EFECT Workshop 2021

Modeling sector coupling using the AnyMOD.jl framework

Methods and applications for sustainable infrastructure planning

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Agenda

1. Background
2. Methods
3. Applications
   a. Power sector modeling
   b. Energy system modeling

Model environment

Simulation

COMPUTABLE GENERAL EQUILIBRIUM MODEL (CGE-MOD)

GLOBAL GAS MODEL

GLOBAL HYDROGEN MODEL

POMATO
Power Market Tool

Optimization

GENESYS-MOD

dynELMOD

AnyMOD.jl

Open-source software framework to generate models

build passing | codecov 91% | chat on gitter | License MIT

AnyMOD.jl

Documentation

- STABLE — last thoroughly tested and fully documented version
- DEV — *in-development version of the tool*

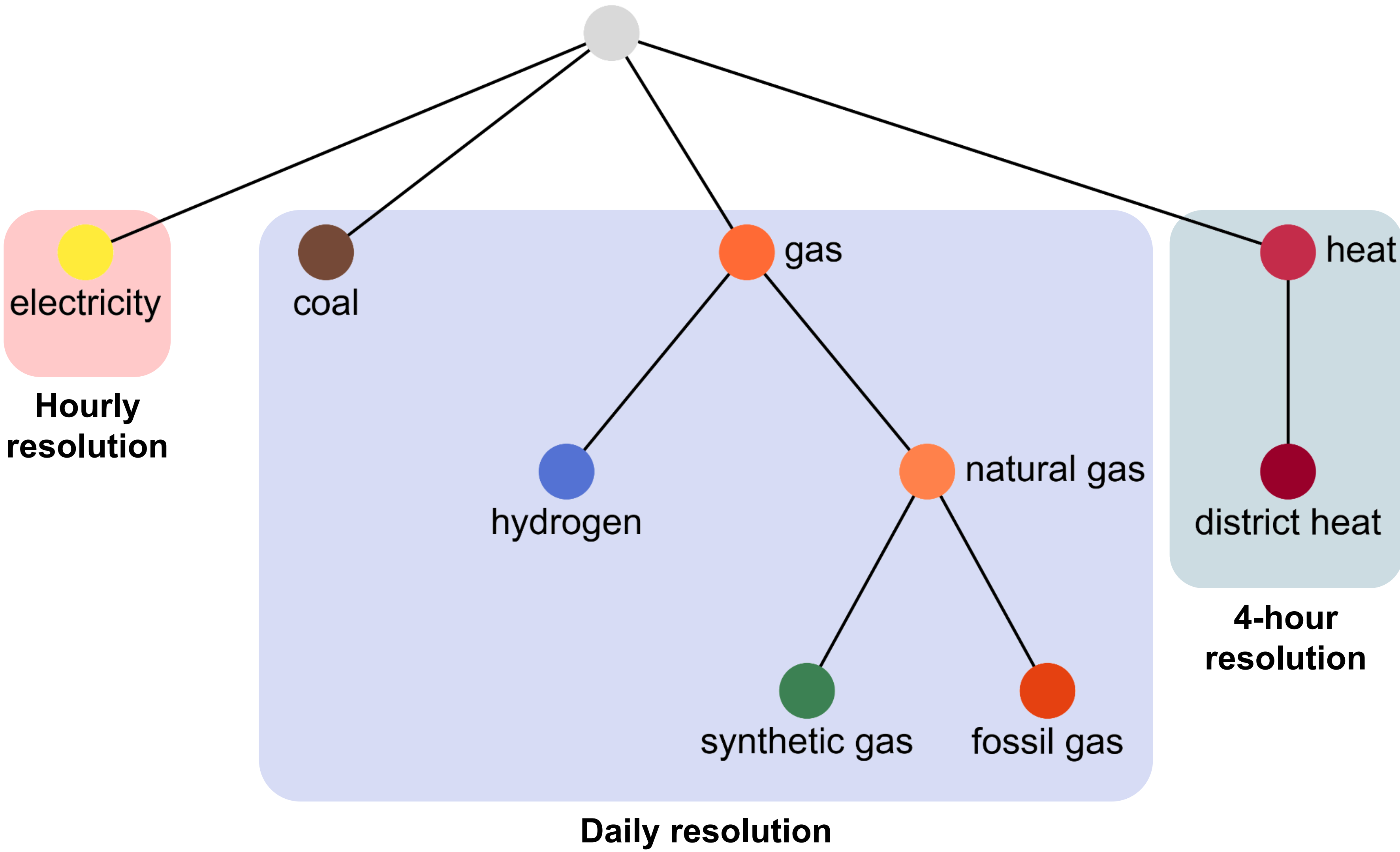
- Developed within the H2020 project *OSMOSE*
- Synthesis between conventional power sector and energy system modeling to improve the representation of sector integration and fluctuating renewables

see Göke (2021a), AnyMOD.jl: A Julia package for creating energy system models, SoftwareX.

Agenda

1. Background
2. **Methods**
   - Increase temporal detail and technological accuracy
   - Decrease computational complexity to solve in reasonable time
3. Applications
   a. Power sector modeling
   b. Energy system modeling

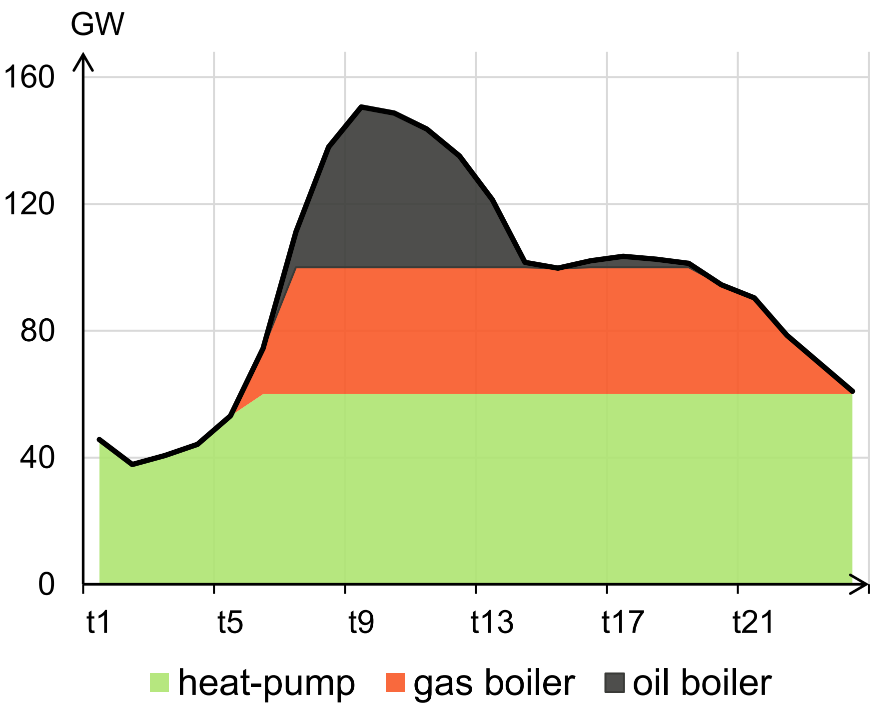
Graph-based formulation enabling different resolutions within single model



see Göke (2021b), A graph-based formulation for modeling macro-energy systems, Applied Energy.

