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Disclosing the heat density of centralized heat networks under the 1.5°C climate target



Sebastian Zwickl-Bernhard¹, Daniel Huppmann², Antonia Golab¹, Hans Auer¹

¹Energy Economics Group (EEG), Technische Universität Wien

²International Institute for Applied Systems Analysis



Parallel Session 4: Improving Integration and Efficiency (Day 1)

Corresponding author/Presenter: zwickl@eeg.tuwien.ac.at



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Current state of the European heating sector

- The average share of renewables in the heating & cooling sector is only just above 20% on average in all EU member states¹
- In Austria it is 34% - but fossil fuels continue to dominant the provision of heating and cooling services here as well
- 900,000 dwellings are heated with natural gas and 500,000 with oil (Austria 2020)
- Retrofitting of 50,000 appliances per year, or more than 130 per day since the viability of green gas is uncertain at the end-user device level
- Requires to a massive expansion of centralized heating (and cooling) networks to...
 - ...ensure a highly efficient usage of renewable heat sources (e.g., biomass/waste, hydrogen)
 - ...achieve significant retrofitting rates by high connection rates
 - ...unburden the electricity sector (high electrification of different energy service needs)

The core objective of this work

- The core objective of this work is downscaling European decarbonization scenarios¹ of the heating sector to the community/distribution grid level serving end-users in 2050.
- In particular, downscaling considers the highly efficient and local use of sustainable heat sources in centralized heat networks (e.g., co-firing hydrogen in cogeneration plants and large-scale waste utilization, etc.).
- In addition, the topography of district heating networks is of particular importance and plays a crucial role in applied downscaling.
- This allows estimates of realistic and cost-effective decarbonized district heating networks in 2050 to be obtained, which can be compared with existing networks. Thereby, the heat density of district heating networks serves as a comparative indicator and permits a rough estimation of the changes needed for centralized heating networks considering the 1.5°C climate target.
- An Austrian case study is conducted, downscaling the results of the heating sector in 2050 from the large numerical energy system model GENeSYS-MOD², from the country to the community/distribution grid levels.

¹Developed in the European H2020 project [openENTRANCE](#) aiming for the 1.5/2.0°C global warming climate target

²Löffler et al., *Energies*, (2017). doi: [10.3390/en10101468](#)

Methodology

NUTS classification	Description	Number	Example (population)
NUTS0	Country level	1	AT Austria (8.86 millions)
NUTS1	Major socio-economic regions	3	AT3 Western Austria (2.78 millions)
NUTS2	Basic regions for the application of regional policies (federal states)	9	AT31 Upper Austria (1.48 millions)
NUTS3	(Small) sub-regions for specific diagnoses (political/court districts)	35	AT312 Linz-Wels (529 thousands)
LAU (former NUTS4/5)	Subdivision of the NUTS 3 regions (communities)	2095	Enns AT312 Linz-Wels (11 thousands)

- Three different scenario-independent downscaling techniques

- 1. Proportional downscaling** using population as a proxy (NUTS0 to the LAU level)
- 2. Sequential downscaling** algorithm using population density and infrastructure requirements of heat technologies/sources as additional criterion (NUTS0 to the NUTS3)
- 3. Iterative downscaling** algorithm based on graph-theory benchmarking (NUTS3 to the LAU level)

