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Tracking CO2 emissions from power generation
- Case study for the German electricity system

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Motivation

Importance to know the volatility of CO_2 emissions on high temporal and spatial scale in energy systems.

- CO_2 emissions for electricity can vary in time and space; the caused CO_2 emissions of, for example a used kWh is influenced by the electricity mix at a given time and place.
- Companies are moving towards CO_2 neutrality. Production decisions can be made by using CO_2 emissions on high temporal and spatial scale.

Research

Research Gap - Studies on emissions in today's energy systems uses data in low- spatial and temporal resolution: No analysis of emissions within a specific region (ex. federal state) or high temporal resolution (ex. hourly).

Research Objective - Modelling the German power plant dispatch and the resulting network power flow; Assessment of model results with available data (power plant supply profiles and quantities, import and export quantities and flows); Evaluation of emissions in situations where regions become net importers or exporters.

Research Questions - Is it possible to model the German energy system with adequate accuracy to reproduce load flows (temporally and spatially) in detail?

How do the CO2 imports / exports resulting from generation and load flows affect the carbon footprint of a region?

Model

Network model of DE + neighboring countries in the year 2018. Network has 2490 lines, 9 links, 2163 substations. Each node has a load time series, Installed capacities (conventional and renewable) and CF time series.

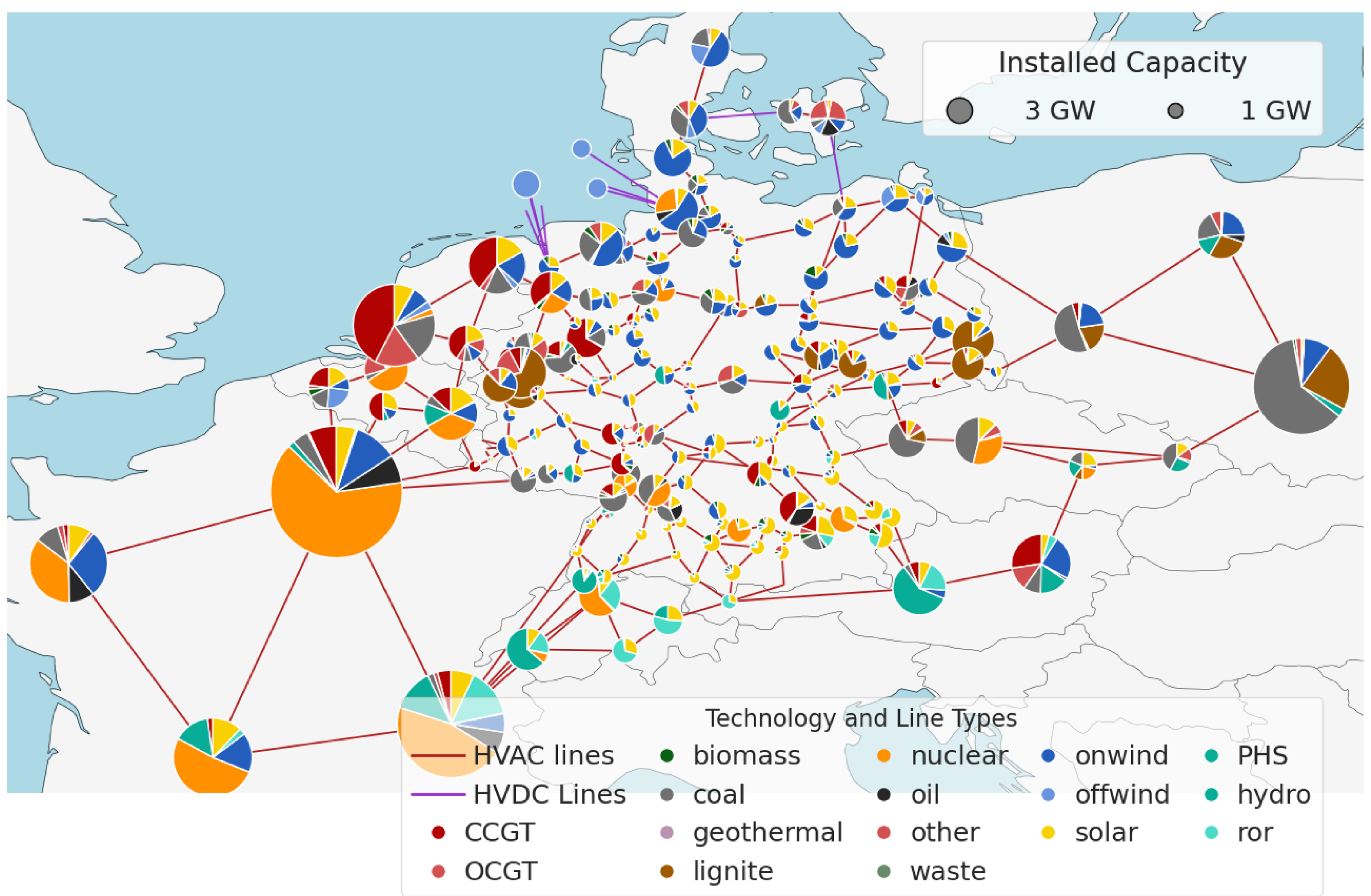

Figure 1: Capacity & line layout for the clustered model of DE + neighboring countries; Resolution; 280lines, 3 links, 180 substations, Full year, 1-hour simulation

