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Weather data‘s spatial aggregation in power system models with high shares of hydropower

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Introduction / Material & Methods

Material & Methods

Power system model:

- highRES (Price, 2022)
  - Electricity system model
  - (Linear) optimization
  - Investment and dispatch
  - Country level
  - Transmission
  - Hourly resolution
  - EU27+CH+NO+UK
  - Target year 2050
  - Hydro capacities fixed
  - Open Source

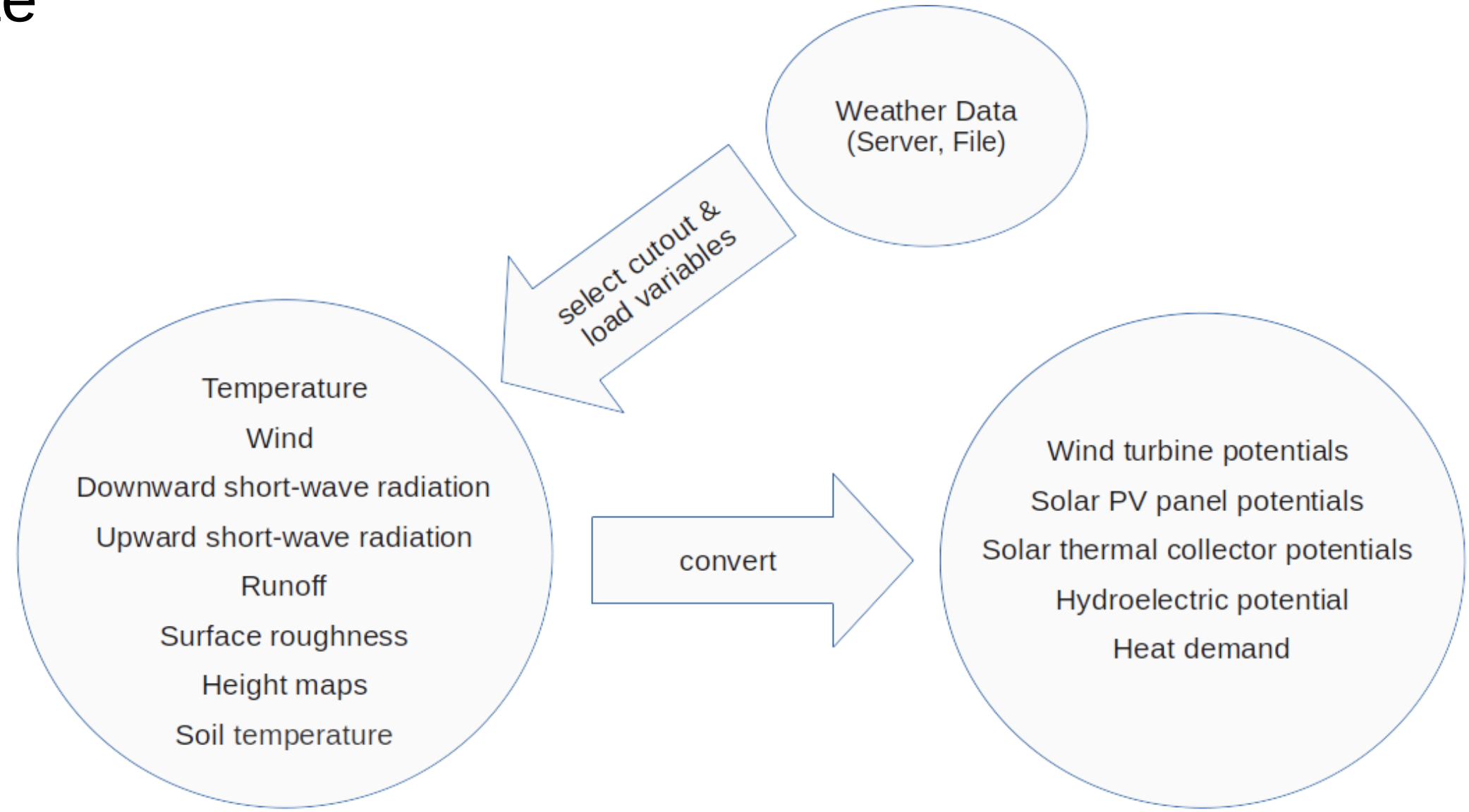
  https://github.com/highRES-model/highRES-Europe

Spatial aggregation:

- Atlite (Hofmann, 2021)
  - Python library
  - Converts weather data to power systems data
  - ERA5 reanalysis
    - 30x30 km grid
  - Free software

