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Impact of the Choice of Regions on Energy System Models

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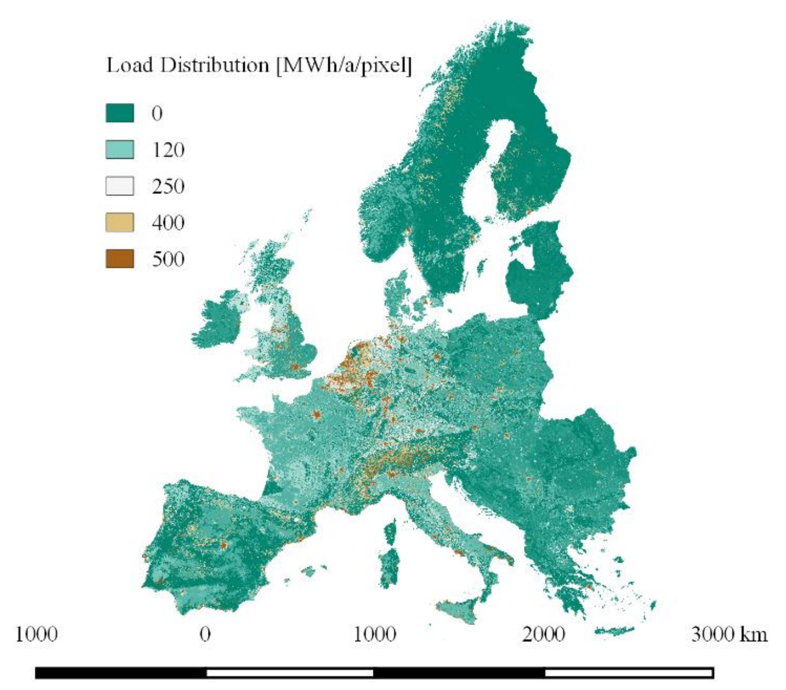
Background and Motivation

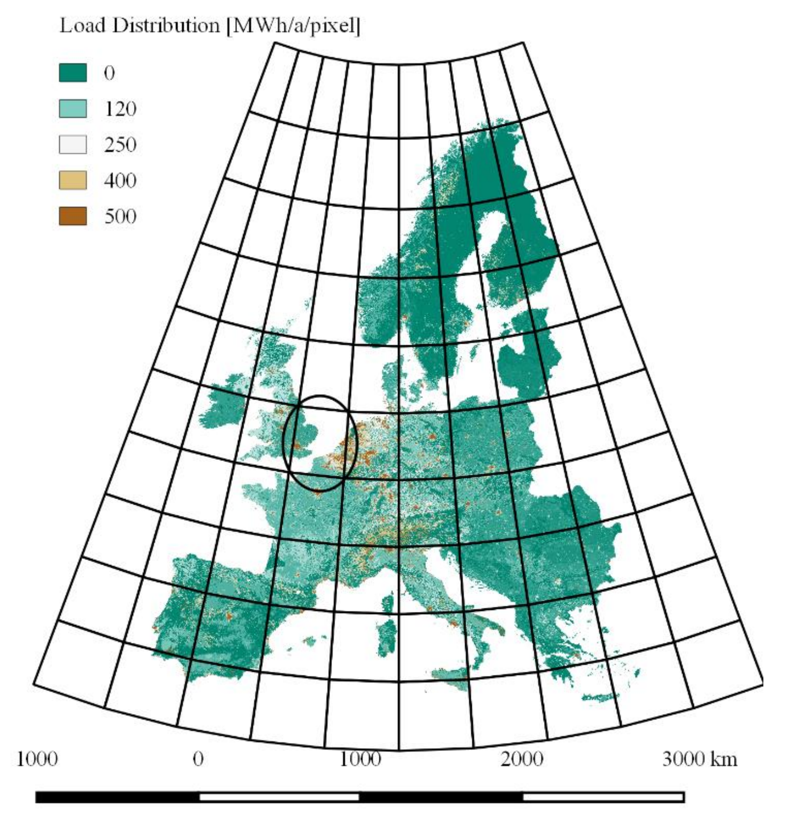
- The electricity system in Europe is increasingly relying on decentralized generation from variable renewable energy sources.
- Analyzing future scenarios requires a deep understanding of the spatial and temporal distribution of wind and solar resources and load patterns.
- Most existing energy system models rely on input data available at country-level, or at the level of administrative divisions.

