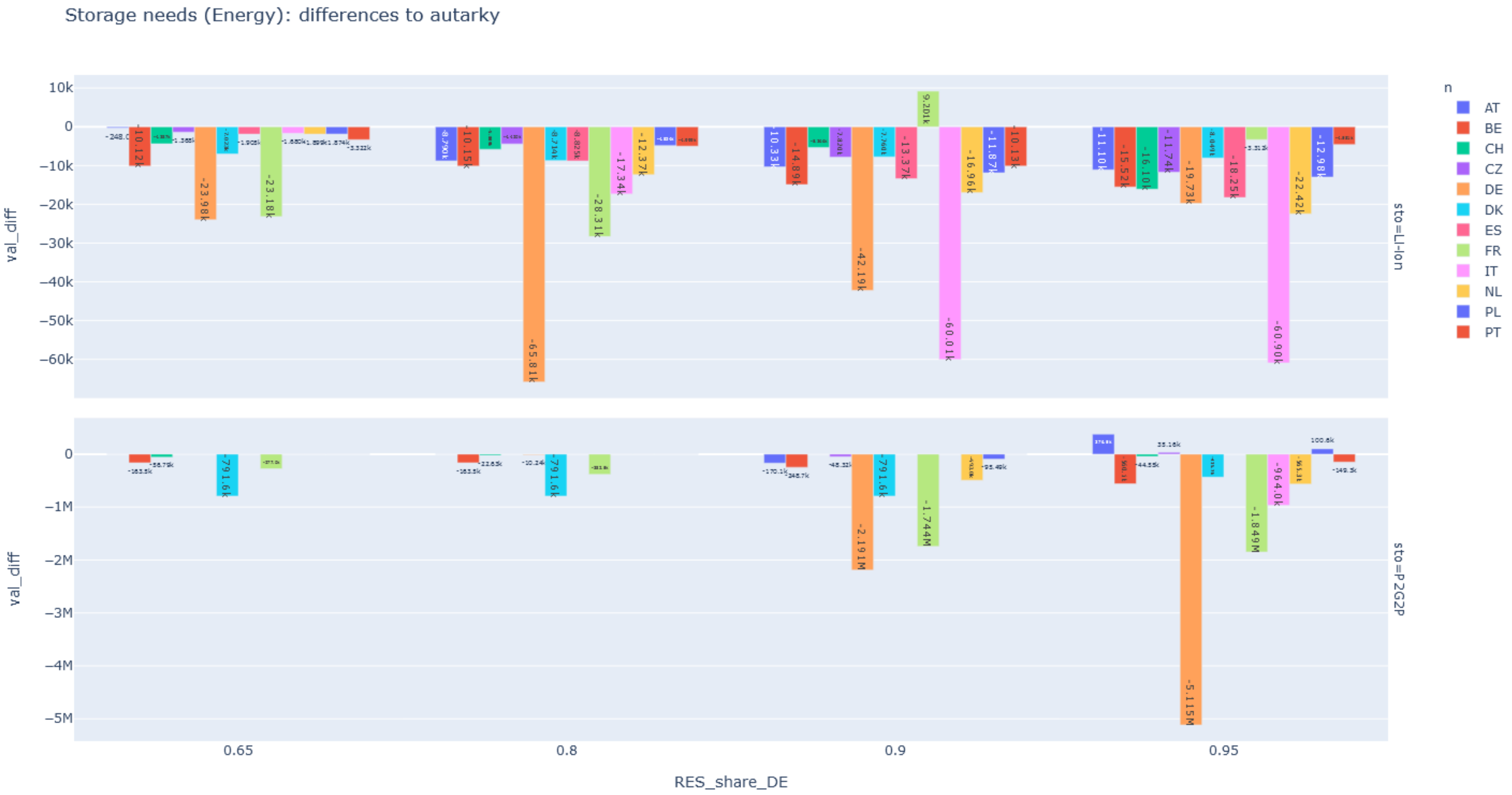
Short-term storage: **Li-ion**

Long-term storage: **P2G2P**



→ Geographical balancing mitigates long-term storage

Country effects - Storage needs (Energy) – difference to autarky



→ Heterogenous effects for individual countries