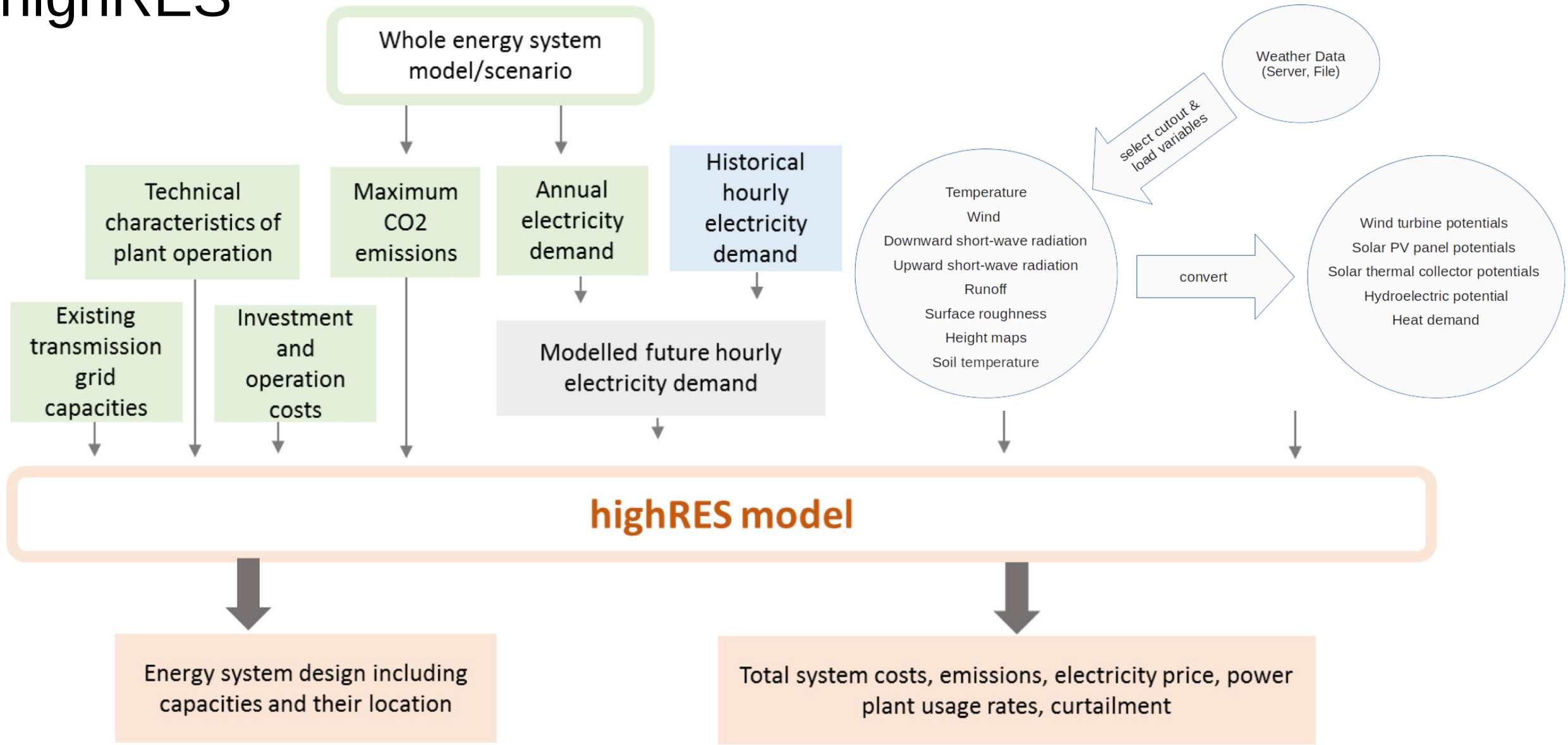
  https://github.com/PyPSA/atlite

Atlite



Source: https://github.com/PyPSA/atlite

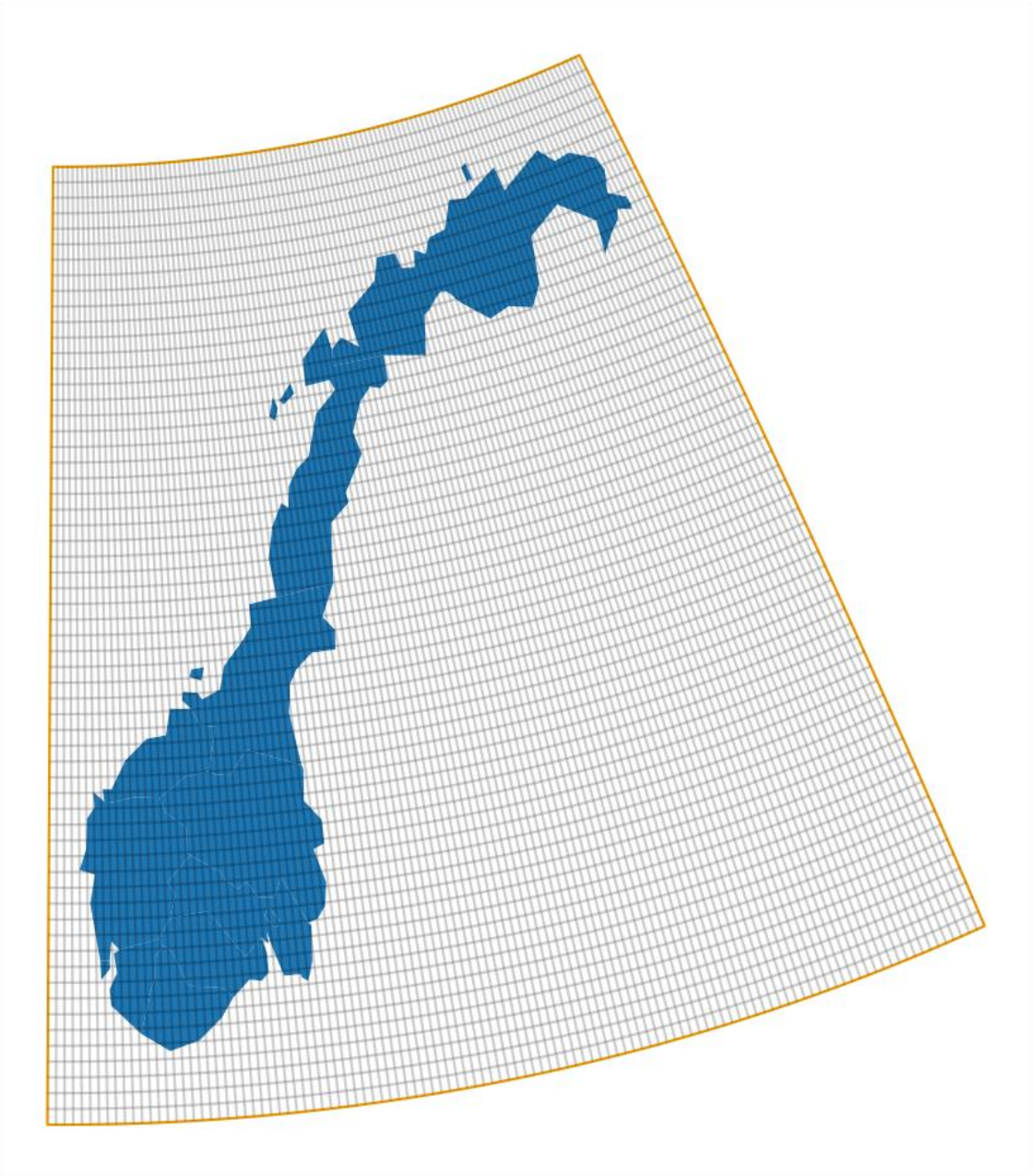
highRES

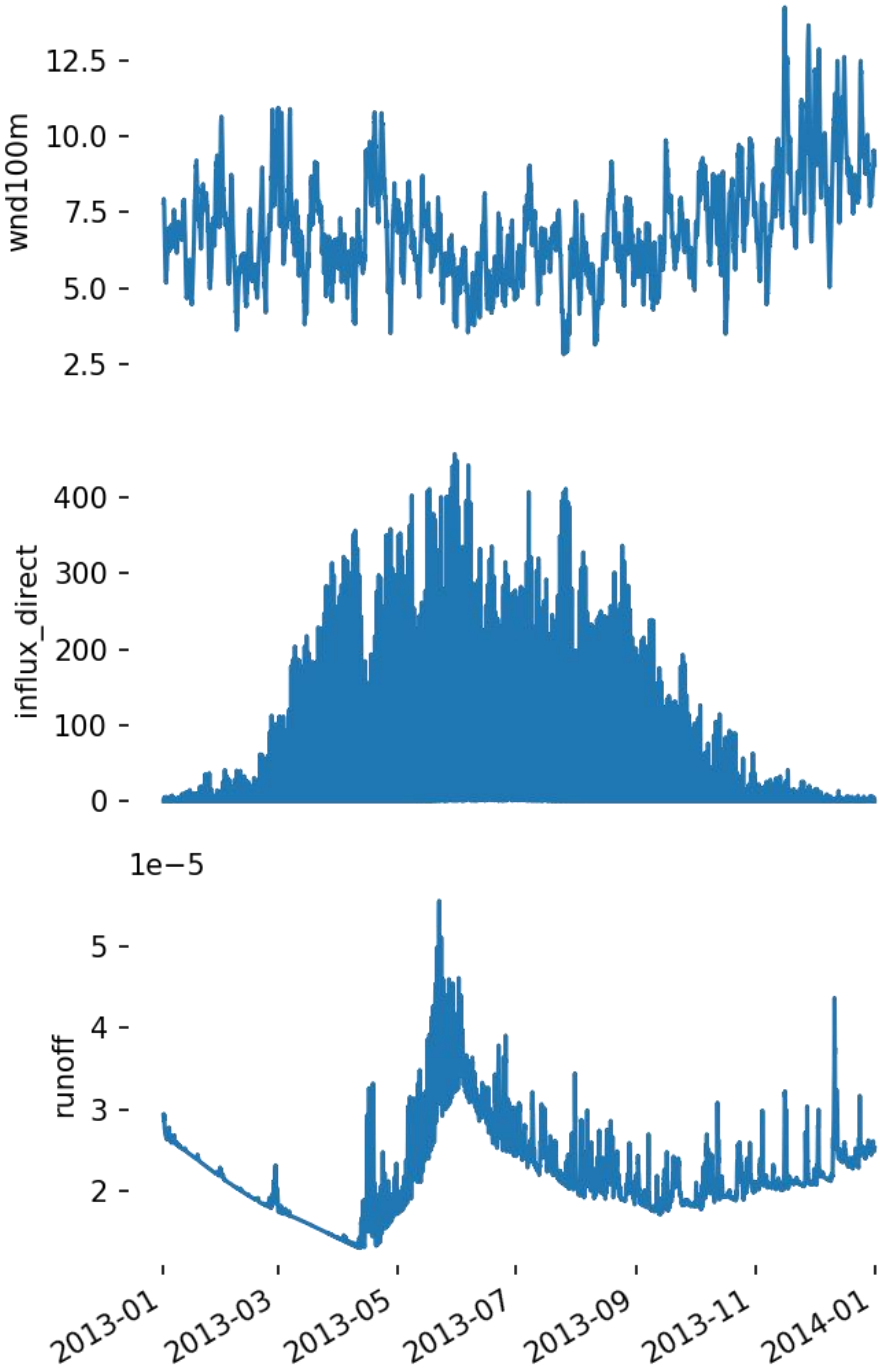


Source: (Price, 2022)