Novel mechanics for technology deployment to account for sector integration

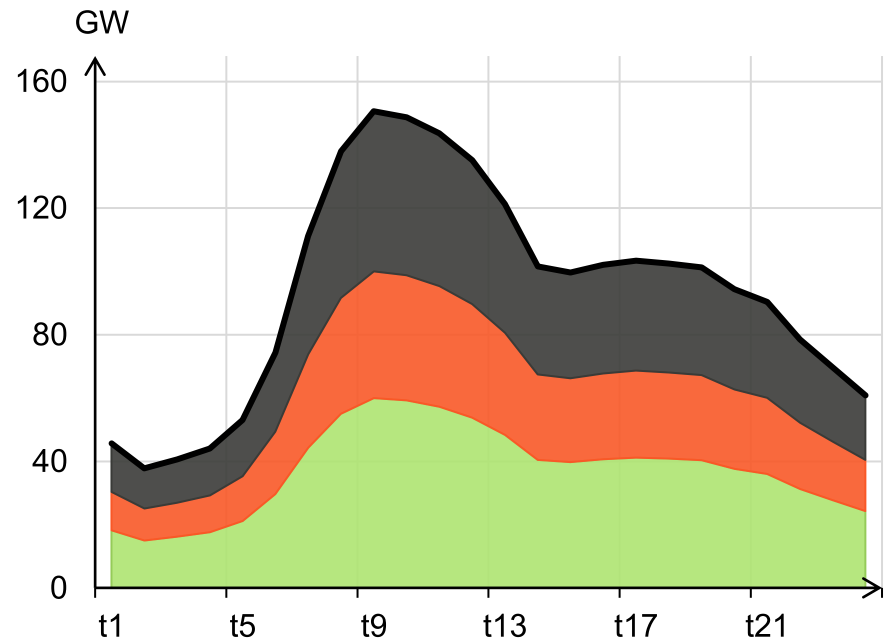
Merit-order



$$\sum_{i \in I} Out_{i,t} = dem_t \qquad \forall t \in T$$

$$Out_{i,t} \leq Capa_i \qquad \forall t \in T, i \in I$$

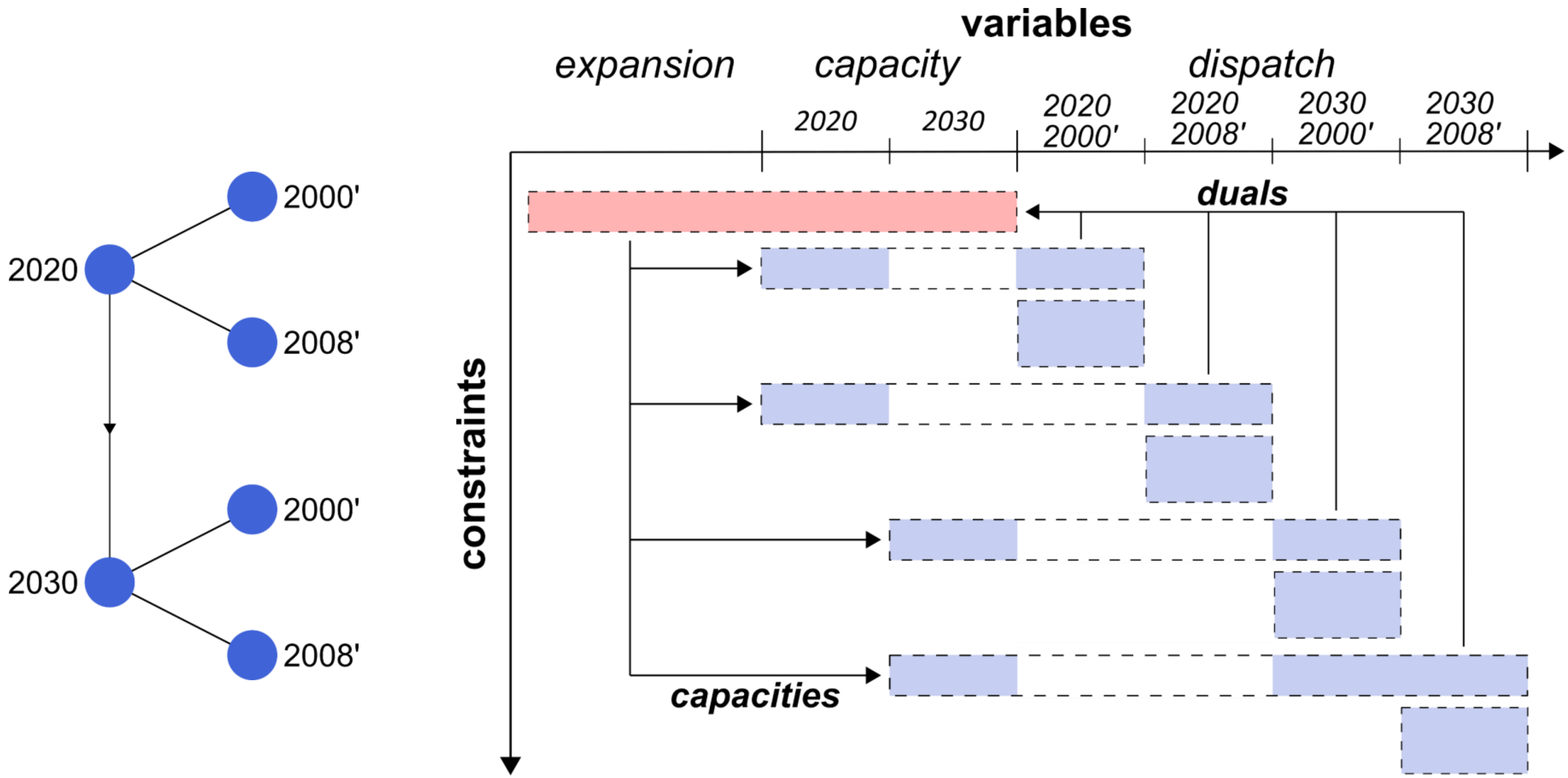
Must-run



$$\sum_{i \in I} Capa_i = peak$$

$$Out_{i,t} = \frac{dem_t}{peak} \cdot Capa_i \qquad \forall t \in T, i \in I$$

Accelerate stochastic optimization of pathways with refined Benders decomposition (work in progress)