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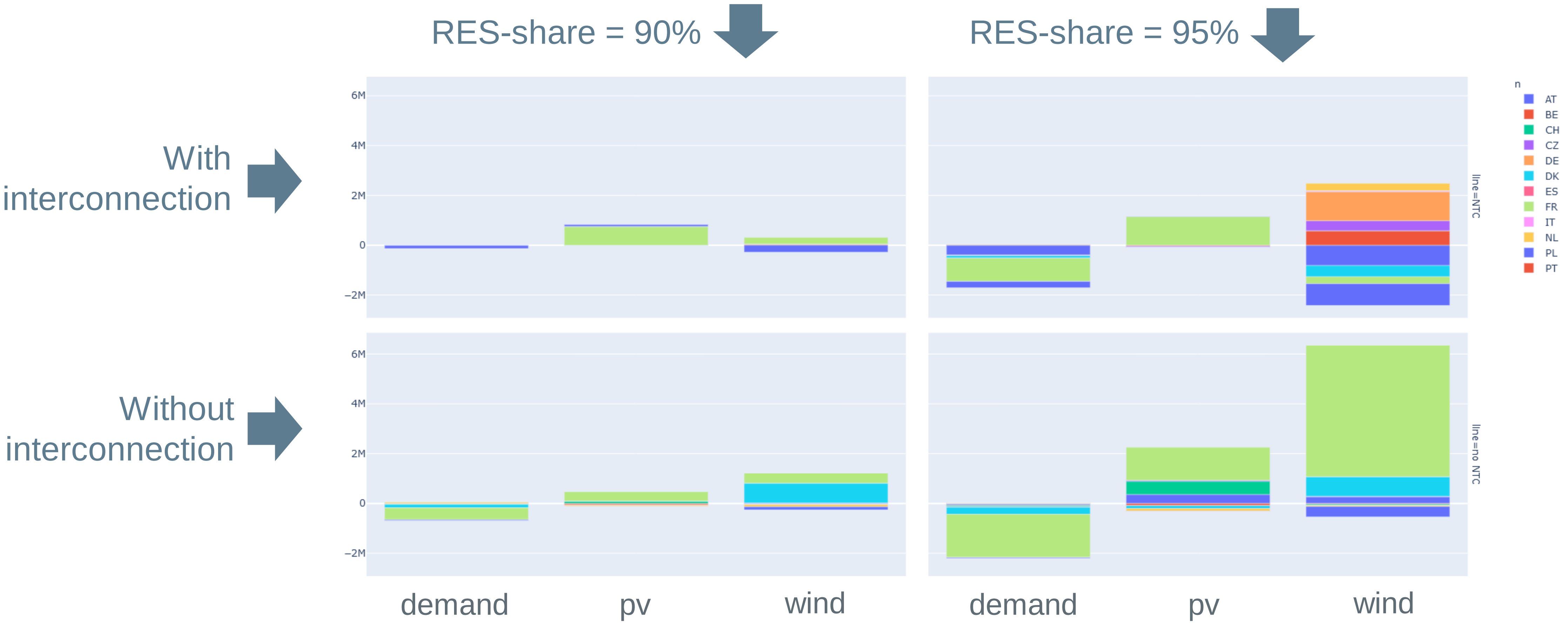
Factor separation - long-term storage needs (energy) – difference to default



Uniform wind patterns lead to
→ more long-term storage in "no-NTC" scenario
→ reshuffling of long-term storage in "NTC" scenario