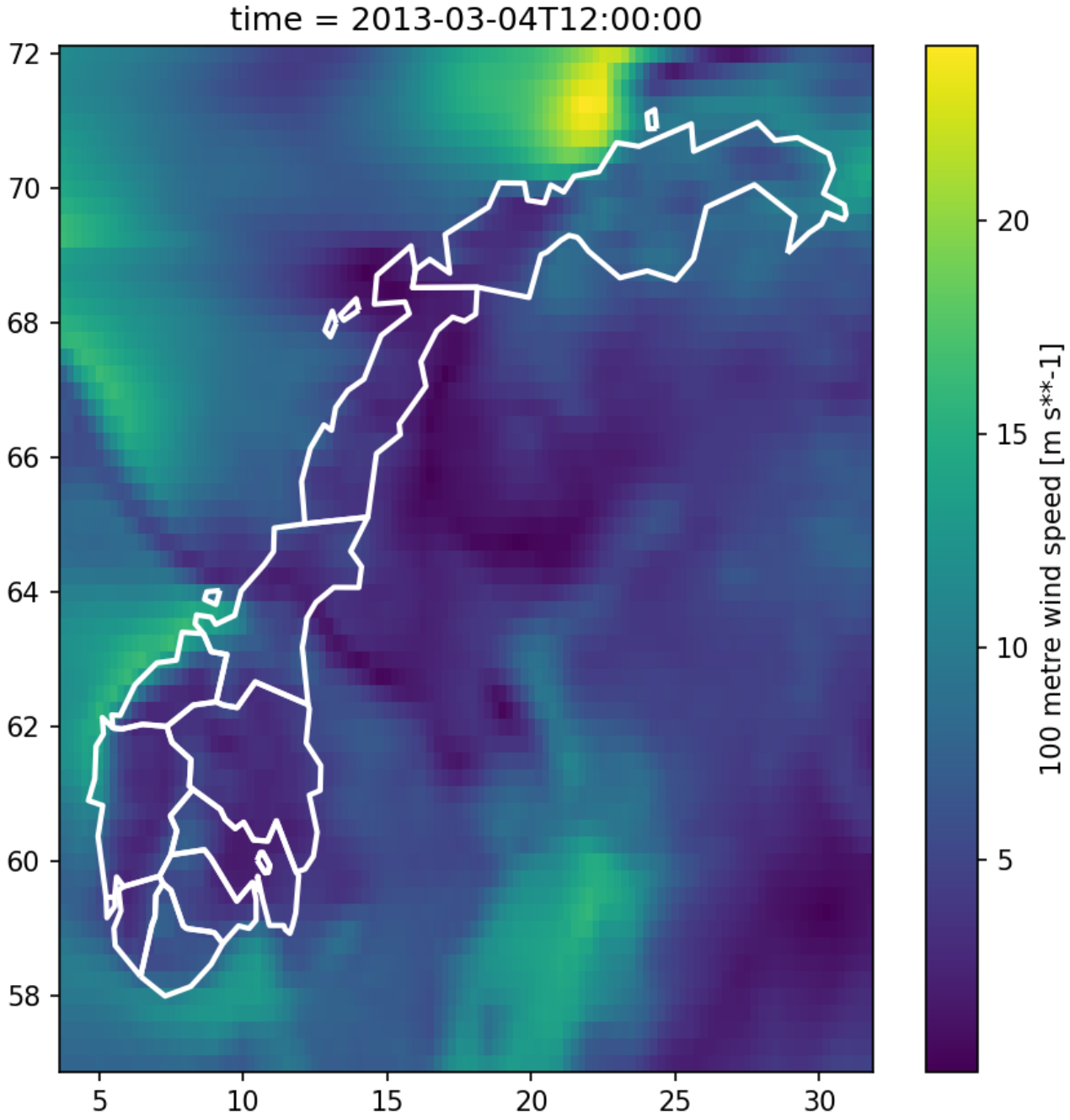
Detailed models are computationally expensive

- Because of dimension size
  - Time (hour) 8760 in a year
  - Space (gridcells) ~2000 in Norway
- Aggregation weather data
- Decisions are usually made on country level





Created using: (Hofmann, 2021)



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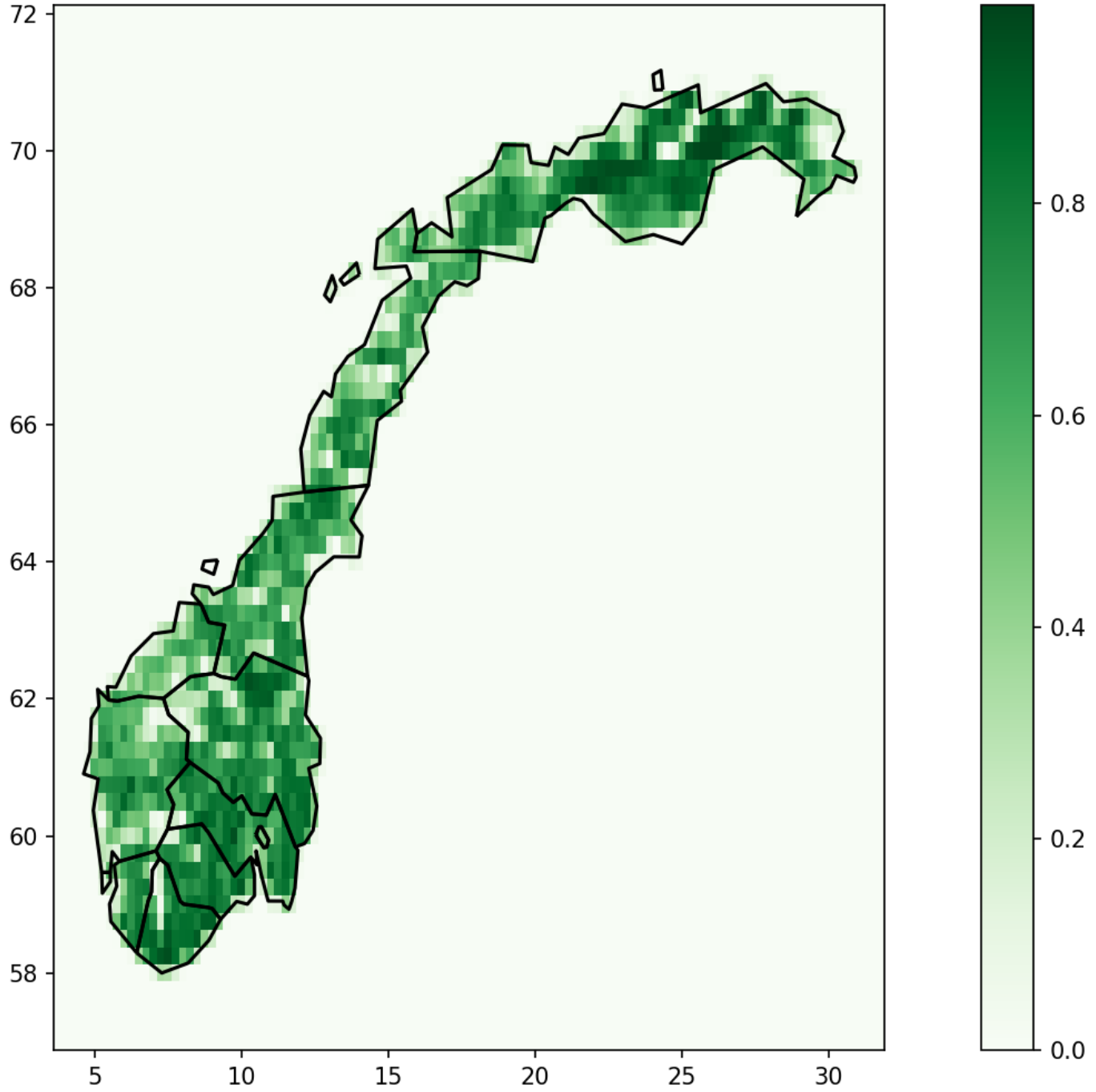