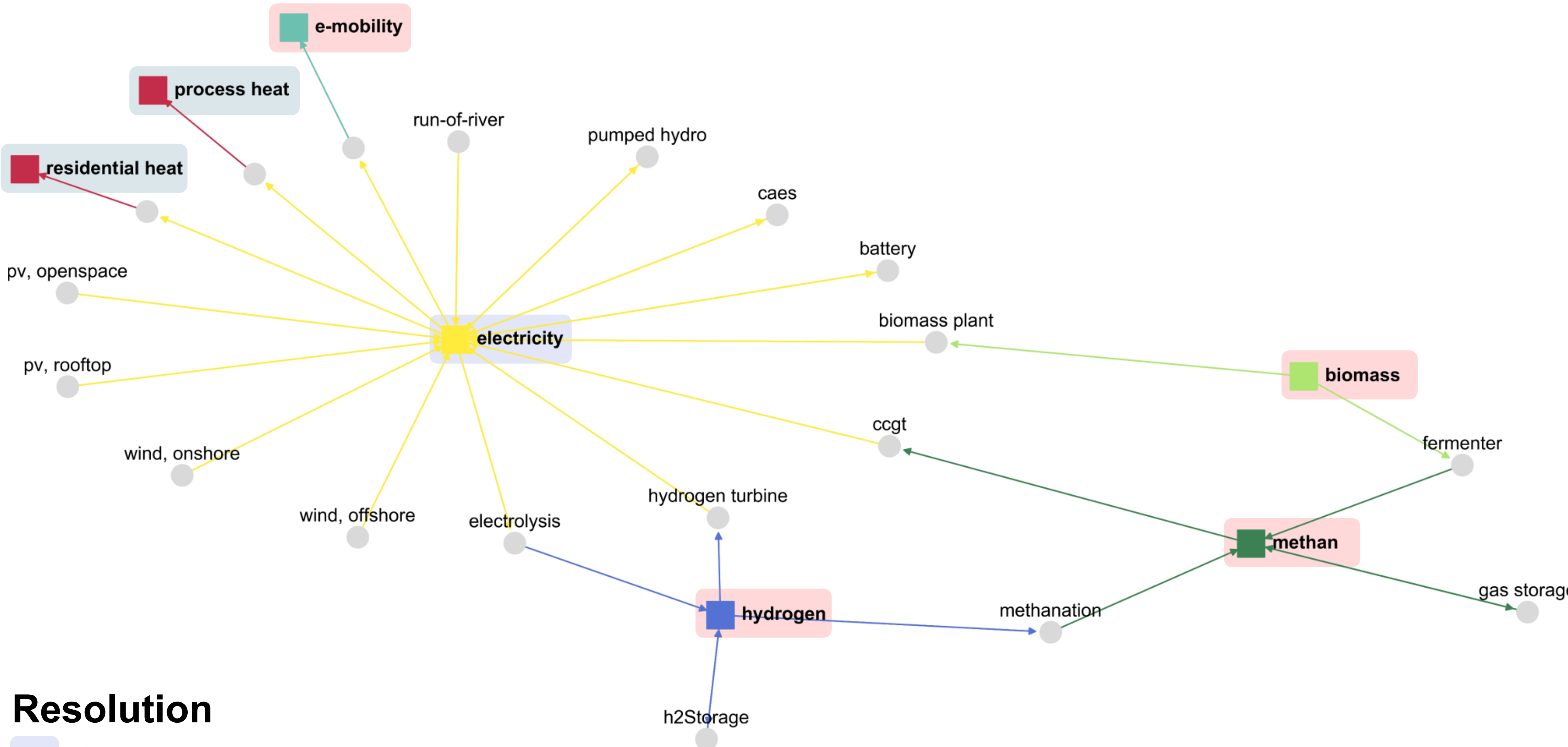
- Graph and matrix depict a model with two consecutive years of capacity expansion each including two single-stage scenarios based on climatic years
- Benders decomposition for this model greatly profits from parallelization

Agenda

1. Background
2. Methods
3. Applications
   a. Power sector modeling
      - Model was developed for a project on decentralization in renewable energy systems
      - Focus on the power sector and a single year to achieve high spatial detail and an hourly resolution
      - Final energy demand derived from *OpenENTRANCE* scenarios from Auer et al.

