Concurrent Session 131: Gas Economics

Presided by: Edmar de Almeida (UFRJ)

Roomchief: Jean Pierre Dib

Presentations: Relative role of electricity and gas in a carbon neutral future: Insights from an energy system optimization model, *Behrang Shirizadeh*
Presenter: Behrang Shirizadeh (Deloitte / CIRED)

Obsolescence of the gas distribution grid in urban areas: An open-source modeling approach for the gas face-out in local neighborhoods, *Sebastian Zwickl-Bernhard*
Presenter: Sebastian Zwickl-Bernhard (TU Wien)

Challenges and Oportunities of LNG in Brazilian market by the Government Program "New Gas Market", *Lauron Arend, Drielli Peyerl, Edmilson Santos*
Presenter: Lauron Arend (USP/IEE)

Obsolescence of the gas distribution grid in urban areas: An open-source modeling approach for the gas face-out in local neighborhoods

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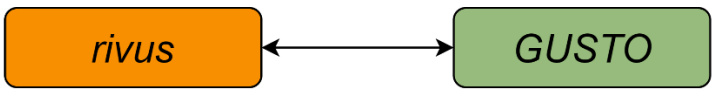
Overview

Decarbonization pathways and the accompanying sustainable energy transformation mean a fundamental change in the provision of energy services. In particular, this applies to the heat supply, which has so far been substantially dependent on fossil fuels, such as natural gas. The main objective of this work is to find the optimal local energy supply for a small urban neighborhood under a targeted local gas phase-out of the district from the gas distribution network. The investigation includes the distribution network infrastructure of several energy carriers (e.g., electricity, gas, and district heating/cooling) and their trade-offs. This provides valuable insights into needed trajectories to a sustainable energy supply. Equally important in the analysis is the expected increase in the cooling demand and identification of its impact on the distribution network grid. The method applied to answer the main research question is a linkage between two open-source models, namely, *rivus* and *GUSTO*. In this work, different scenarios are carried out, which consider relevant scientific literature on the development and future role of natural gas in the heat supply, providing further insights, especially on the local level of energy system planning. Among others, the following scenarios are analyzed: (i) high electrification of the urban neighborhood including the provision of the heat and cooling demand, (ii) connection to a district heating and cooling network, (iii) connection to a significantly enhanced district heating network, which enables both, the provision of heat and cooling services using the same infrastructure, and (iv) a very limited heat supply via synthetic gas. The contribution of this work has high relevance especially due to findings of previous works. As stated in [1], the profitability of the natural gas supply significantly depends on the number of users/customers. Thus, the gas phase-out of local neighborhoods can be seen as a trigger for feedback-loop effects that promotes an extensive replacement of natural gas and speed up the sustainable transformation of the energy system.

Methods

This work uses the two open-source models *rivus*[1] and *GUSTO* [2], which both enable the optimization for distribution networks. However, the strengths of the models lie in the individual high resolution of the spatial or temporal resolution (see Figure 1). Hence, in the first step, *rivus* models the optimal distribution network for multiple energy carriers in the small urban district taking into account technical and economic parameters. In a second step, GUSTO is used to optimize der energy technology dispatch with a high temporal resolution considering different (local) objective functions (e.g., profit maximization, boosting local self-reliance, minimizing greenhouse gas emissions, etc.). Both open-source models are implemented in *Python*, using the *Pyomo* package. The case study analyzed is a small urban district in the vicinity of the Vienna University of Economics and Business, so-called Viertel2, and the surrounding area. The boundaries of the area were chosen to achieve high diversity in terms of generation capacity units, energy demand profiles, building structure and efficiency, as well as the availability of multiple energy carrier infrastructures. Note that the contribution of this work serves as an analytical and methodological extension of the previous work of the author (see [3]). The latter work has so far neglected a high-resolution spatial analysis of urban neighborhoods.



	rivus	GUSTO
Resolution strengths	High spatial	High temporal
Optimization	Distribution network infrastructure (multiple energy carriers)	Local energy technology capacities and dispatch
Objective function	Minimizing total costs	Different objective functions (e.g., costs, self-reliance)

Figure 1 Description of the open-source models rivus and GUSTO

[1] See https://github.com/tum-ens/rivus.