→ Goal: Cluster high resolution maps to obtain regions with homogenous wind, solar potentials or load density, and analyze impacts on energy system models.

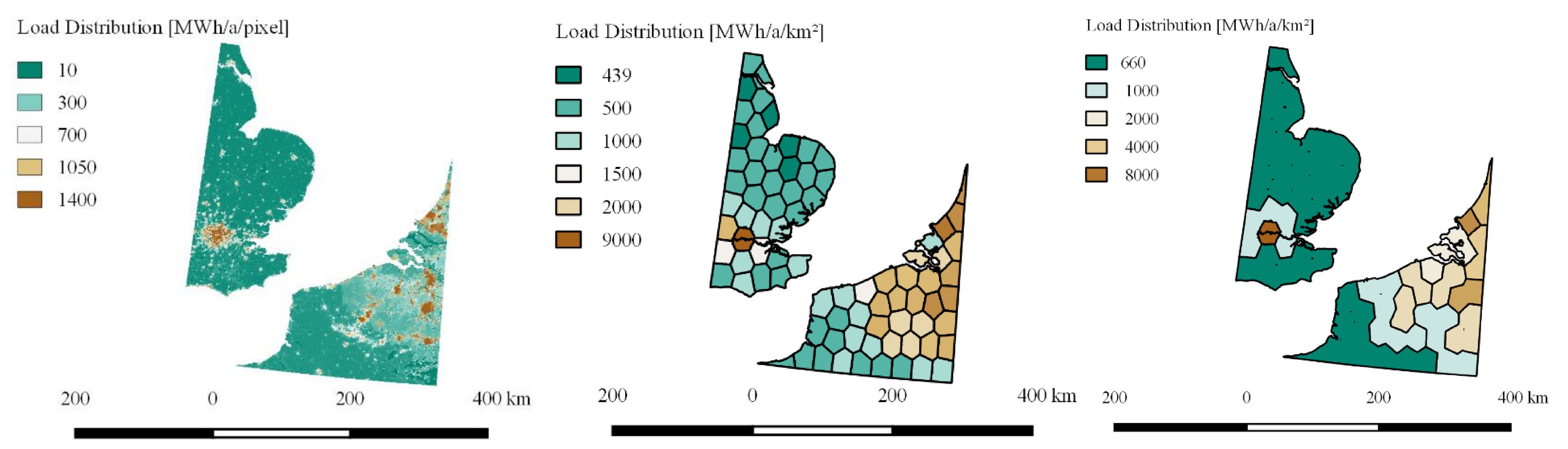