   b. Energy system modeling

Overview of energy carriers and technologies

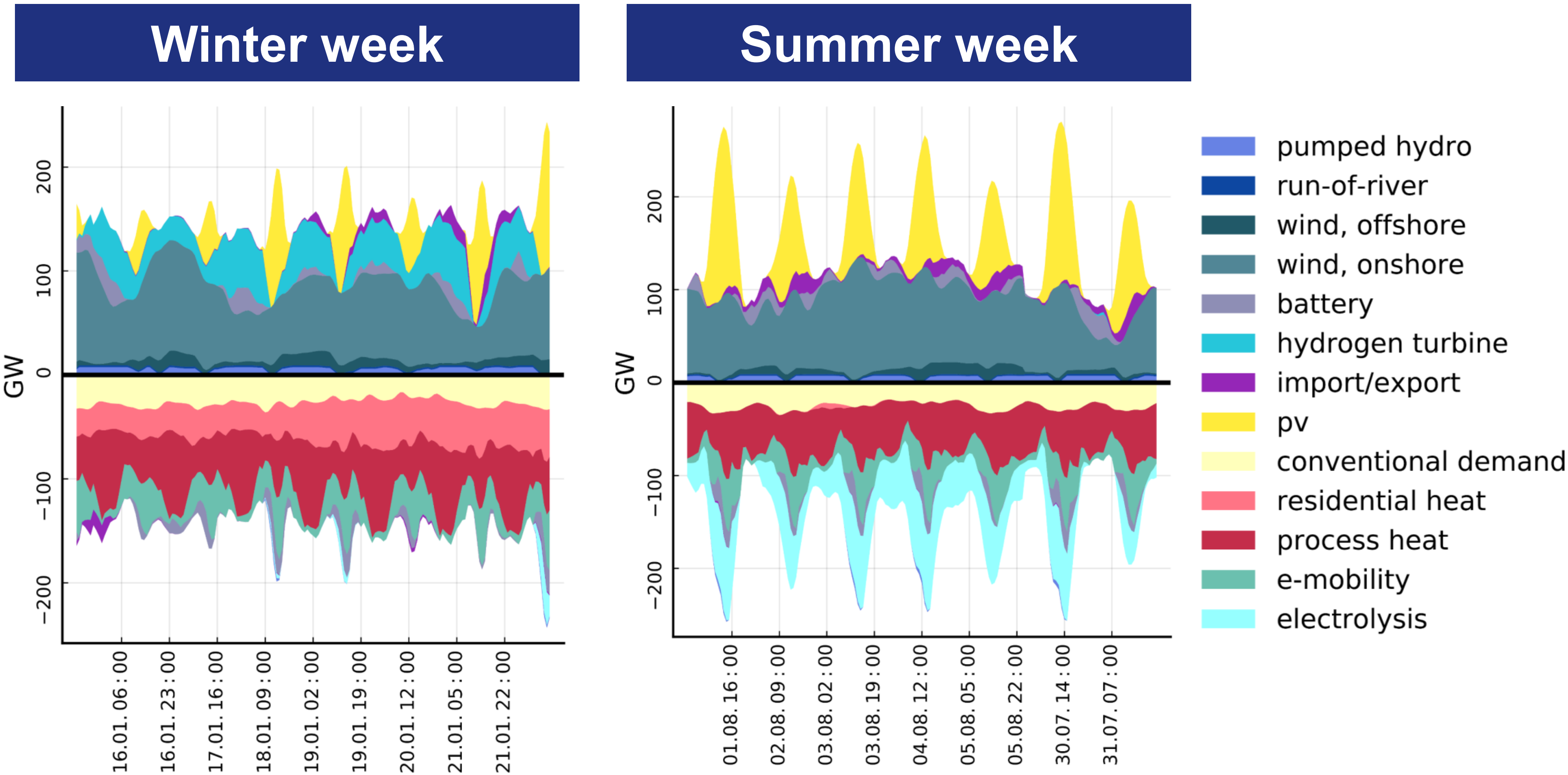


Resolution

- hourly
- 4-hour steps
- daily

see Göke et al. (2021), Accounting for spatiality of renewables and storage in transmission planning.

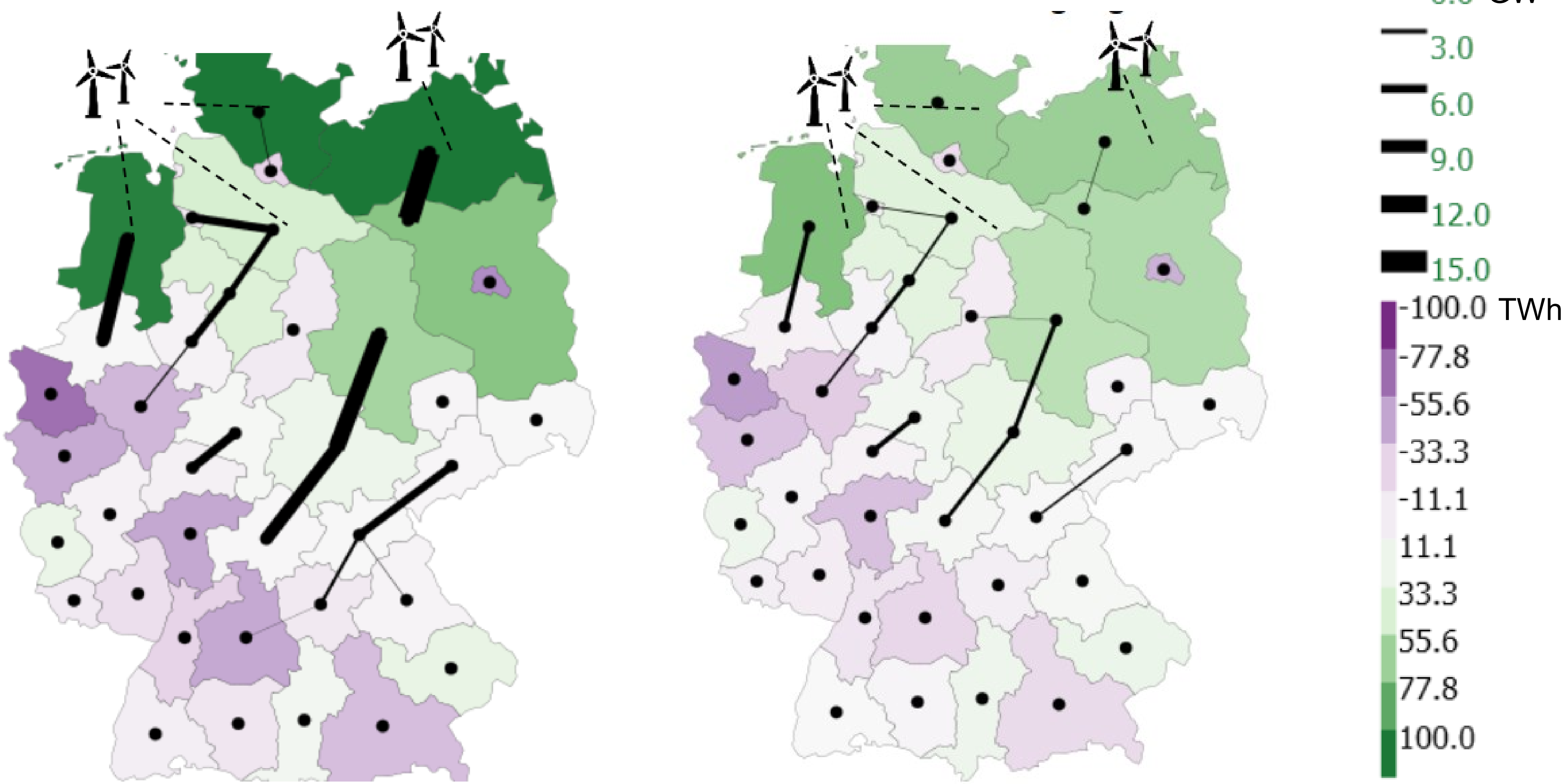
Hourly supply and demand of electricity



see Kendziorski et al. (2021), 100% Renewable Energy for Germany, DIW weekly report.