Results and Conclusions

The expected results of the case study are to identify the optimal distribution network of the different energy carriers in the urban neighborhood over the predefined planning horizon. In particular, these take into account a local gas phase-out and thus a sustainable future provision of energy service in the neighborhood. See, for example, Figure 2, which already shows preliminary results in the high electrification scenario (i) and highlights selected electricity distribution network capacities and their expansion in the small area. Besides, the results of this work show with a high temporal resolution the impact of different operation strategies of local energy technologies within the neighborhood and their implications on the distribution network in particular. Furthermore, different sensitivity analyses (e.g., electricity and CO2 prices, etc.) are carried out.

Figure 2 Distribution network capacitiy expansion within the urban neighborhood

References

[1] D. Then, C. Spalthoff, J. Bauer, T. M. Kneiske and M. Braun, "Impact of Natural Gas Distribution Network Structure and Operator Strategies on Grid Economy in Face of Decreasing Demand," *Energies,* vol. 13, no. 3, p. 664, 2020. *https://doi.org/10.3390/en13030664*.

[2] sebastianzwickl and B. Stickler, "sebastianzwickl/GUSTO: Gusto," Zenodo, *https://doi.org/10.5281/zenodo.3946097*.

[3] S. Zwickl-Bernhard and H. Auer, "Open-source modeling of a low-carbon urban neighborhood with high shares of local renewable generation," *Applied Energy,* vol. 282, p. 116166, 2020. *https://doi.org/10.1016/j.apenergy.2020.116166*.

TECHNISCHE UNIVERSITÄT WIEN

Energy Economics Group

Demystifying natural gas distribution grid decommissioning

IAEE Online Conference - ENERGY, COVID, AND CLIMATE CHANGE

Sebastian Zwickl-Bernhard

09.06.2021

Todays‘ agenda

- Motivation and background
- Core objective and novelties
- Methodology and open-source modeling approach
- Results
- Conclusions and outlook