Reference technique

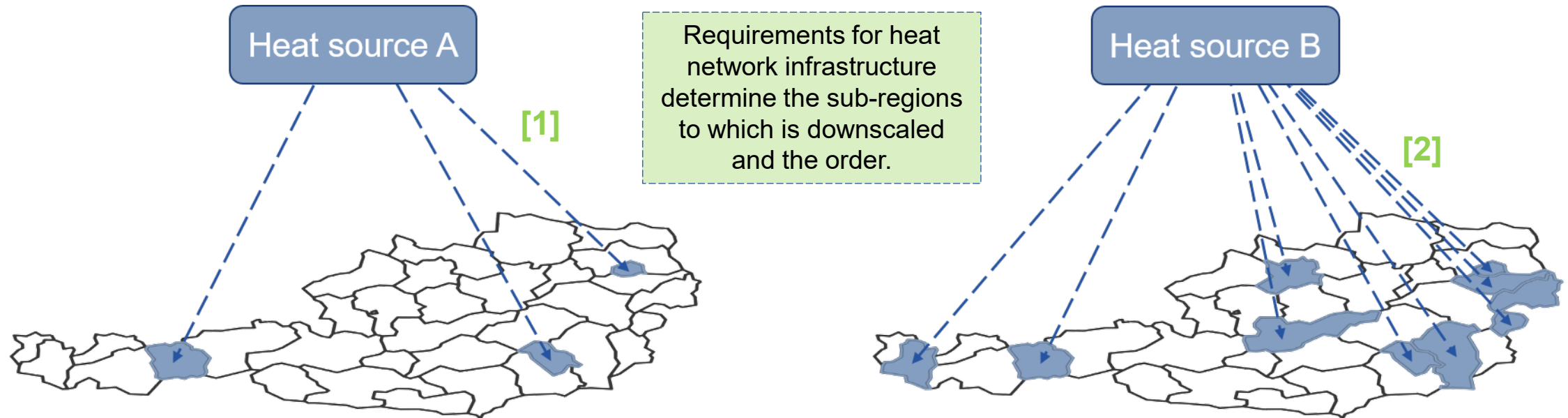
Techniques developed

The Nomenclature of Territorial Units for Statistics (NUTS) were created by Eurostat in order to define territorial units for the production of regional statistics across the European Union.

Main concept of the sequential downscaling algorithm

Heat source A has **high requirements** for heat network infrastructure (e.g., hydrogen)

Heat source B has **median requirements** for heat network infrastructure (e.g., biomass)