Grid expansion and net exports

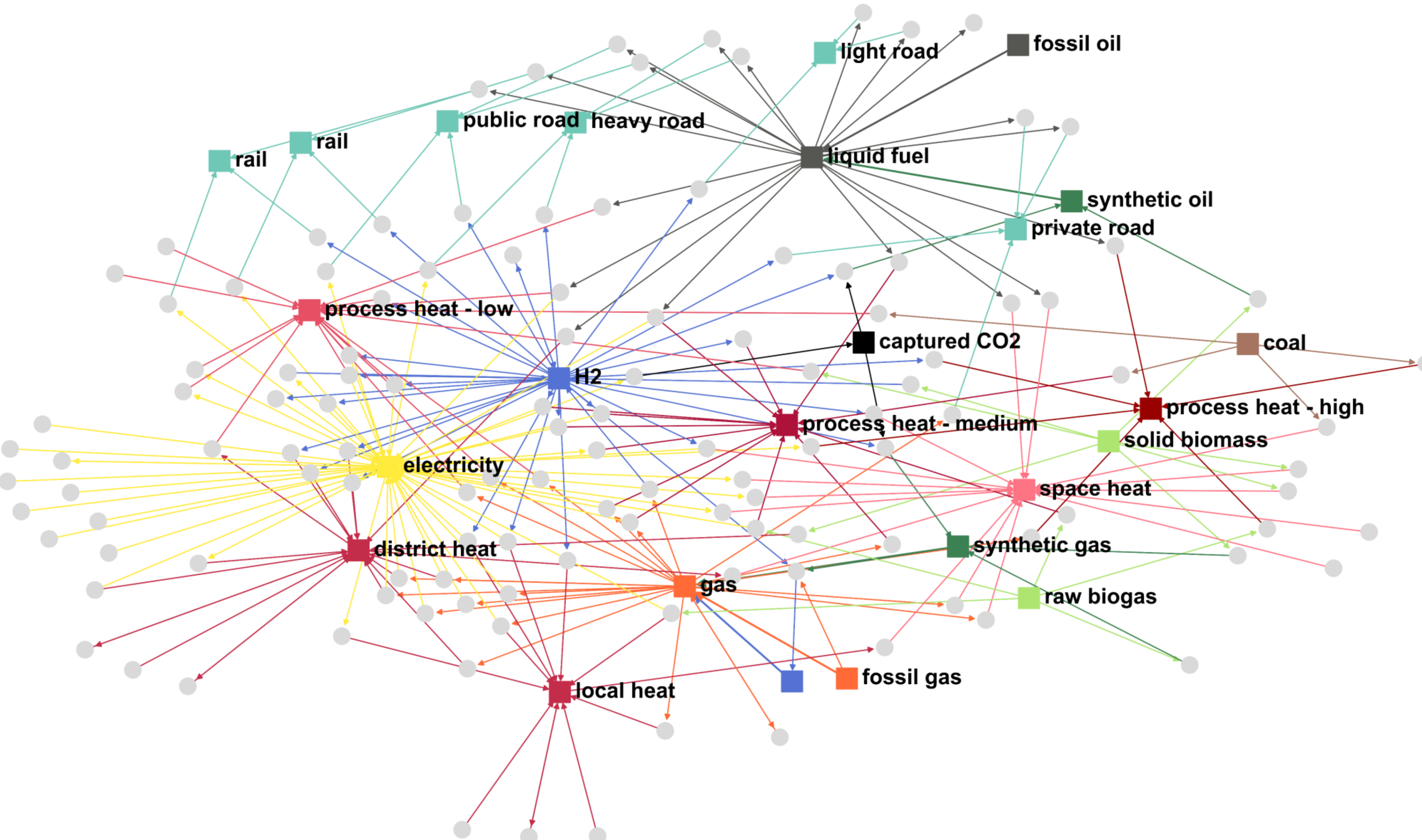
Centralized	De-Centralized



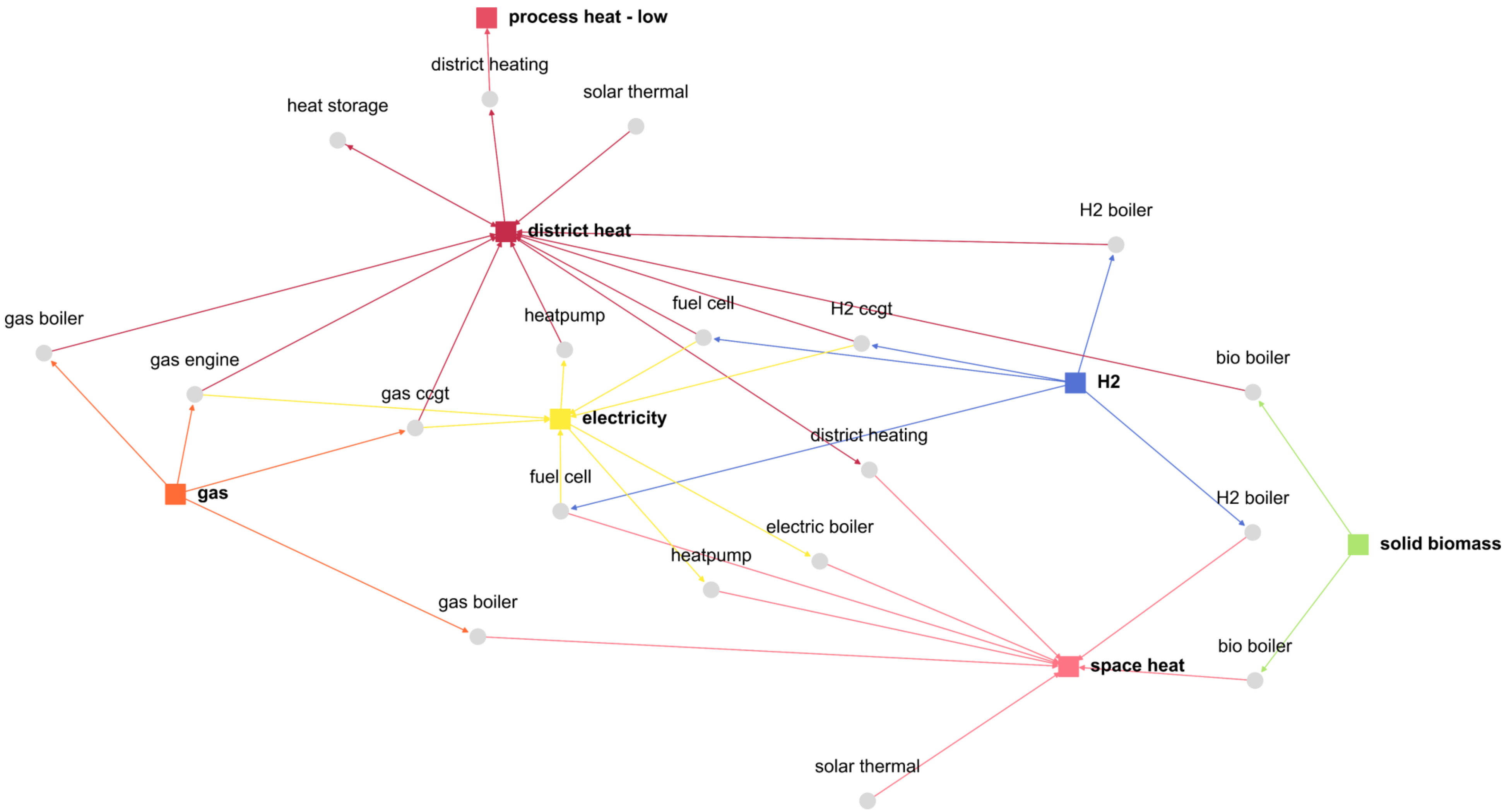
Agenda

1. Background
2. Methods
3. Applications
   a. Power sector modeling
   b. **Energy system modeling**
      - Scenarios for long-term development of the European energy system for the *OSMOSE* project
      - Optimizing a pathway from 2020 to 2050 across all sectors of the energy-system
      - Reduction of detail to ~400 time-steps and 96 regions