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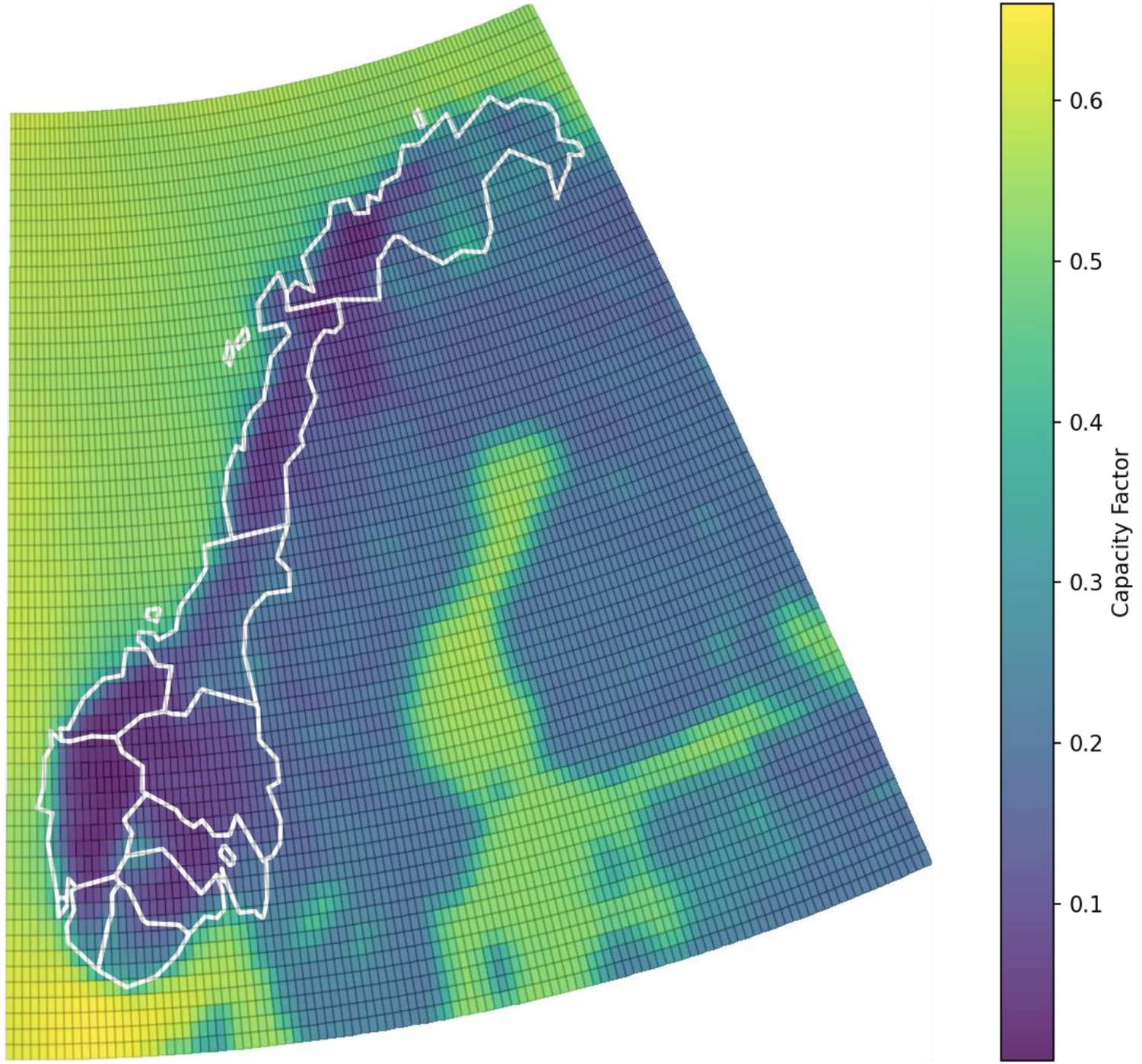

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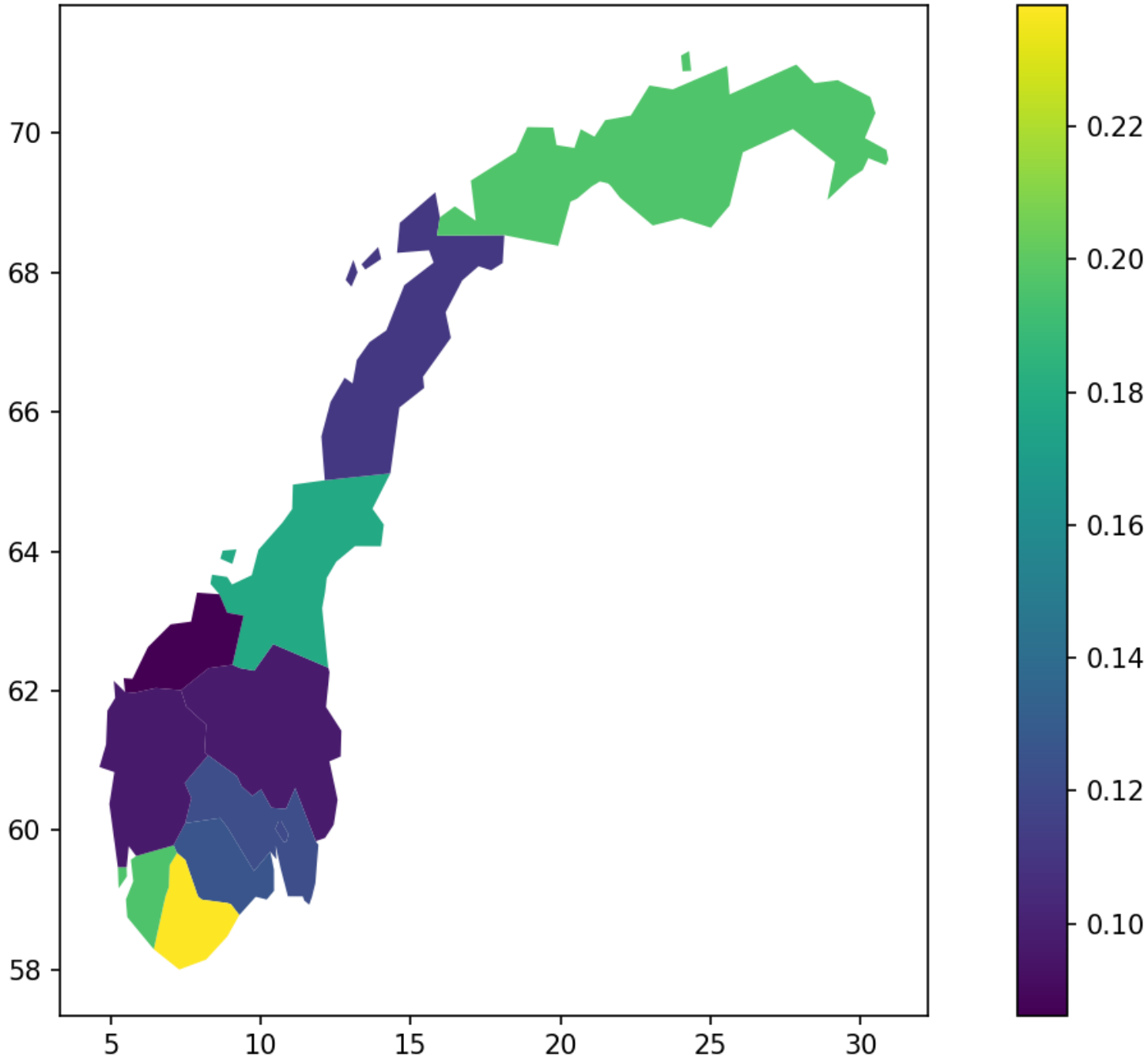