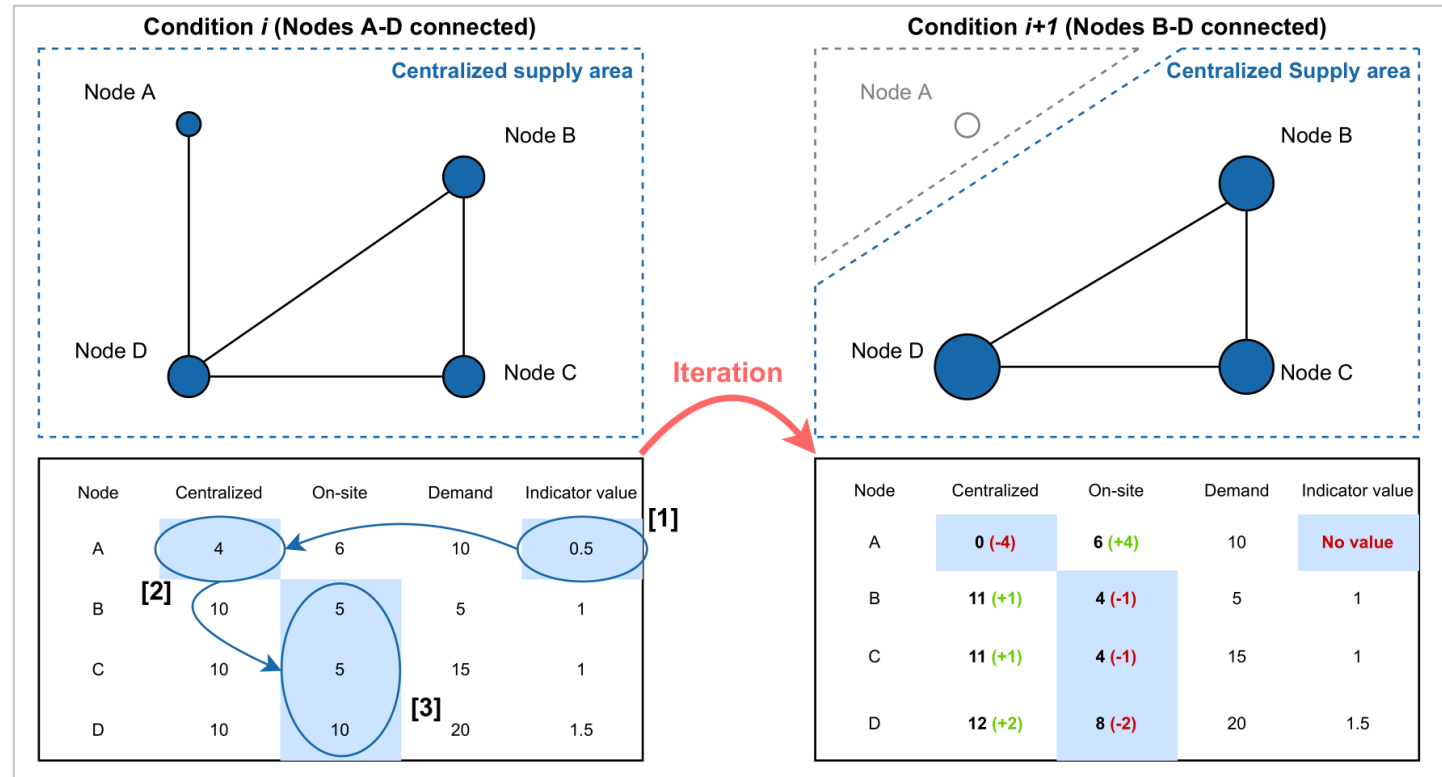


[3] Heat sources without requirements for heat network infrastructure are downscaled last. For example, direct-electric heating is disaggregated to all sub-regions proportionally.

Main concept of the iterative downscaling algorithm

$$c_n = \frac{q_n}{q_{max}} \times \frac{\alpha_n}{\beta_n}$$

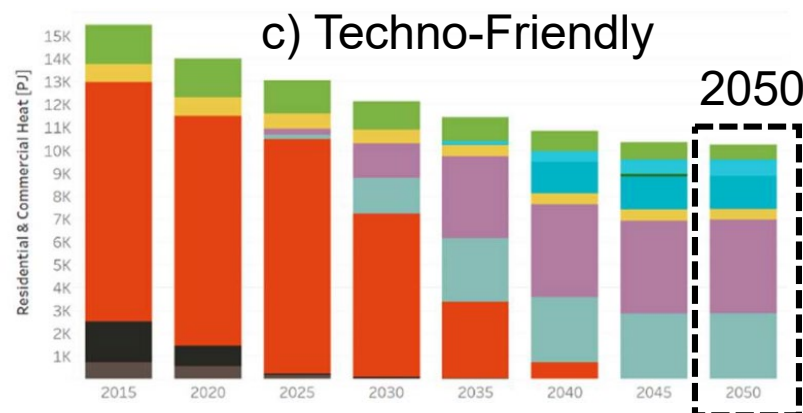
Cluster(ing) coefficient c
=
Indicator value



- (i) High connection rate to the centralized heat network at the nodes
- (ii) Connection of those nodes with a high amount of heat demand and heat density respectively

Numerical example and scenarios

- Four different decarbonization scenarios of the European energy system aiming for the 1.5/2.0°C global warming climate target¹
 - Directed Transition scenario (strong policy incentives)
 - Societal Commitment scenario (strong societal acceptance, decentralized renewables)
 - Techno-Friendly scenario (market-driven breakthrough of renewables)
 - Gradual Development scenario ("little of each")
- Values of the decarbonized heating sector in Austria 2050 obtained by the large-numerical energy system model GENeSYS-MOD