Overview of energy carriers and technologies



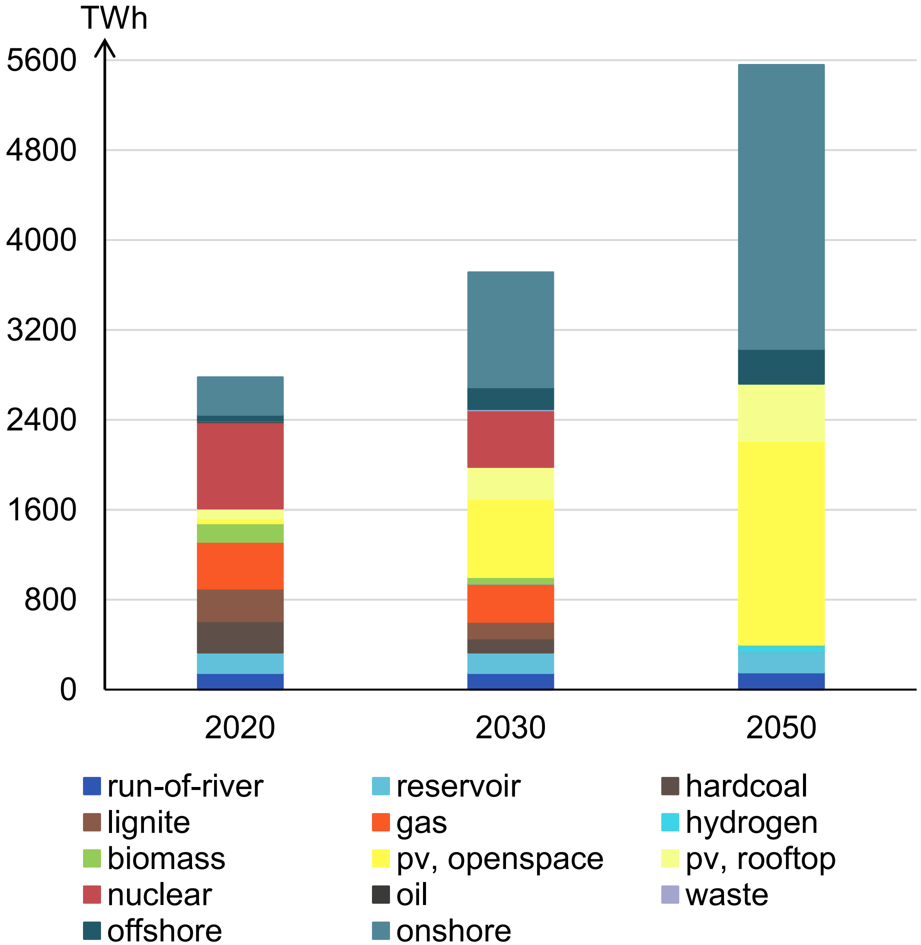
Technological options for space and district heating



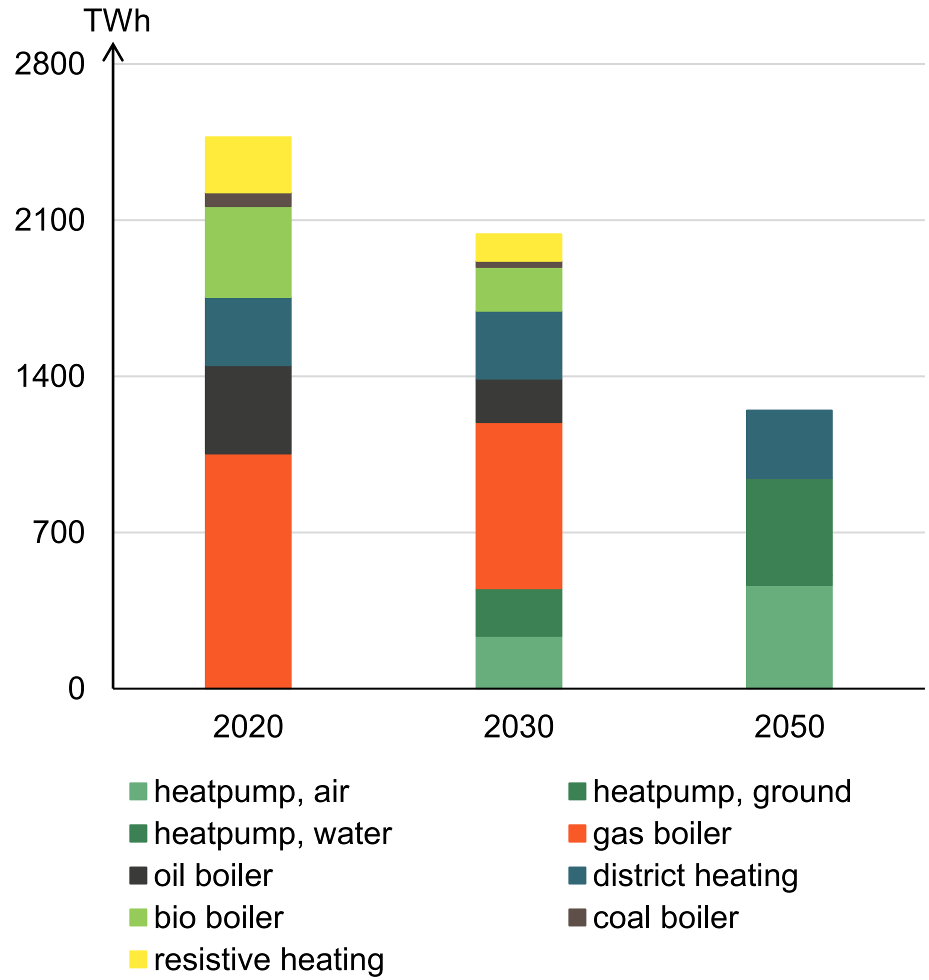
Development of power and heat generation in EU27

(preliminary results)