Clustering Method



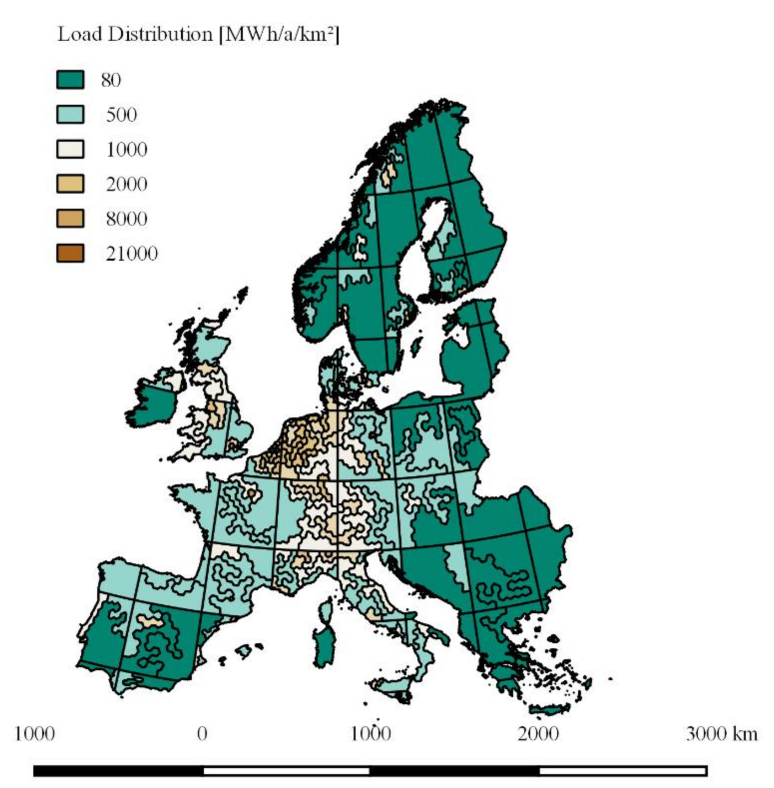
(a) Initial load raster (15 arcsec resolution).



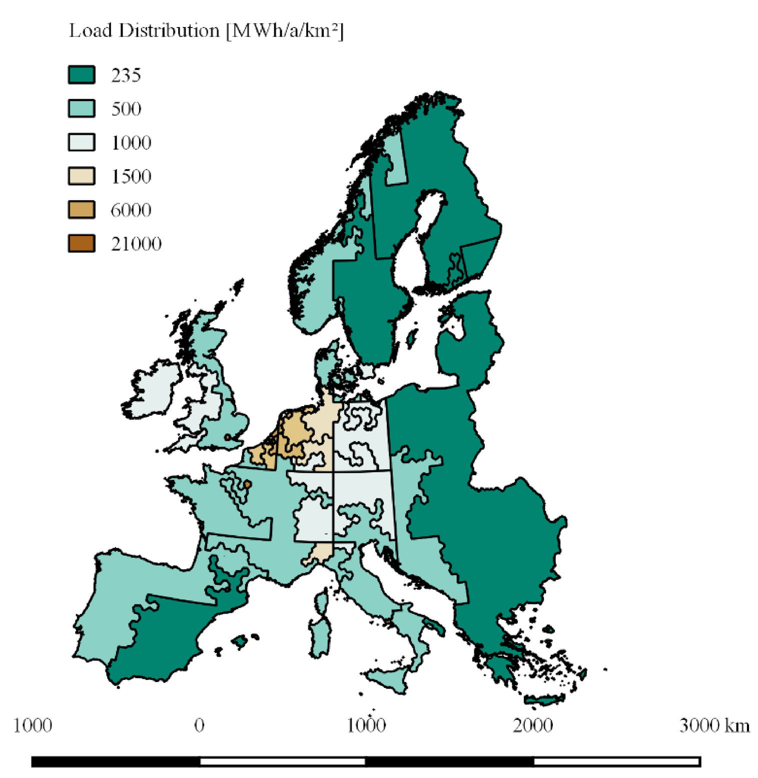
(b) Division into smaller parts.