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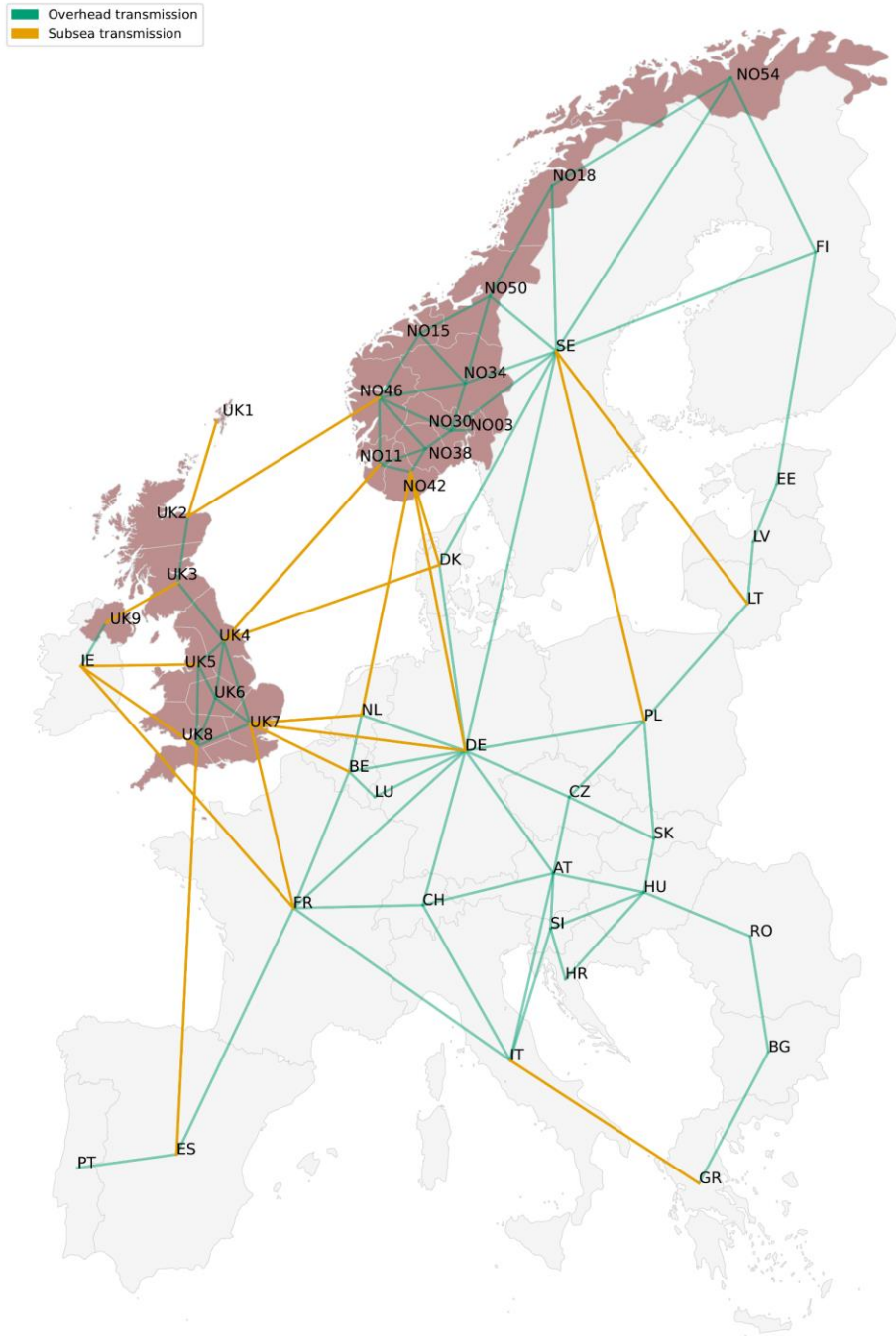
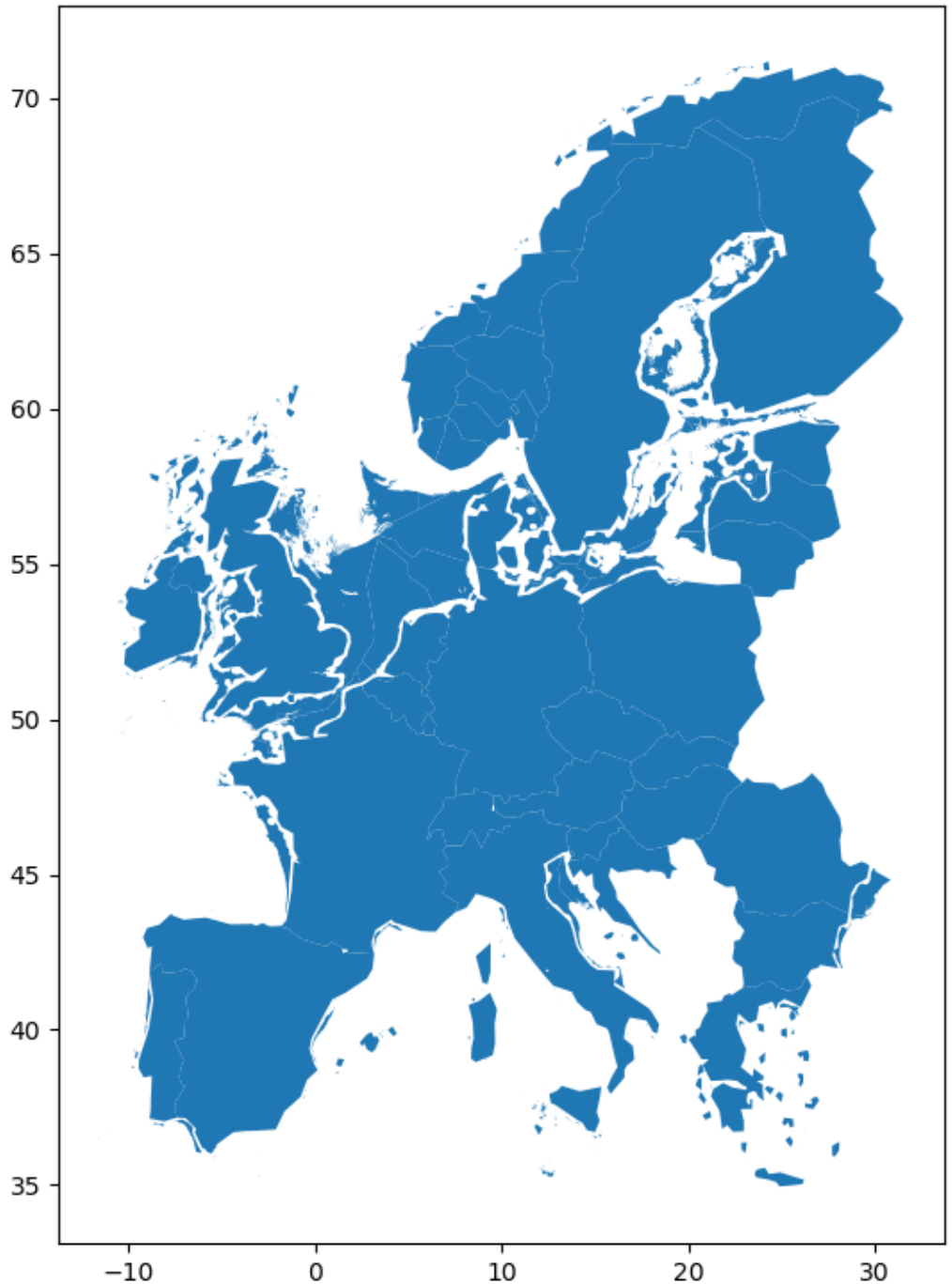


Courtesy of VÅGERÖ, O.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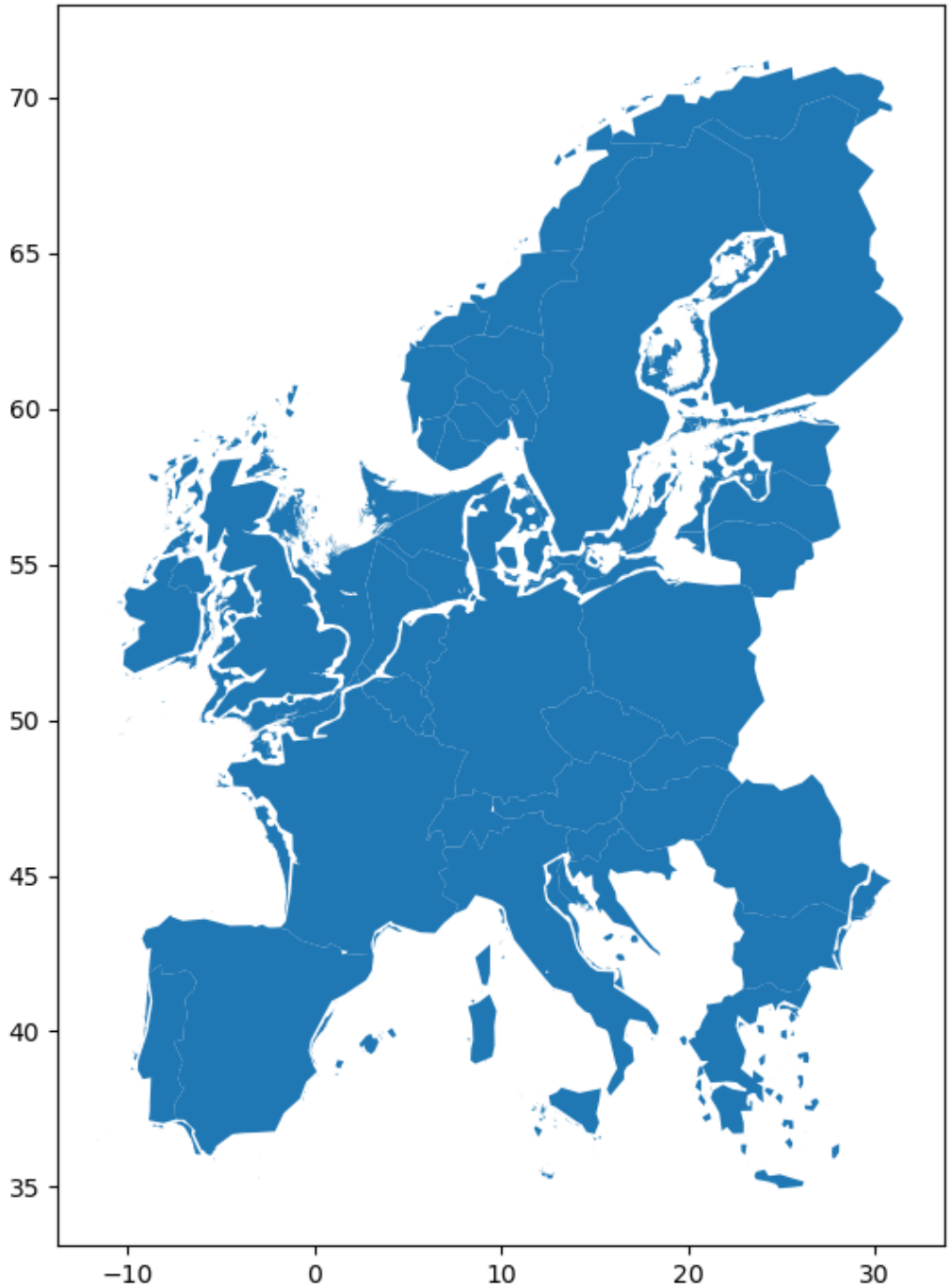
Research question / hypothesis

- But different weather within a country

  What are the differences between a grid cell model for a high hydropower country and a low hydropower country?
  - Optimal generation capacities?
  - System costs?