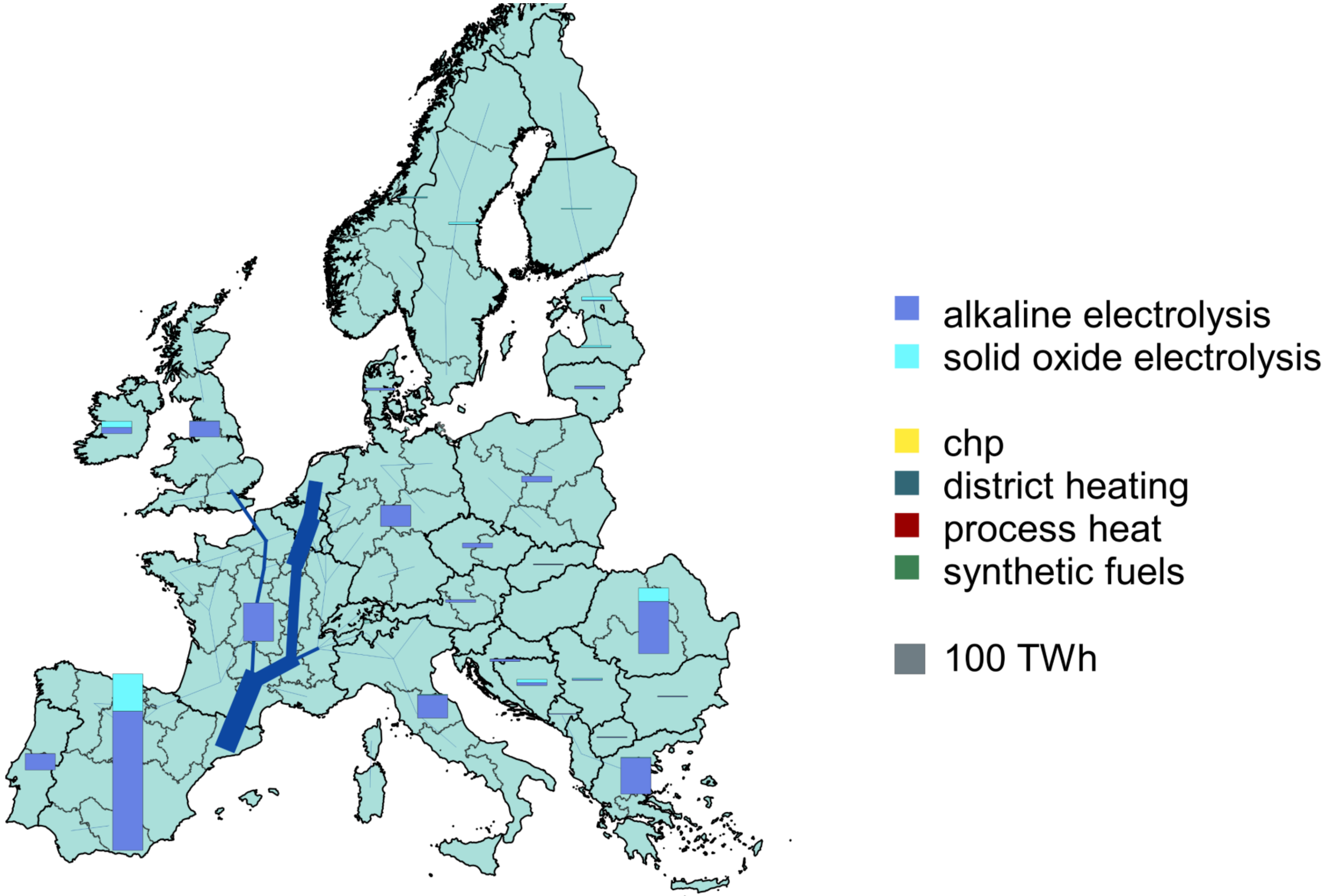
Power generation



Space heat



Transmission grid and consumption for hydrogen in 2050
(preliminary results)



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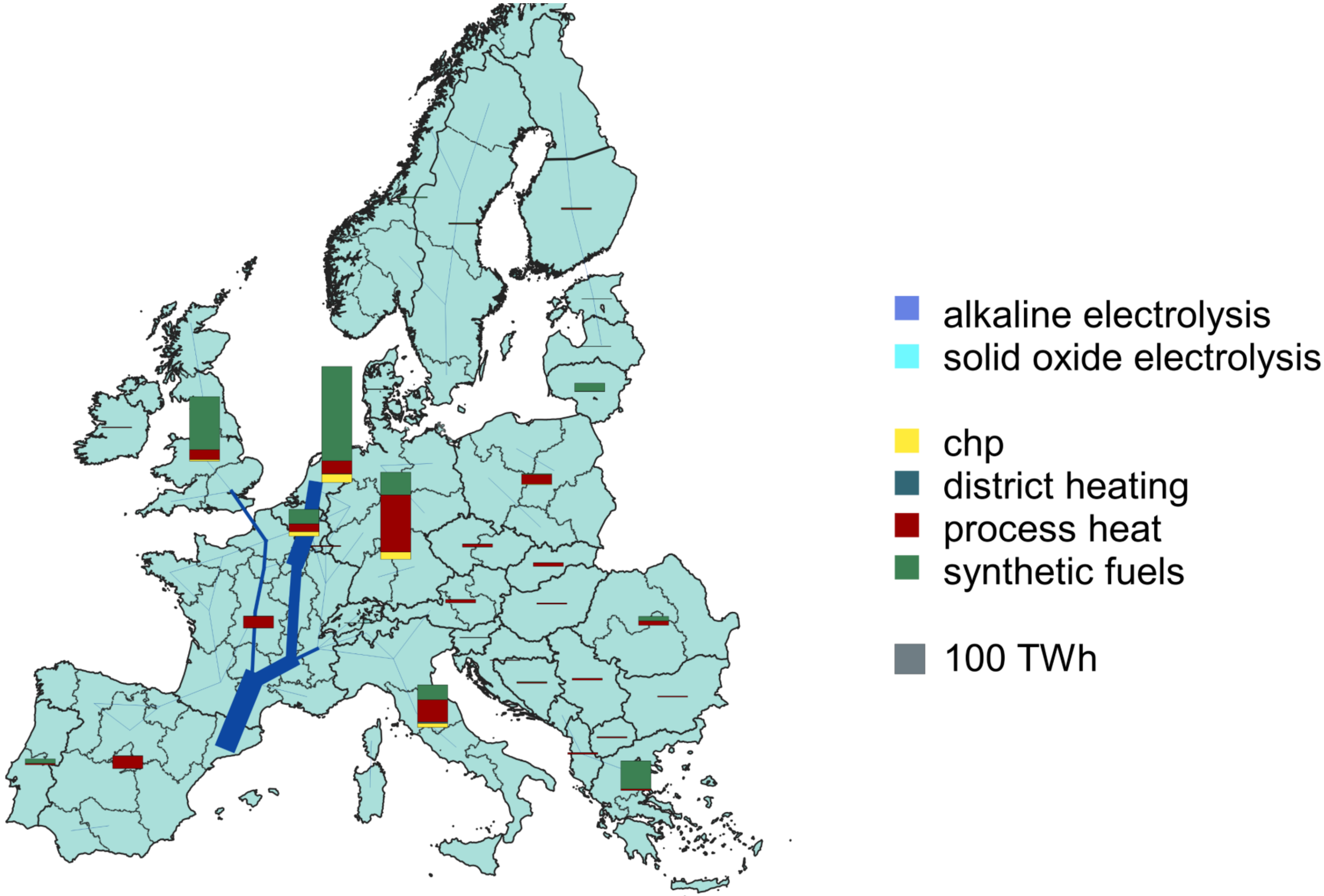

References

Auer, H. et al. 2020. “Development and modelling of different decarbonization scenarios of the European energy system until 2050 as a contribution to achieving the ambitious 1.5°C climate target.” *Elektrotechnik und Informationstechnik* 137(7):346–358.

