Optimising a Fully Renewable European Energy System Seizing the Flexibility of Gas and Heat Storage Technologies

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MOTIVATION

- **integration of sectors electricity, gas, heat** and transport will be characteristic for the future energy system
- large-scale sector-integrated models in high temporal and technological resolution are not state-of-the-art yet[a]
- influence of optional repurposement of methane infrastructure on optimal system is not sure from overall system's perspective

RESEARCH QUESTIONS

- how do high technological detail AND the integration of gas and hydrogen infrastructure influence future overall system cost?
- how is the interplay between electrical, gas and thermal energy storage towards full decarbonisation?

ENERGY SYSTEM MODELLING FRAMEWORK

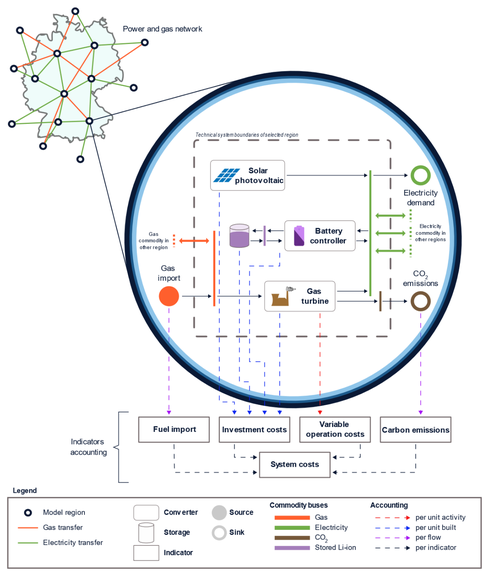

Figure 1 - Modelling concept of REMix.[b]

- **linear cost optimisation**
- written in GAMS, data preprocessing with Python
- designed for modelling **large-scale energy systems**
- sector-integrated models for Europe
- **capacity expansion and dispatch of all assets**
- parallel solving with PIPS-IPM++
- modelling to generate alternatives (MGA)
- multi-criteria optimisation
- pathway optimisation
- open source since September 2023 →

GitLab repository[b]

REMix
Renewable Energy Mix

OPTIMISATION MODEL

- hourly resolution *(planned)*
- **hydrogen imports** from five different world regions ranging between 5.5 ct/kWh (min. scenario) and 18.2 ct/kWh (max. scenario) in 2050[c]

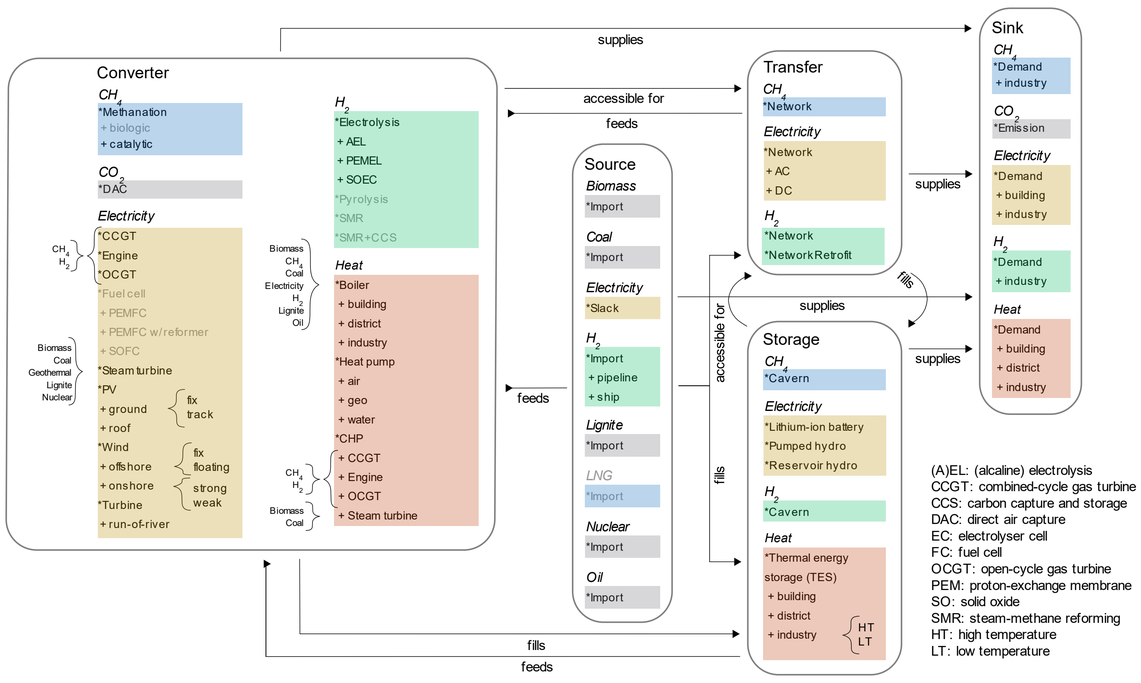

Figure 2 - Technological scope (own visualisation): more than 90 technologies in the model.