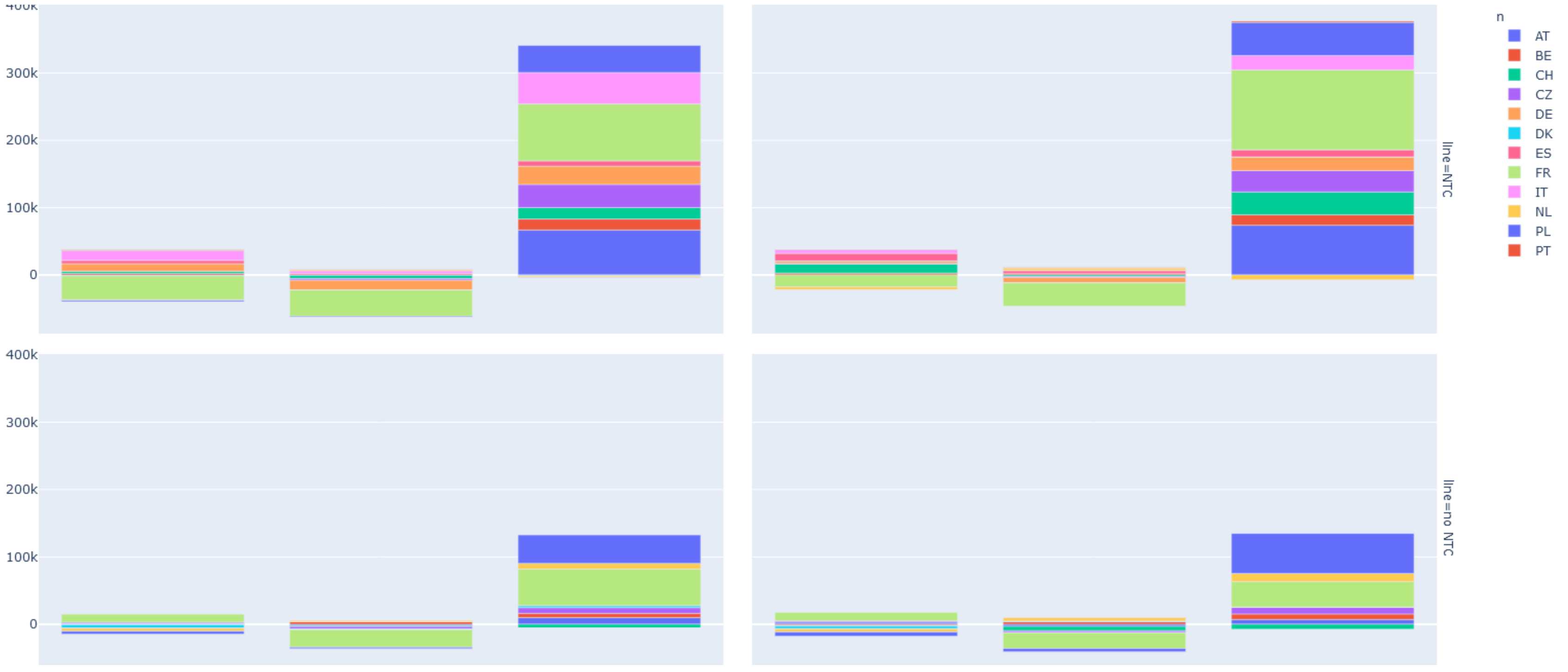
3.2 Factor separation - short-term storage needs (energy) – difference to default