- Can hydropower reduce the effect through balancing?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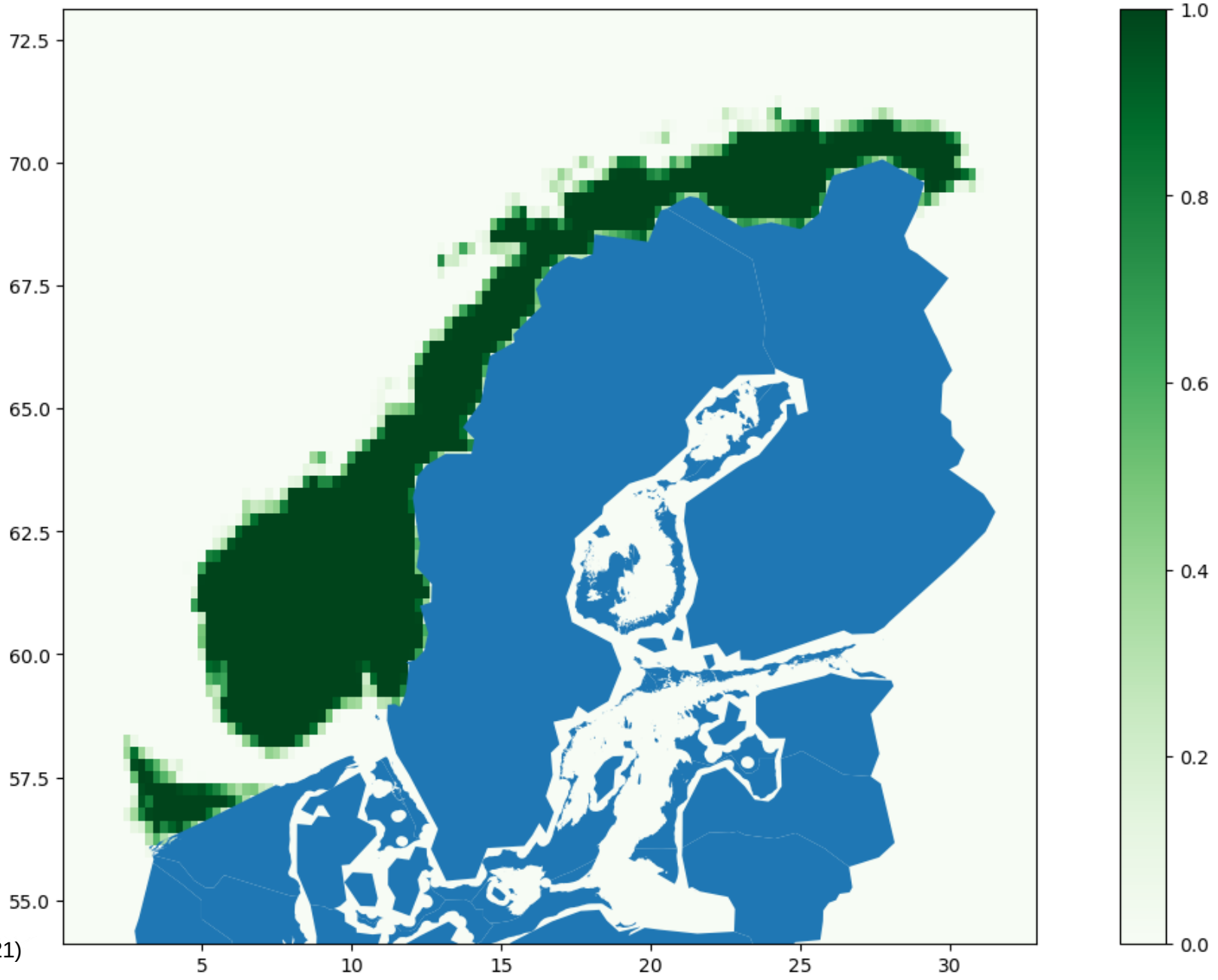


Created using: (Hofmann, 2021)

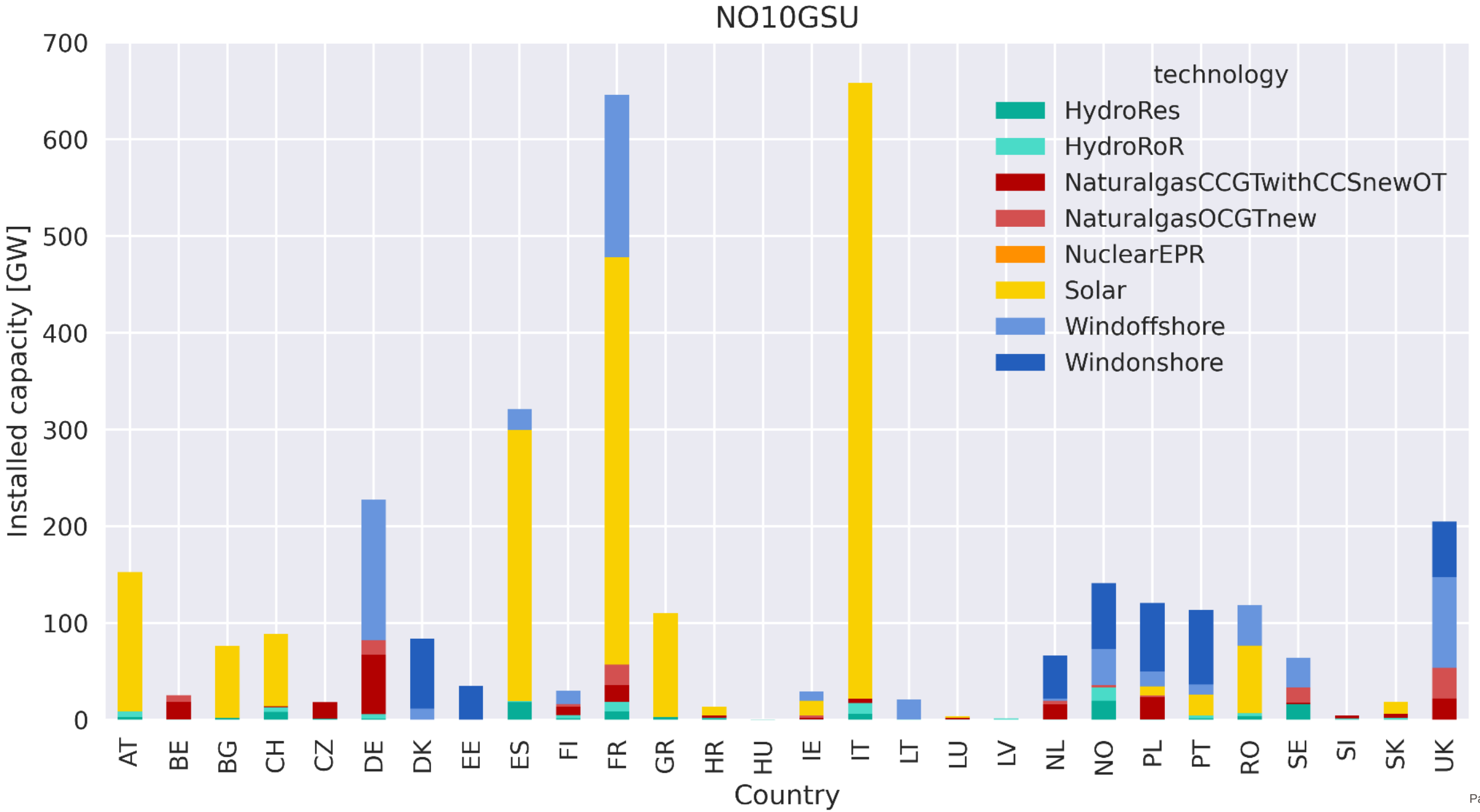
Resources

- 3.5 days
- 200 GB memory
- 64 cores

Different scenarios/variables

Country	Weather year	Spatial resolution	Transmission expansion	Demand
Norway	1995 (average)	30x30km grid	Fixed	Current
United Kingdom	2010 (worst)	Region	Unlimited	Scaled
	2014 (best)	Country		