Technology



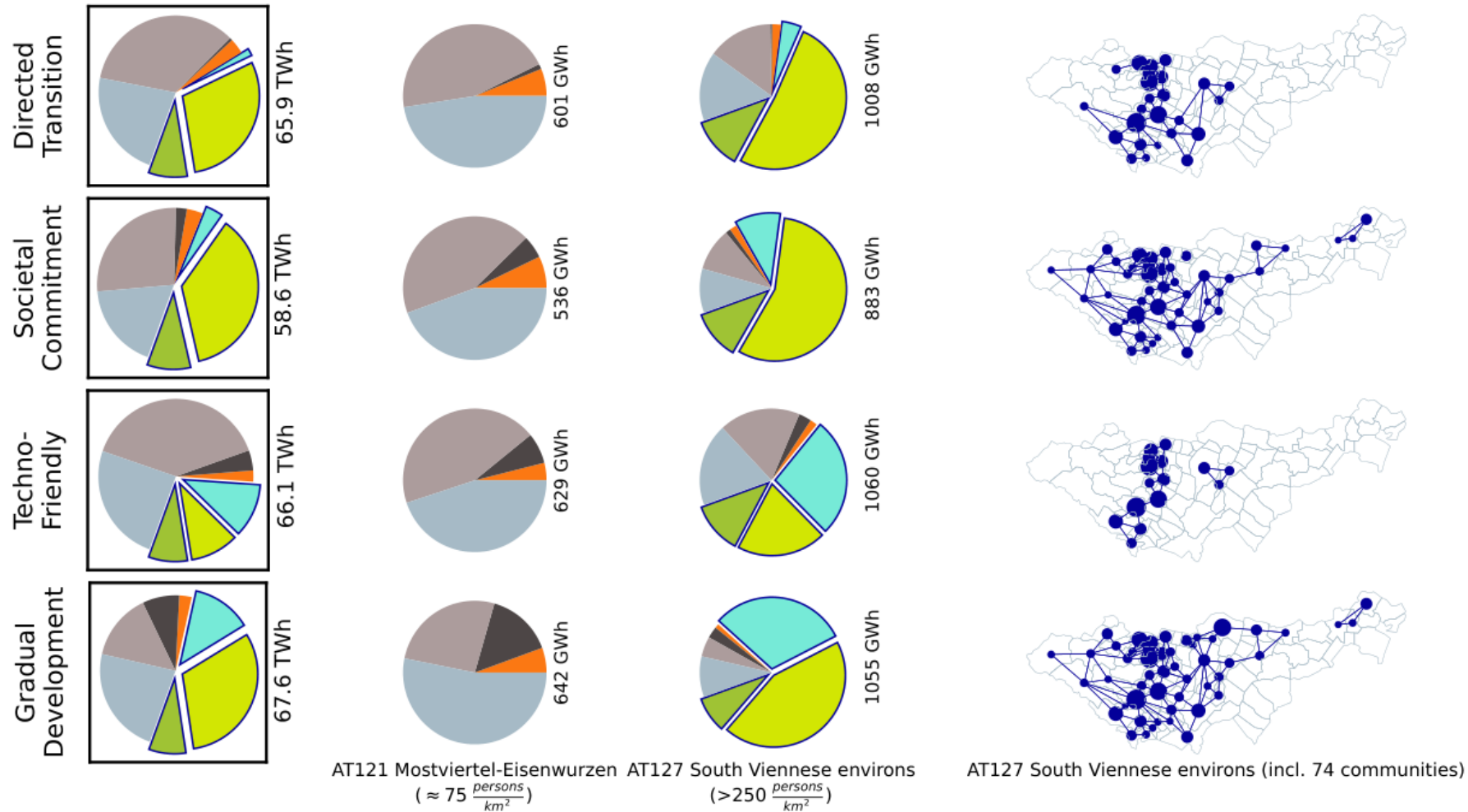
¹Scenario a) to c) considers the 1.5°C global warming target and d) the less ambitious 2.0°C.