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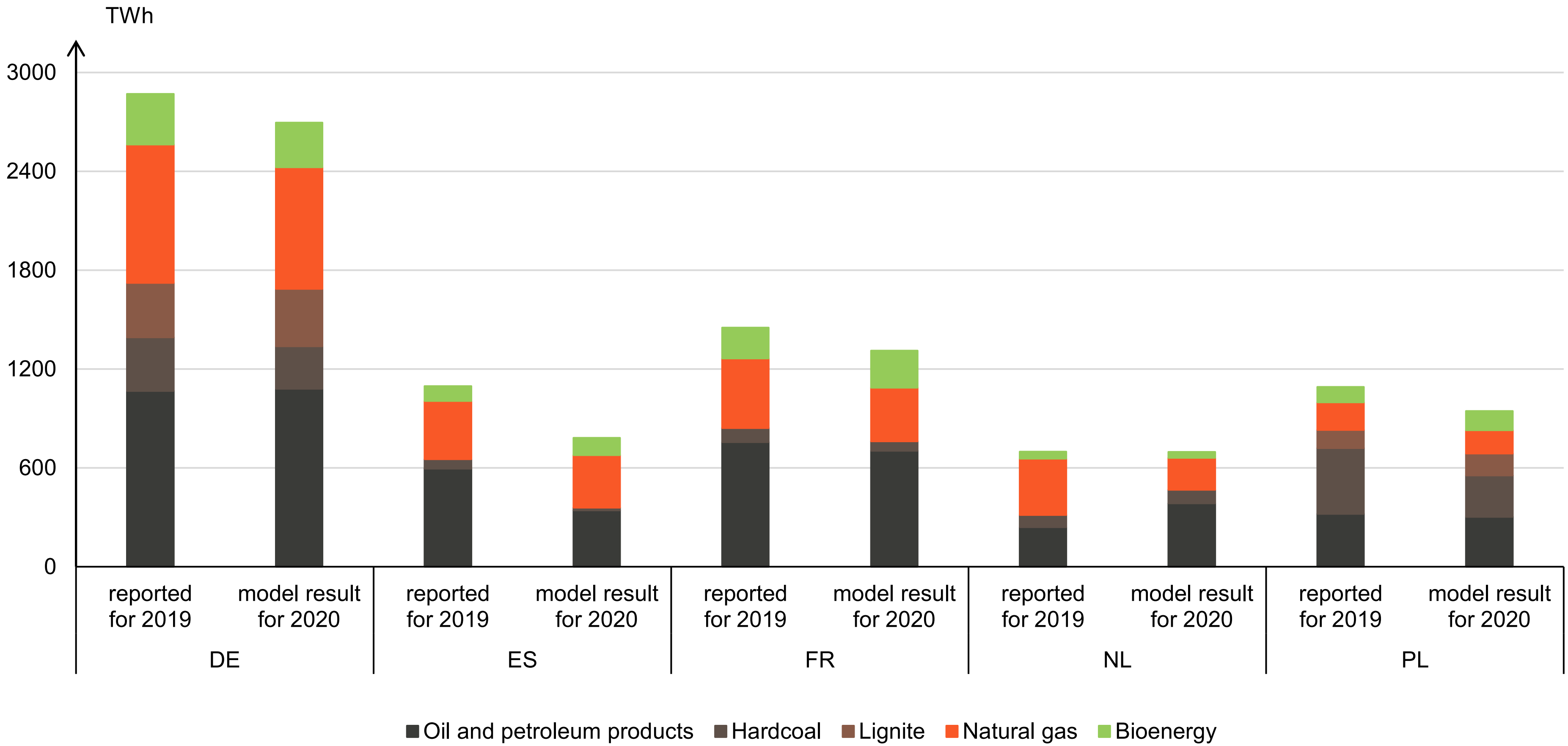
Kendziorski et al. 2021. “100% Renewable Energy for Germany: Coordinated Expansion Planning Needed.”. *DIW weekly report.*

OSMOSE. 2019. “European Long-Term Scenarios Description.” *Project report.*

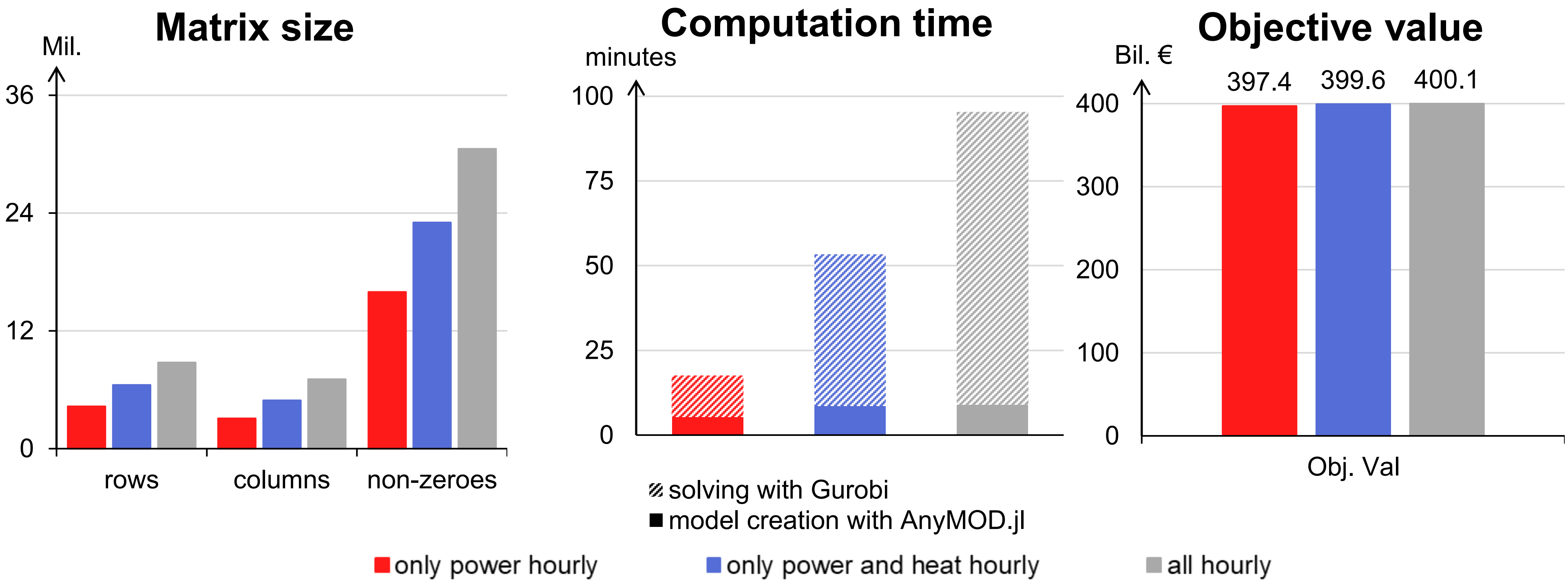
GitHub @AnyMOD.jl

@anygoeke

Gross inland consumption, excl. non-energy consumption



Backup: Impact of temporal resolution on model performance



Results

- Selective variation of temporal resolution greatly reduces computational complexity but has a minor effect on results
- Reductions of the objective can be interpreted as the value of system inherent flexibility

Backup: Static and linear trust-region

- Variables of top-problem are
  - **fixed**, if heuristic solutions provide the same results
  - **limited**, if heuristic solutions provide different results
- Fixed variables are treated as parameters to speed-up top- and sub-problem
- Bounds on limited variables are removed once gap reaches a certain threshold