Results


NO10GSU
Installed capacity [GW]
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technology
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NaturalgasCCGTwithCCSnewOT
NaturalgasOCGTnew
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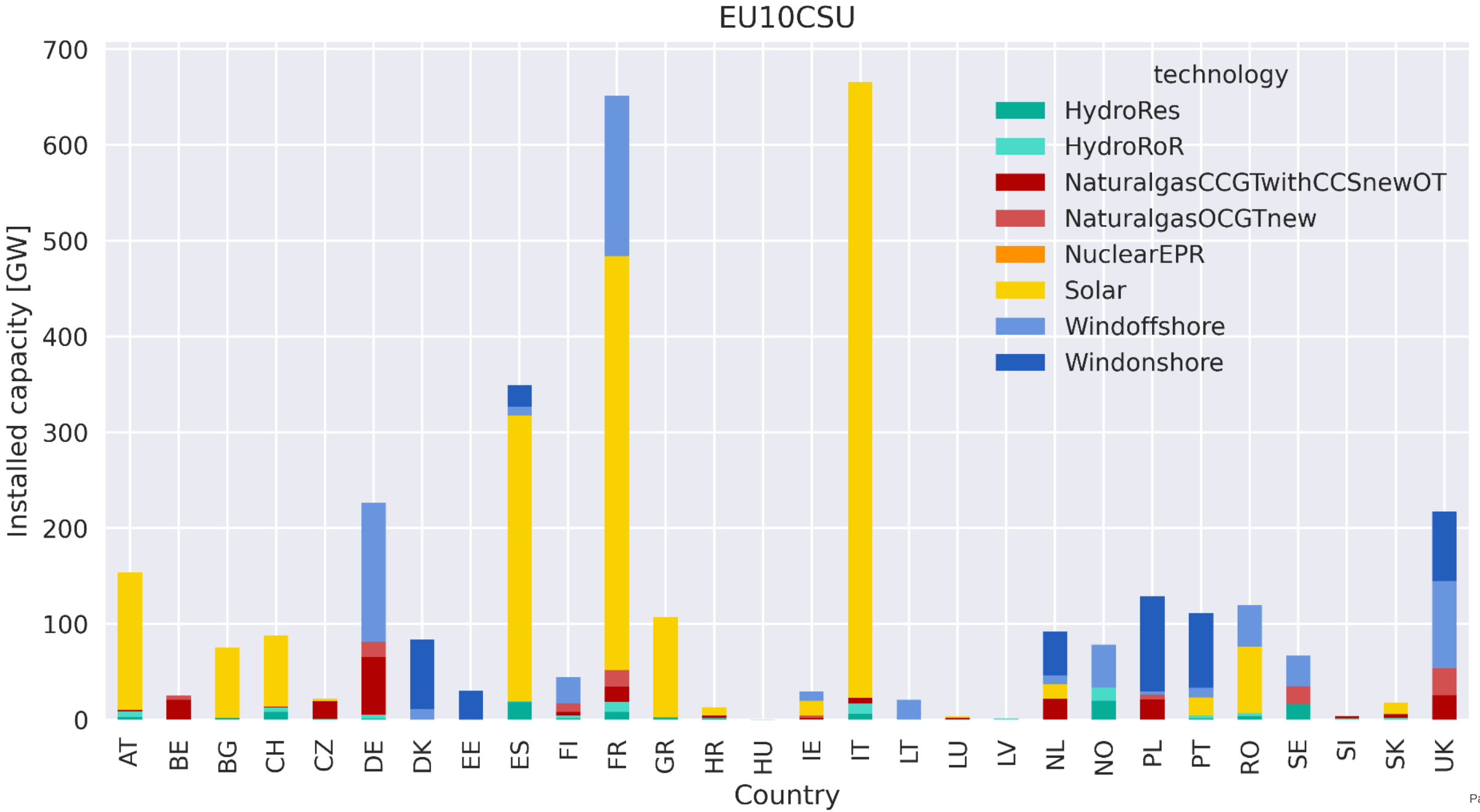
Solar
Windoffshore
Windonshore