Simulation

The Optimisation Problem (linear optimal power flow problem - LOPF)

- Find the cost-optimal energy system operation for one year

$$\min_{g_{i,s,t}\, f_{l,t}} \left[\sum_{n,s,t} o_{i,s}\, g_{i,s,t} \right]$$

g - generator
o - operational costs
s - technology type
t - time discretization
n - substation/node
l - transmission line

Subject to

- Meeting energy demand at each node n and time t
- Todays installed conventional and renewable capacities (g) at each node n
- Transmission constraints between nodes for each line l
- Wind-, solar-, hydro-production time series (can be curtailed)
- Conventional-production time series (where available)

Results

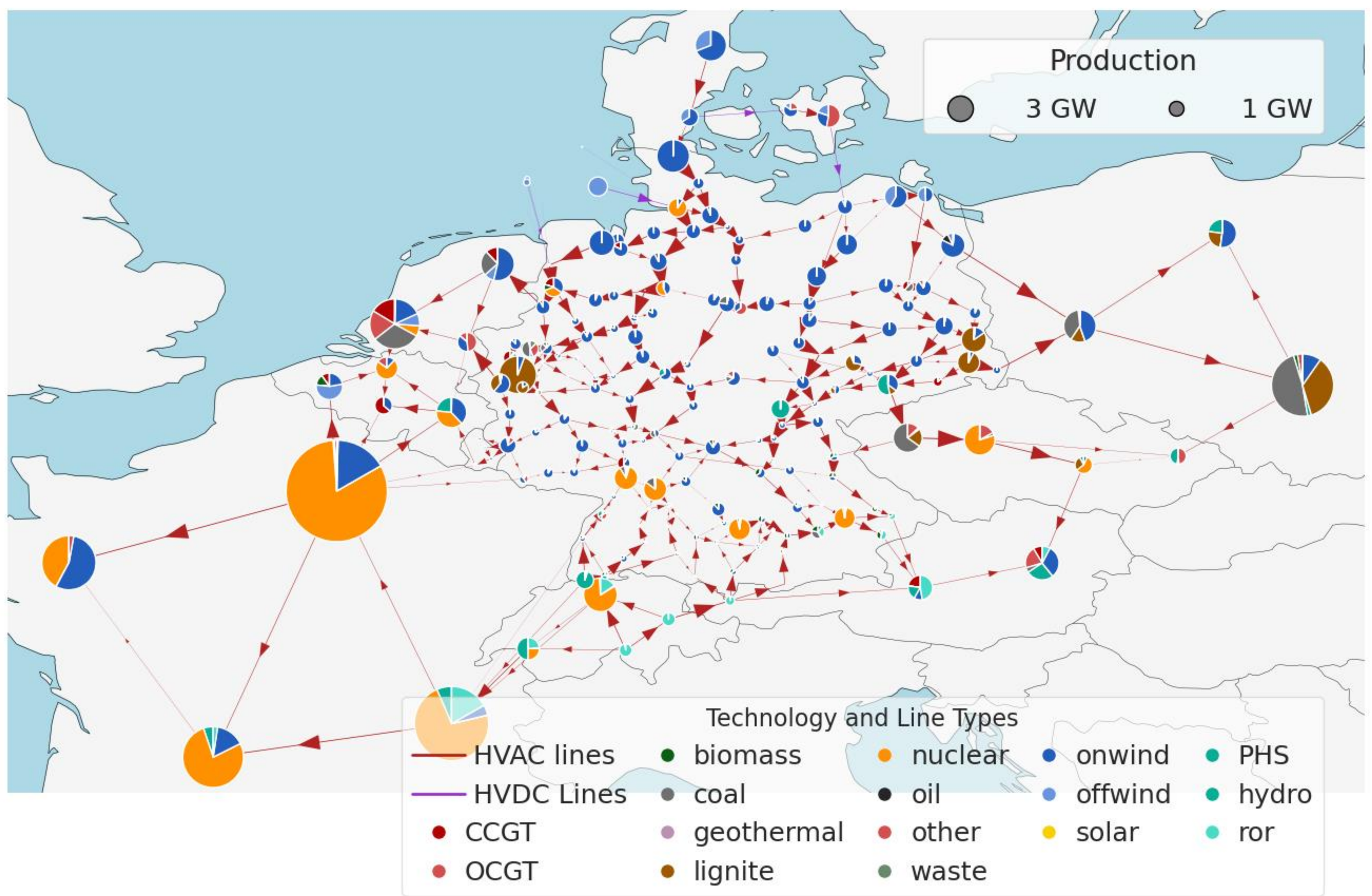

Figure 2: Resulting flow pattern for production timestep 2018-12-08 17:00

Further steps

Assessment of model results with available data (power plant supply profiles and quantities, import and export quantities and flows) for all countries. Find examples for net importer and export regions.

Answering research questions - Is it possible to model the German energy system with adequate accuracy to reproduce load flows (temporally and spatially) in detail? How do the CO2 imports / exports resulting from generation and load flows affect the carbon footprint of a region?