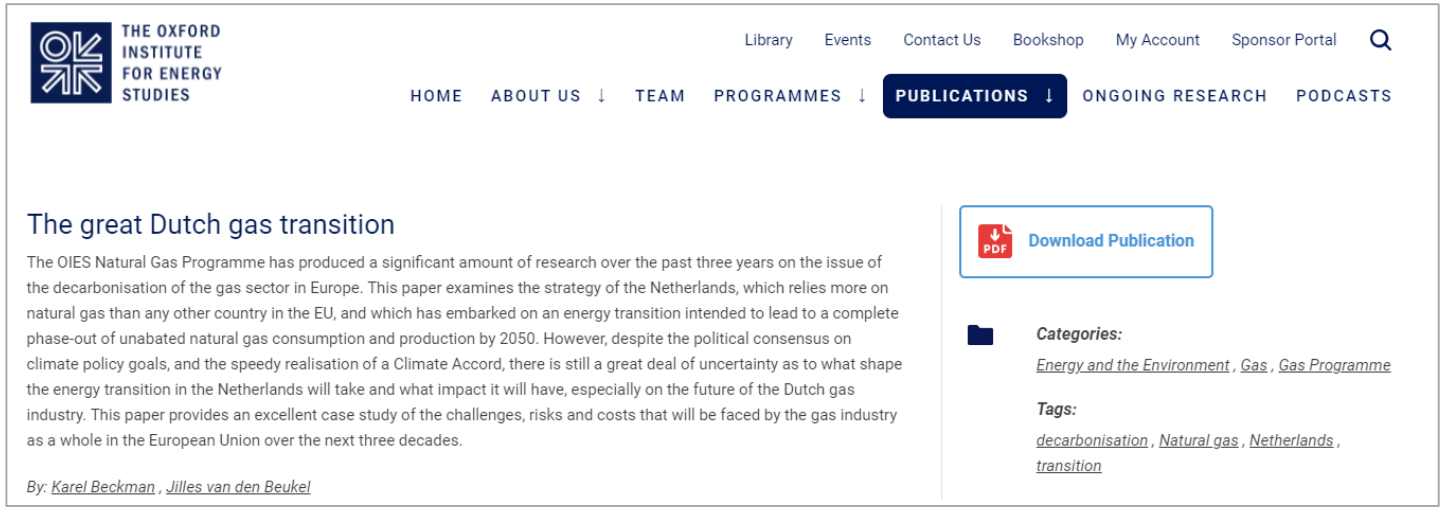
Limited expectations for „green“ gas

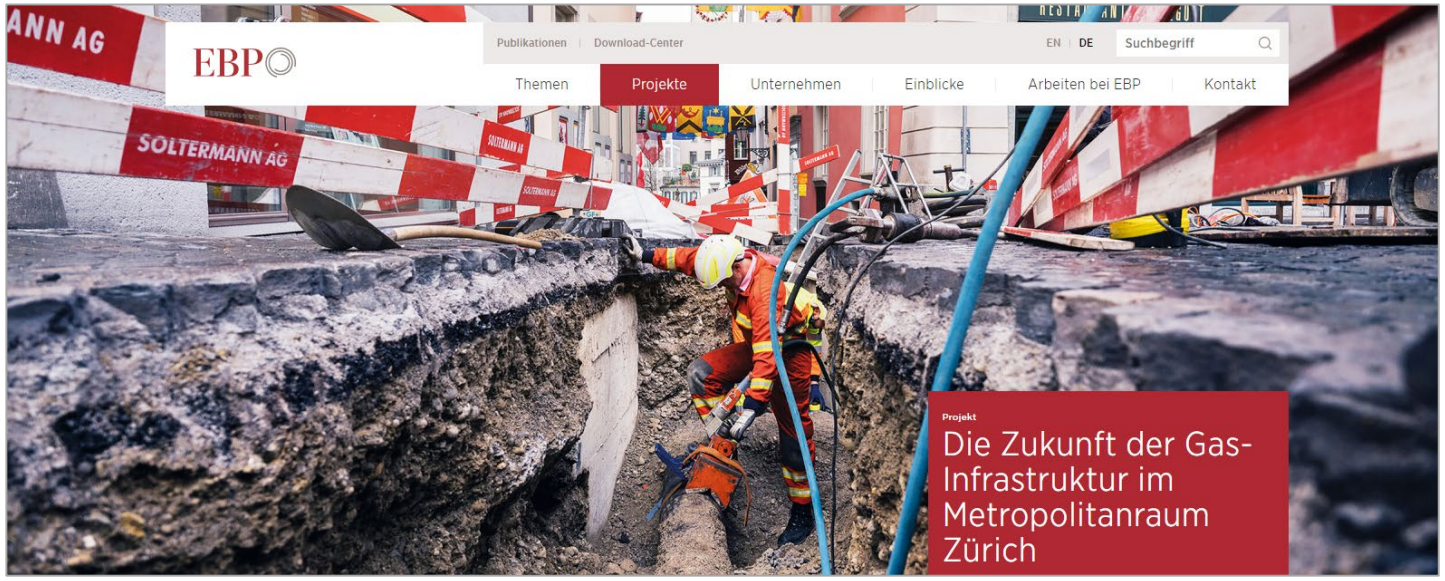
- Gradual or complete substitution of fossil gas is a myopic approach
  - Current needs 8 billion m^3/yr in Austria
  - Independent of technically available Austrian potentials (Biomethan: 4 billion m^3/yr and hydrogen 2 billion m^3/yr)
  - Theoretically, biomethan could cocer half of the demand in the next 20 years
- Difficult that the quantities of green gas needed for all energy services will be economically available
  - Increase of the demand expected in case of profitable hydrogen production in different sectors (e.g., heavy industry, freight transportation/mobility)
- Further niche applications of hydrogen due to sector coupling and specific industry processes