Heat generation on the country, sub-region, and community level

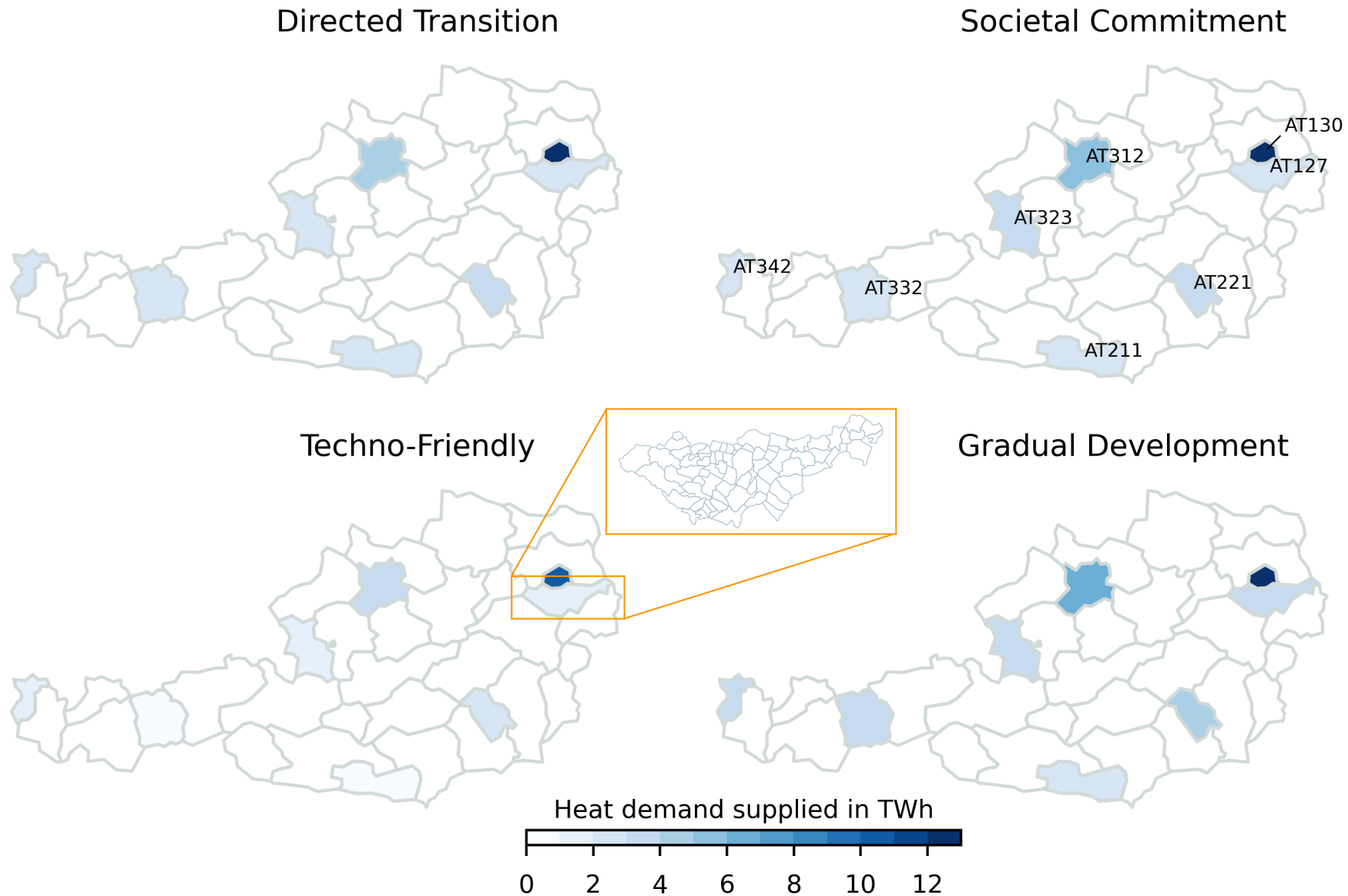
Storage Biomass Direct electric Gas H_2 HP (air) HP (ground) Network-based heat supply

Austria (country) Rural (sub-region) Urban (sub-region)