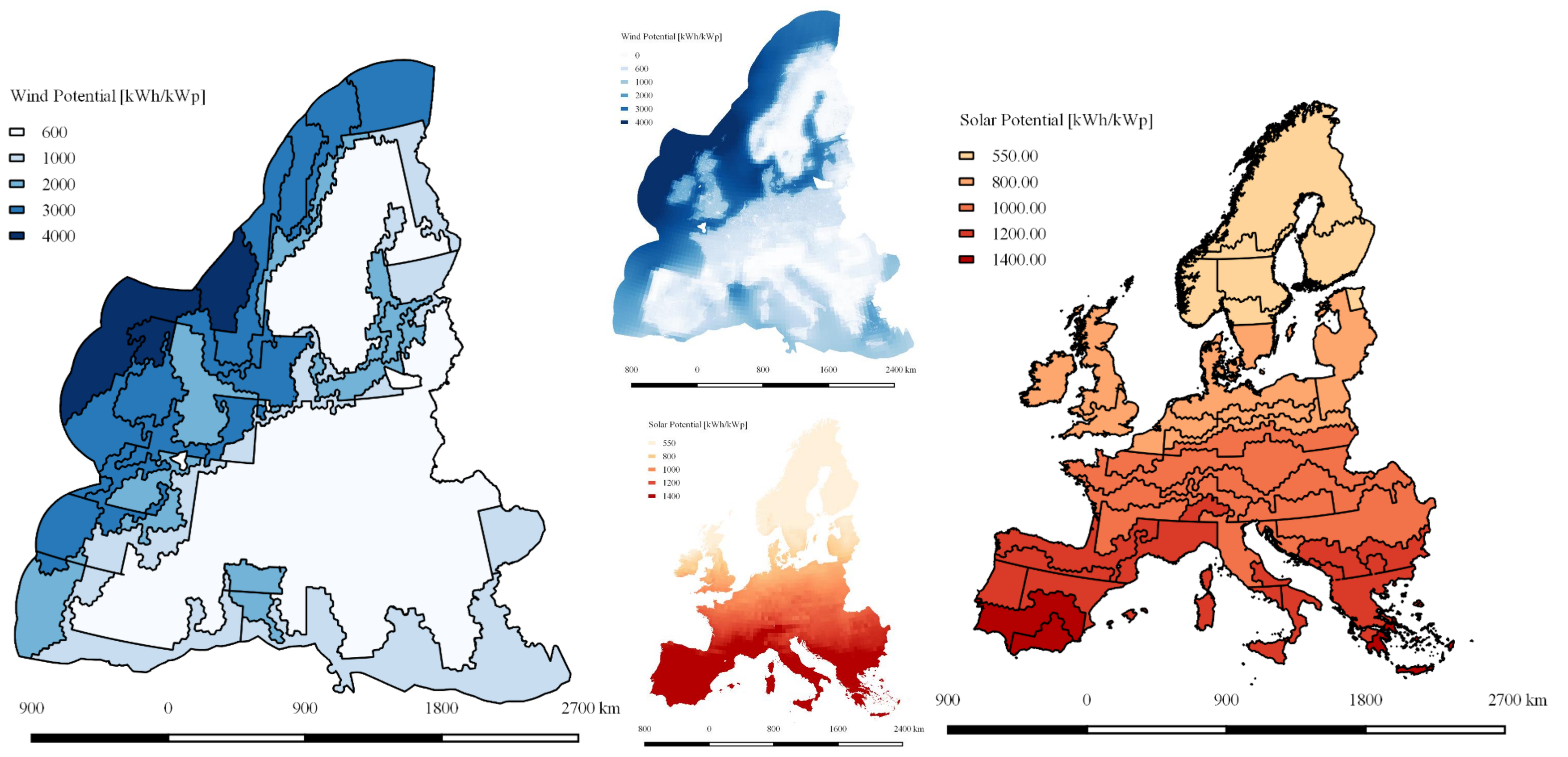
(c) Each raster part is clustered using *k-means++*, then with the *max-p regions* algorithm [1,2].



(d) Recomposition of the whole map



(e) Results of 2nd *max-p regions* clustering.



(f) Same process is repeated for the wind and solar potential maps.

Figure 1: Clustering methodology steps, as applied to the load raster map.