RES-share = 90%

RES-share = 95%

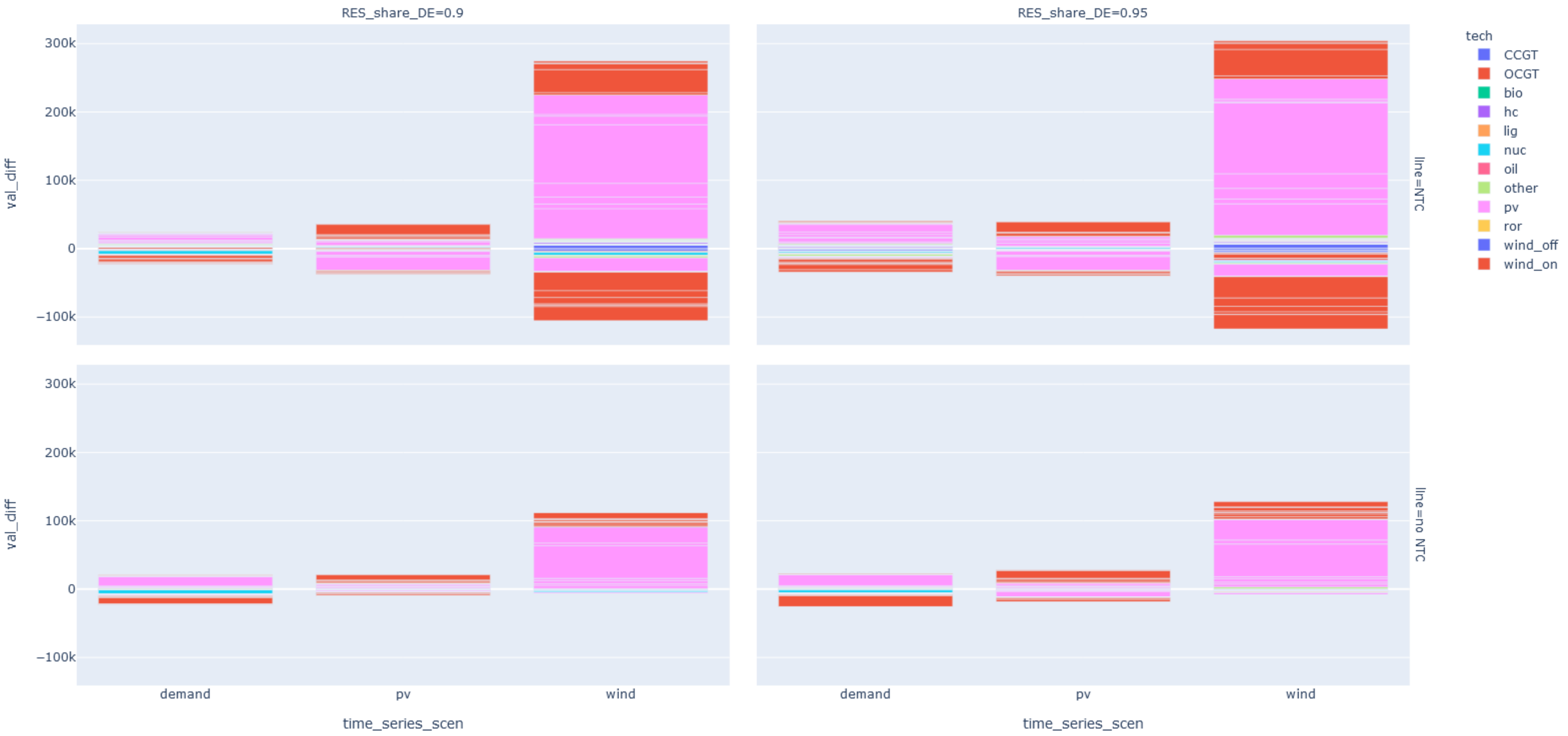
With interconnection

Without interconnection



Uniform wind patterns → more short-term storage (in “no NTC” and “NTC”)
… which is triggered by higher PV capacities

3.2 Factor separation - power plant capacities – difference to default



- Uniform (German) wind patterns → higher investments into PV
- Uniform wind and PV patterns have limited influence

4 Conclusion

(1) Need for storage in Europe decreases with interconnection

- Long-term storage decreases much stronger than short-term storage

(2) Differentiated wind, PV, and demand profiles have a **small effect** on storage need

- *Differentiated wind and PV profiles* have *a decreasing effect*
  - Different effects for energy and power & for long- and short-term storages
- *Differentiated demand profiles* have an *increasing effect*

(3) Portfolio effect might be most important?

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Thank you for your attention!

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