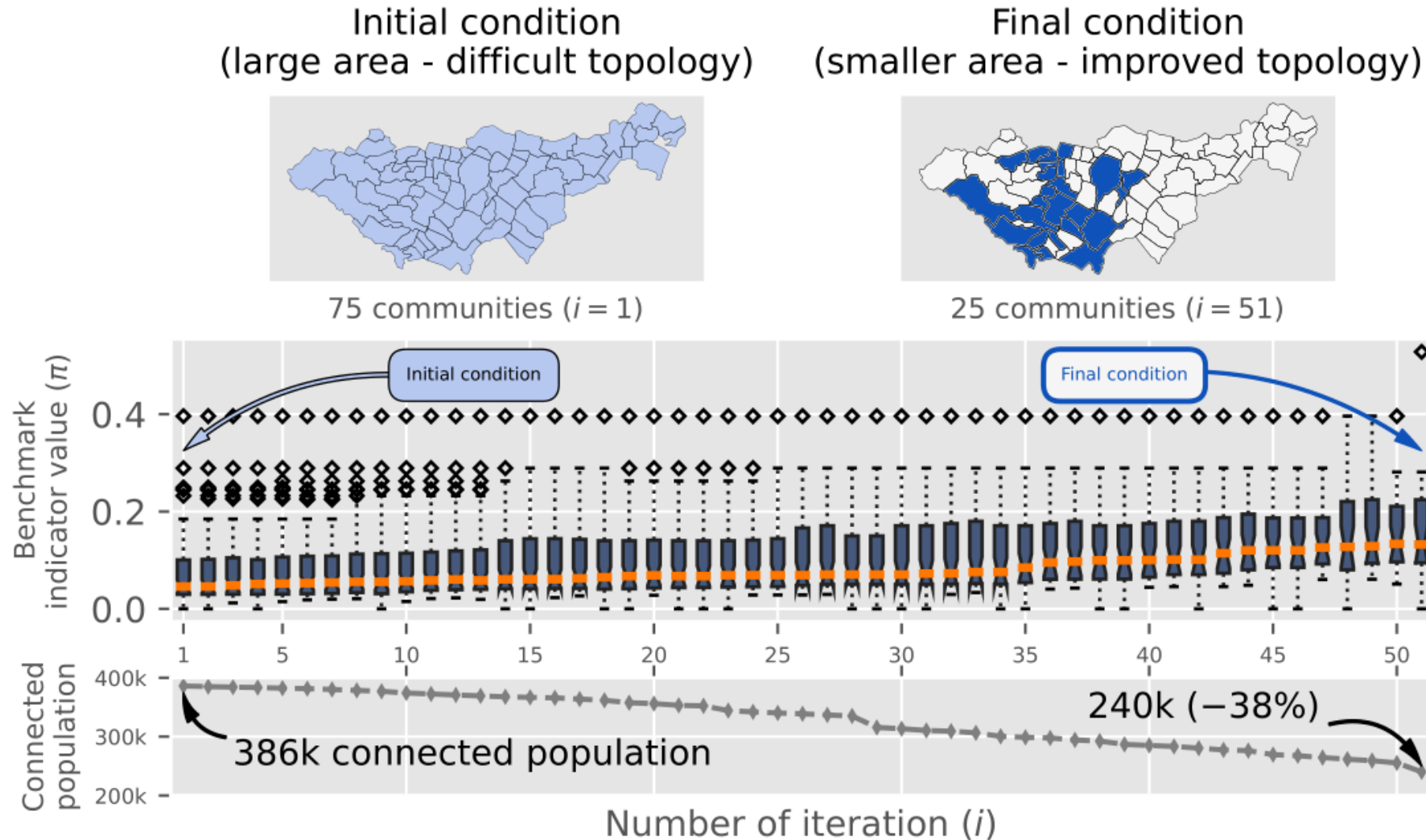
Centralized heat networks (community level)