- **17 heat groups**—7 with thermal storage—**to represent different temperature regimes**[d]
- in total **45 different heat technologies**

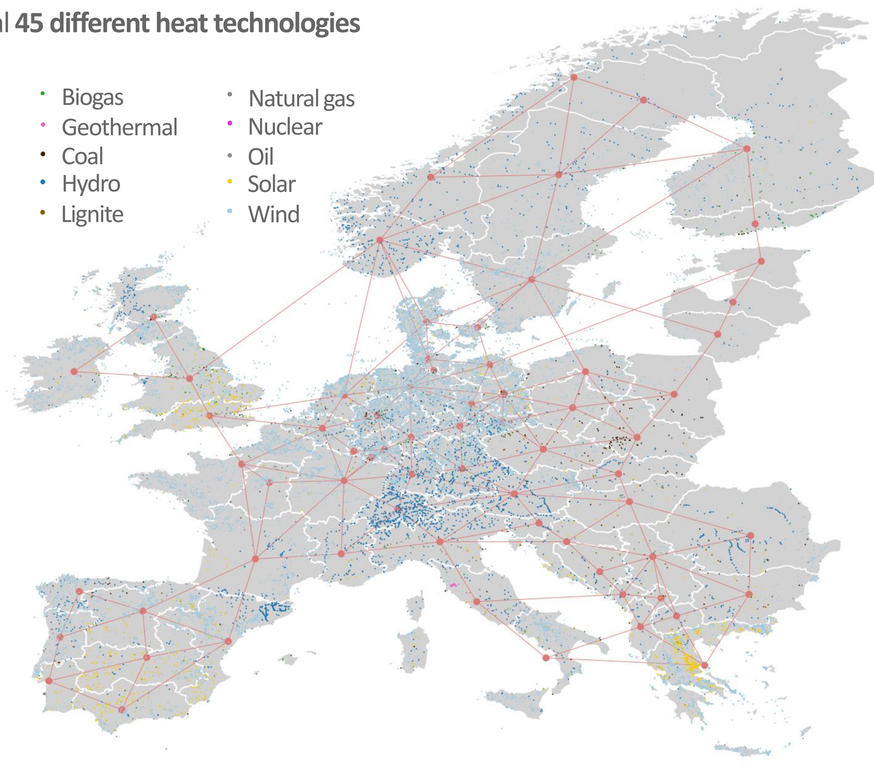

Figure 3 - Geographical scope: 70 nodes in Europe, powerplant data compiled with powerplantmatching[e], aggregated electricity[f] and gas networks[g] from open data.

RESULTS *(INTERMEDIATE)*

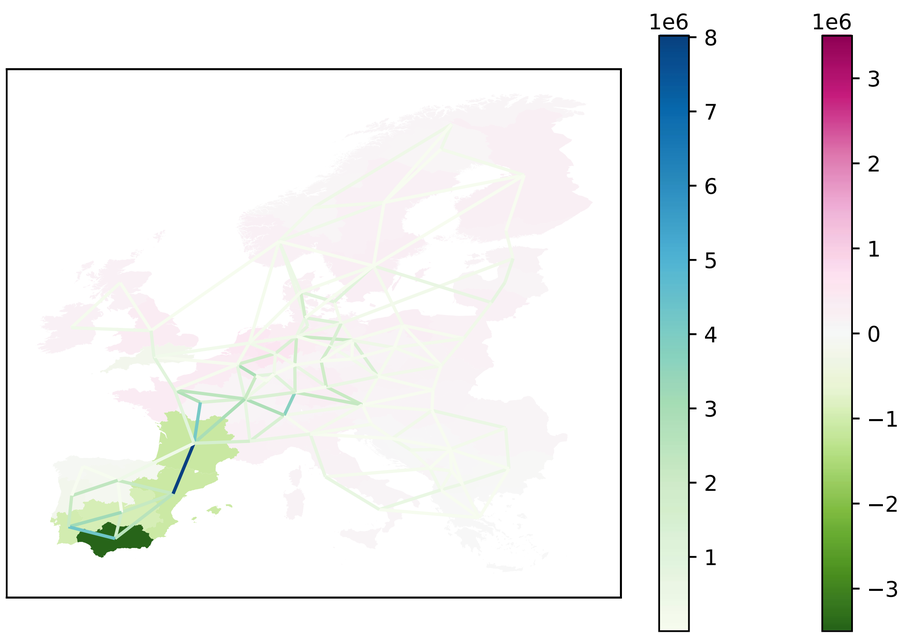

Figure 4 - Hydrogen import-export balance per model region. The colour coding of the regions refers to hydrogen imports (pink) and exports (green, in GW). The lines show absolute net flows via transfer links (in GWh).

- first runs indicate that heat sector is decorbonised mostly by means of electrification
- hydrogen caverns can play a significant role as seasonal energy storage
- methane infrastructure plays no significant role in climate-neutral energy system

OUTLOOK

- how does the **flexibility from heat** (thermal energy storage) **and gas sector** (methane and hydrogen caverns) complement a cost-minimal **climate-neutral European energy system**?
- develop from target optimisation to myopic pathway in 5-year steps
- will energy transfer in form of electricity or gas be more important?

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