Energy System Model and Data

Model	*urbs*, a linear programming optimization tool for expansion planning and unit commitment [3].
Coverage	EU28 minus Malta and Cyprus, plus Switzerland and Norway.
Time steps	Hours of the first weeks of January, April, July and Octobre to represent the full year of 2015.
Load time series	Hourly time series for each country [4] are disaggregated into sectoral load time series. Sectors are distributed geographically based on land use types [5]. Load is aggregated again for the new model regions. The same load time series are used in 2015 and 2050.
Renewable time series	Wind and solar hourly capacity factor time series are generated by combining MERRA-2 radiation, temperature and wind speed data [6] with maps of land use, elevation, and protected areas.
Power plants	Conventional power plants in operation in 2015 [7] were allocated to the regions based on their coordinates, then aggregated based on their types. Renewable capacities are collected from IRENA [8] and distributed geographically based on potentials and land use. In 2050, initial capacities are zero.
Transmission	Transmission lines are extracted from GridKit [9].
CO_2 emissions	There are no limits for 2015. For 2050, we assume a 95% reduction compared to 2015.

Results and Discussion

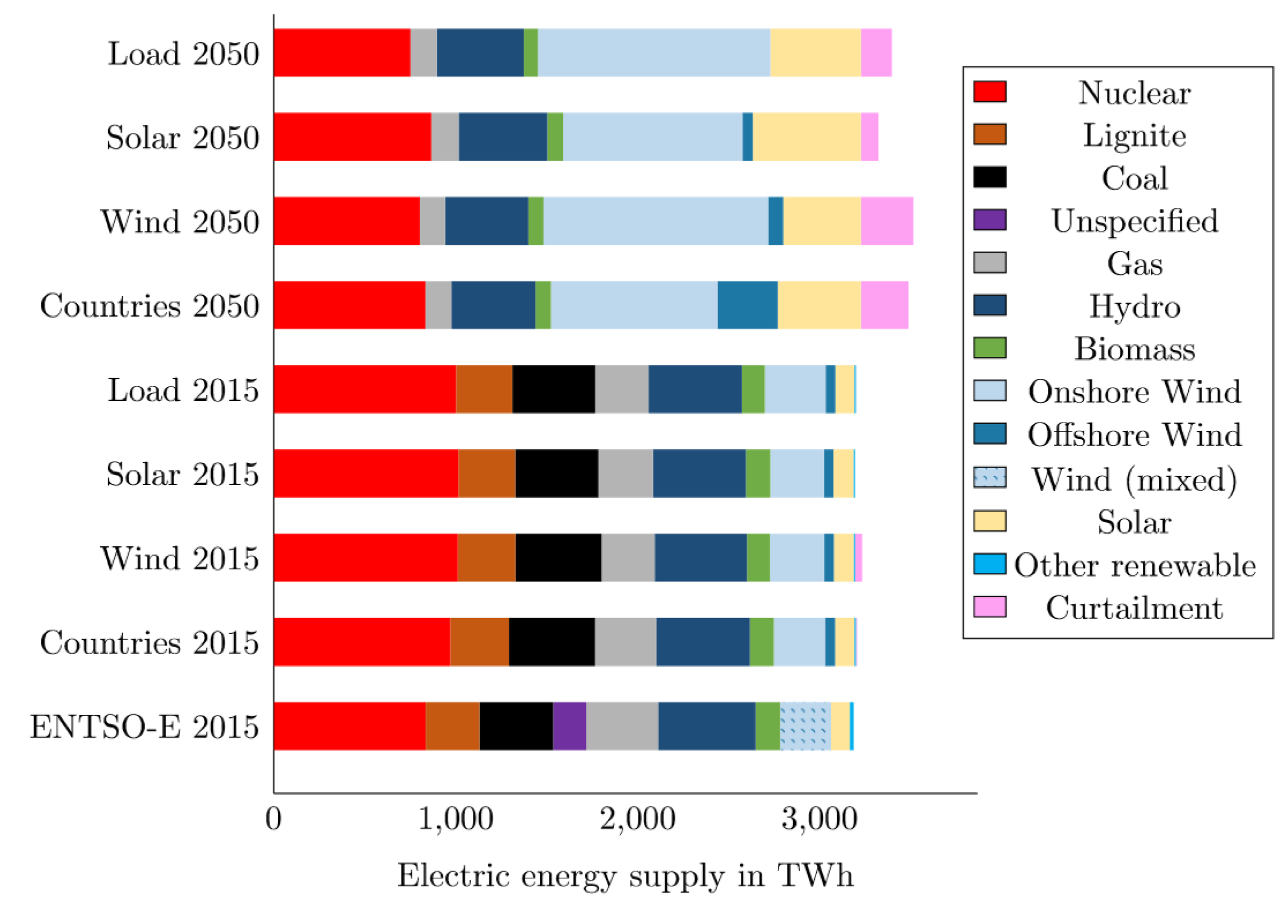


Figure 2: Electric energy supply in Europe in TWh according to the *urbs* model and to ENTSO-E statistics of 2015.

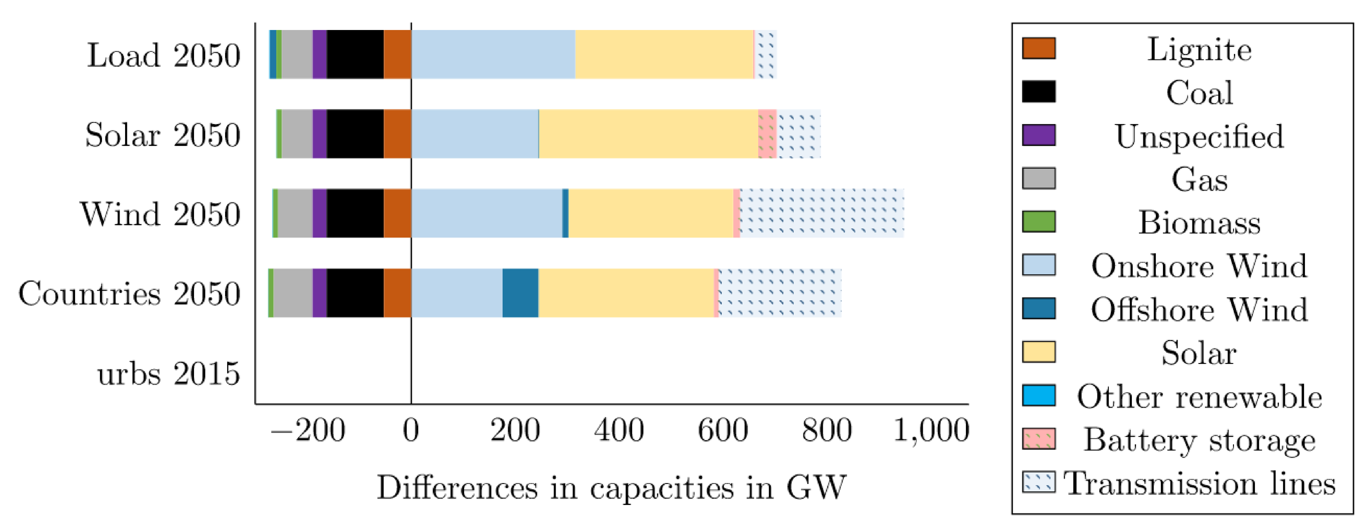


Figure 3: Differences in capacities of power plants, storage units, and transmission lines in GW compared to the capacities in 2015.

- Good match for 2015 despite different transmission capacities between the regions and different time series for load, solar, and wind.
- Major discrepancies between the models for 2050.
- In *Wind*, areas with good potentials are not mixed with low potential areas. Hence, wind expansion is favored in regions with good potential. Transmission lines connect them to low potential regions.
- In *Solar*, regions resemble horizontal bands. Transmission lines between the centroids would be expensive and unnecessary (no regions with strong wind potential), so the model favors solar photovoltaic and batteries.
- In *Load*, areas with high load densities are compact, landlocked cities that do not need many transmission lines to the large regions. The latter invest heavily in onshore wind and PV, but not in offshore wind.

Acknowledgement

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