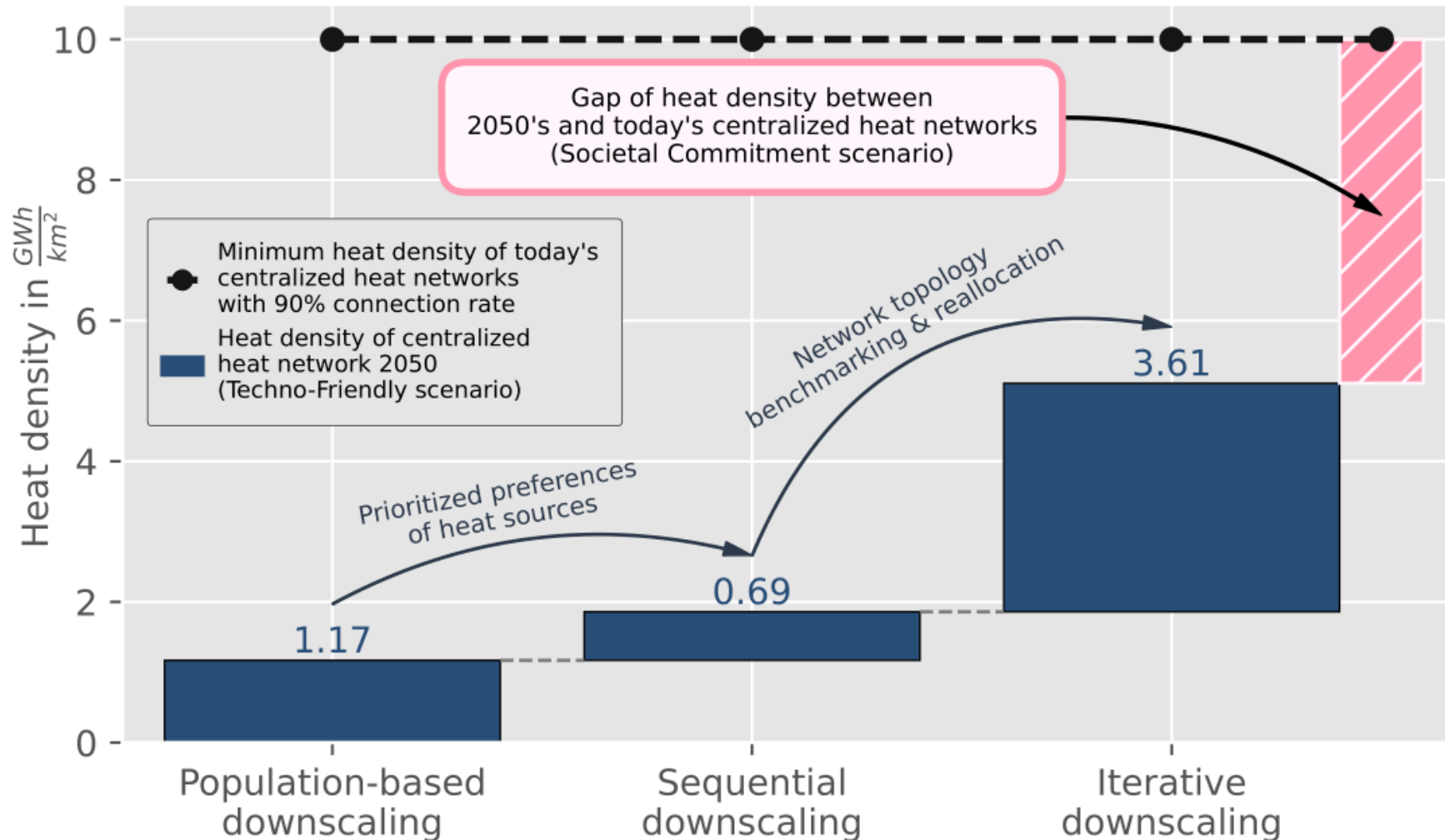
Heat demand supplied by centralized heat networks in TWh



Centralized heat network topology improves by reducing supply area



Heat density of the centralized heat network in Graz (AT221) 2050 obtained by different downscaling techniques



Conclusions

- We found that the prioritized perspective of efficiency and local utilization of renewable heat sources implies substantial changes for the further development of district heating networks in the decarbonized Austrian heat supply toward 2050.
- The results demonstrate that particularly densely populated areas are still beneficial supply areas for district heating networks and offer adequate heat densities.
- Nevertheless, most district heating networks in 2050 (seven of eight) will not reach the heat density benchmarks of today's networks and have a significant heat density gap.
- However, considering the increasing importance of local renewable heat sources feeding into district heating networks, we assume that these centralized networks will become required in the future and crucial in the decarbonization of the heating sector.
- We anticipate our work as a starting point for discussing the role of centralized heat network infrastructure for enabling large-scale, highly efficient and local integration of renewable heat sources such as biomass/waste, hydrogen, ground-sourced heat pumps, or geothermal units.

Acknowledgments / References

Collaborators

Daniel Huppmann (International Institute for Applied Systems Analysis)

Antonia Golab (Energy Economics Group – Technische Universität Wien)

Hans Auer (Energy Economics Group – Technische Universität Wien)



Further references

H. Auer et al. (2020). Development and modelling of different decarbonization scenarios at the European energy system until 2050 as a contribution to achieving the ambitious 1.5°C climate target – establishment of open source/data modelling in the European H2020 project openENTRANCE, *e&i Elektrotechnik und Informationstechnik*, 1-13. doi: [10.1007/s00502-020-00832-7](https://doi.org/10.1007/s00502-020-00832-7)



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