EU10CSU
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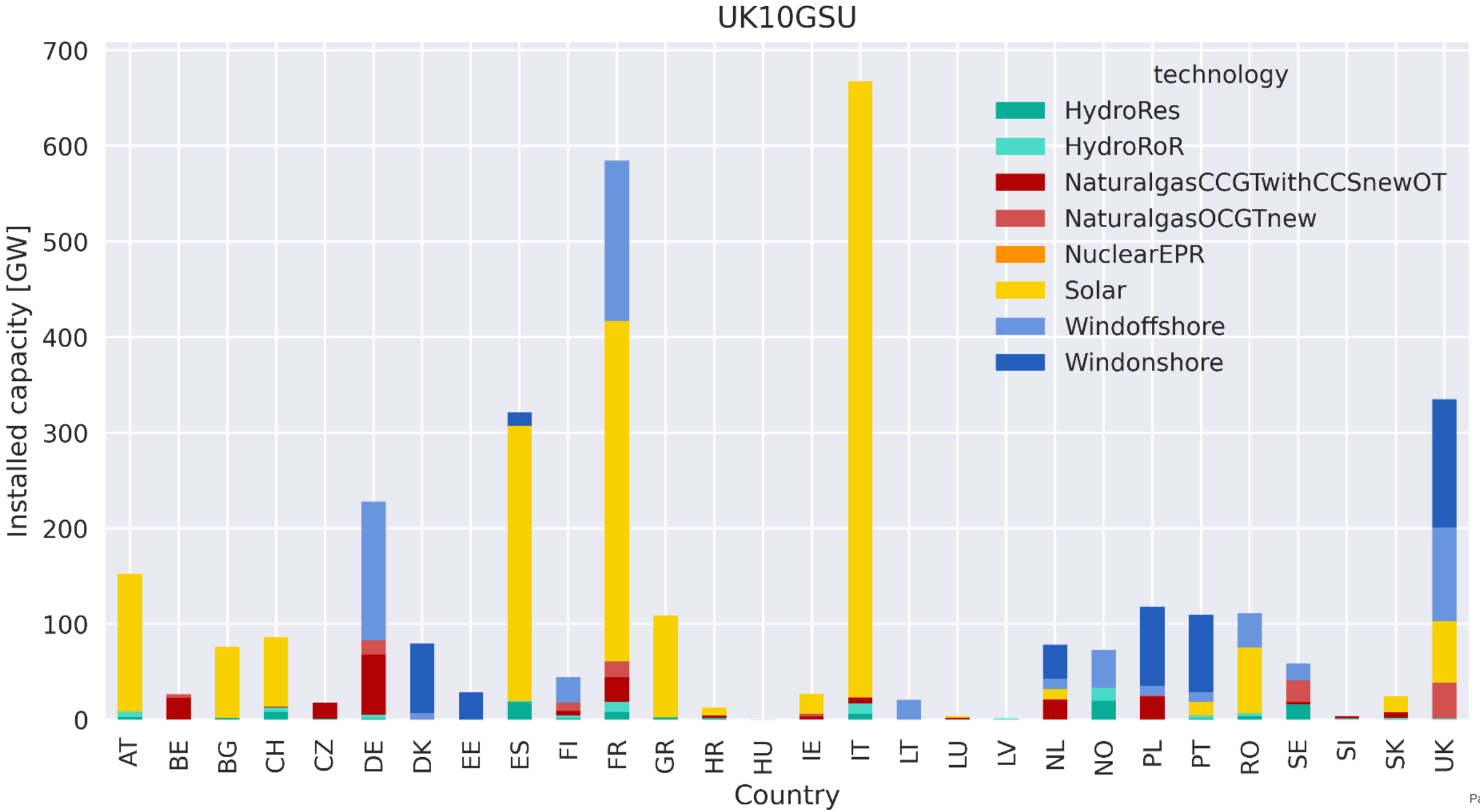
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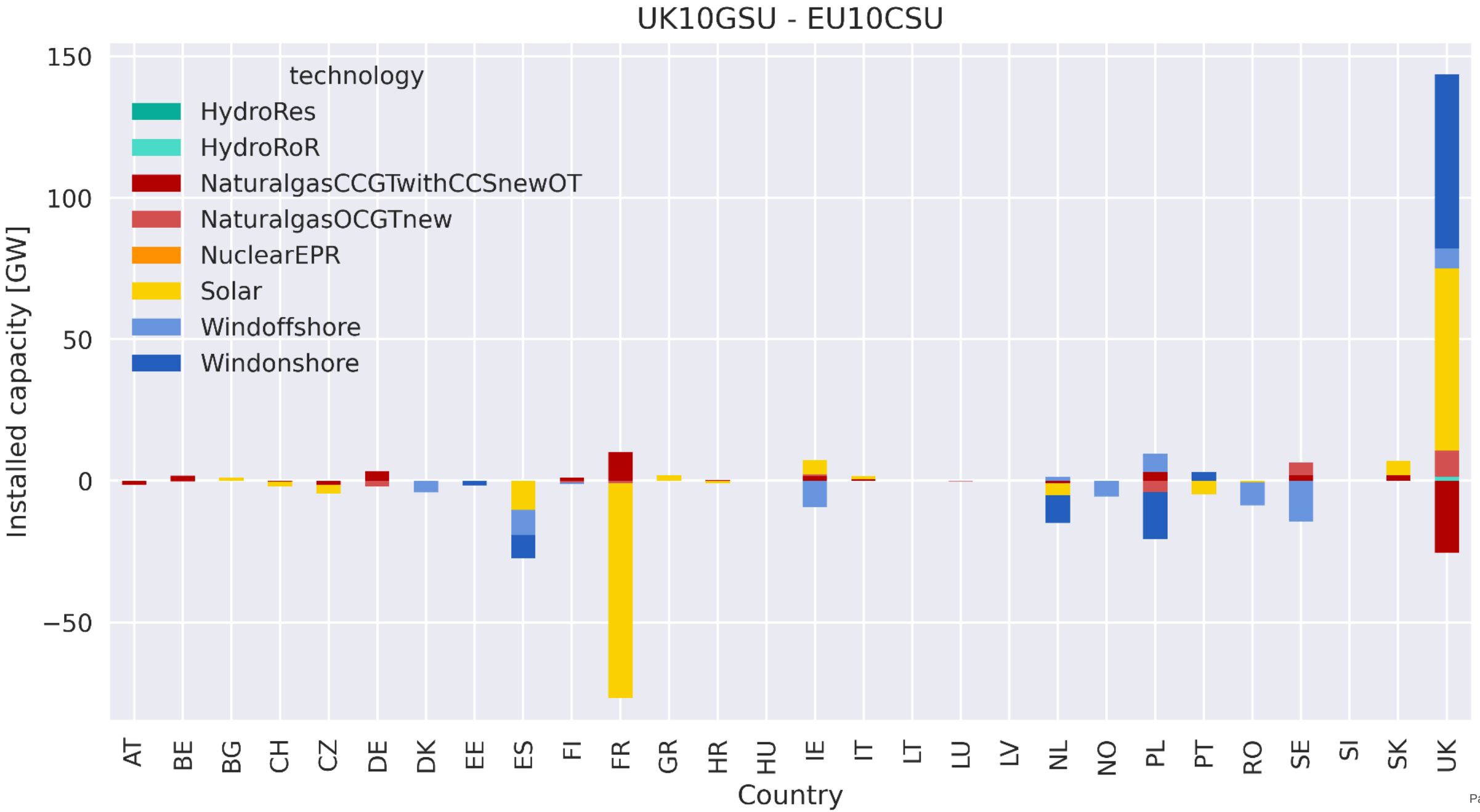
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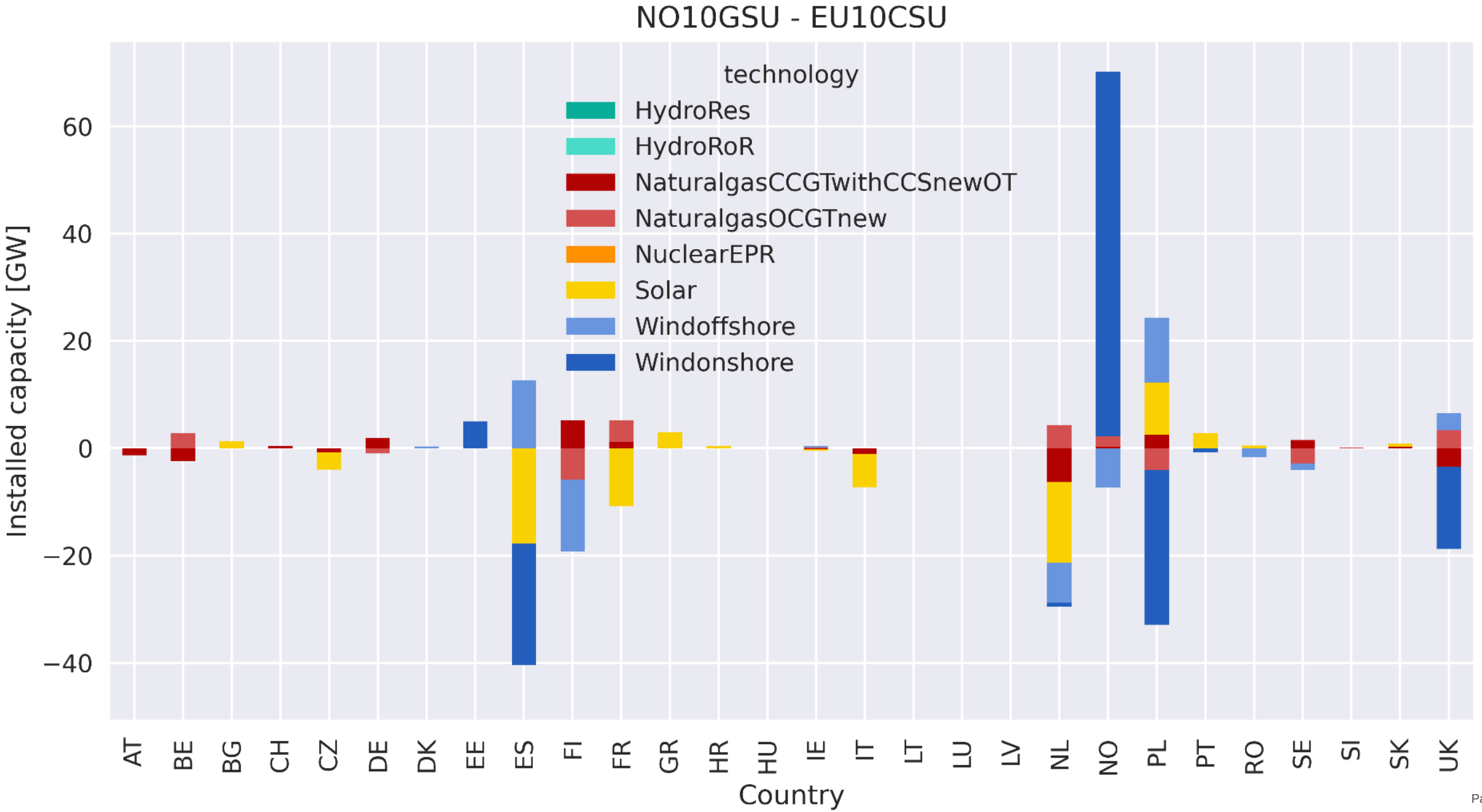
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Country

Discussion / Conclusions

What about?

- Countries / hydropower: effect stronger in UK but also larger system
- Weather years: consistent effect
- Spatial resolution: clear impact, NO starts exporting
- Transmission:
  - different system design, more solar when lower transmission
  - effect similar direction
- Demand: scaled more pronounced Norway existing hydro
- System costs: yes, but small 1.7% UK 0.1% NO (EU wide costs)

Conclusions

Comparison to literature:

- Frysztacki (2021, 2022)
  - Importance of spatial resolution
  - Similar shift from offshore to onshore
  - Smaller regions
  - No cutoff
  - Still some aggregation

Limitations:

- Only two countries
- Compounding factors
- No distribution grid (copper plate)

Conclusions II

Future research:

- Smaller areas/regions
- Cutoff – choice arbitrary
- Sub-classes for technologies
- Hydro plays a role, but size of country also very important

Recommendation:

- Focus countries on high resolution and rest on lower resolution
- Evaluate aggregation

Sources

- Frysztacki, M. M., Hörsch, J., Hagenmeyer, V., & Brown, T. (2021). The strong effect of network resolution on electricity system models with high shares of wind and solar. Applied Energy, 291, 116726. https://doi.org/10.1016/j.apenergy.2021.116726
- Frysztacki, M. M., Recht, G., & Brown, T. (2022). A comparison of clustering methods for the spatial reduction of renewable electricity optimisation models of Europe. Energy Informatics, 5(1), 4. https://doi.org/10.1186/s42162-022-00187-7
- Hofmann, F., Hampp, J., Neumann, F., Brown, T., & Hörsch, J. (2021). atlite: A Lightweight Python Package for Calculating Renewable Power Potentials and Time Series. Journal of Open Source Software, 6(62), 3294. https://doi.org/10.21105/joss.03294

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- Price, J., & Zeyringer, M. (2022). highRES-Europe: The high spatial and temporal Resolution Electricity System model for Europe. SoftwareX, 17, 101003. https://doi.org/10.1016/j.softx.2022.101003

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Thank you!
Questions?