Scope of this work

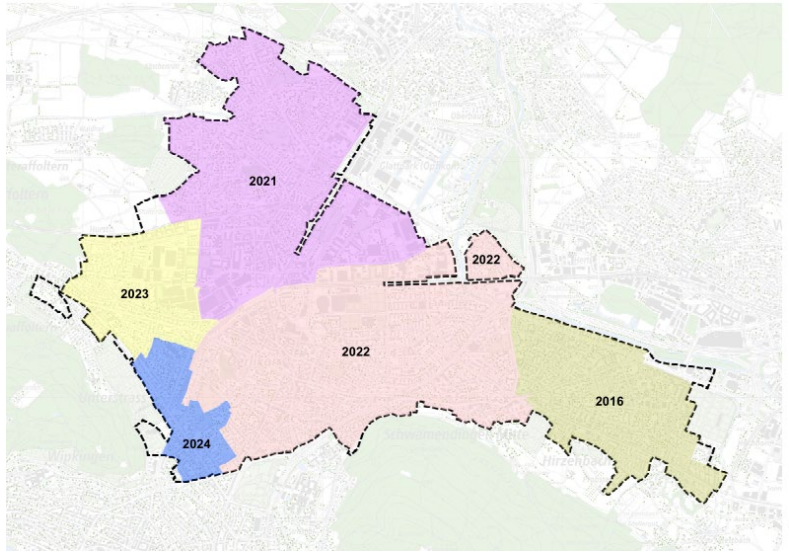
- Demystifying the unique/dominant position of natural gas in the provision of heat services
- Decommissioning of the existing gas distribution grid infrastructure
- Trigger emerging sustainable and high-efficient energy supply alternatives
- No continue repowering of conventional energy technologies
- No maintance of know-business models
- Costs of inaction (e.g., penalties for failing to meet climate targets)

Gasless neighborhoods in Zürich and Utrecht



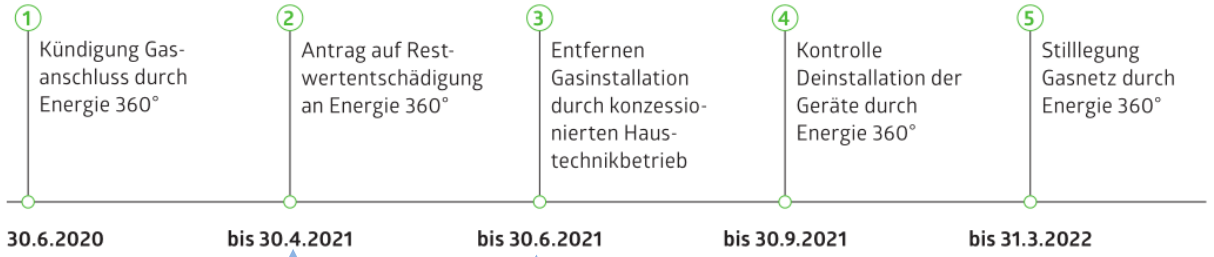


Gas distribution grid decommissioning in Zürich



Practical realization timeline

Zeitplan



Remove the end-user‘s device

Submit application for remaning value compensation

Entschädigungstabelle

Remaining value compensation payments according to date of device installation

Zeitpunkt der Geräteinstallation	2002*	2003	2004	2005	2006	2007	2008	2009	2010	2011*
Entschädigung bei Netzstilllegung 2021	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%

https://www.energie360.ch/de/energie-360/wissen/energieplanung/zuerichnord/

Core objective and novelties

- Decommissioning of the natural gas distribution grid and a corresponding natural gas phase-out in the heat supply of an urban neighborhood
- Alternative distribution grid capacities and sector coupling technologies are required to ensure an adequate, but sustainable development in the provision of local heat energy services (low temperature)
- Two different local deep decarbonization pathways:
  (i) High Electrification and (ii) Expansion of the district heating network
- Introduction of wide-range benefit indicators (qualitative and quantitative)
- Consideration of the increasingly important cooling demand service needs

Methodological and analytical extension

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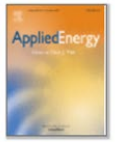
Applied Energy

Volume 282, Part A, 15 January 2021, 116166



Open-source modeling of a low-carbon urban neighborhood with high shares of local renewable generation

Sebastian Zwickl-Bernhard, Hans Auer

(c) Side by side location of *V2* (green), *UNI* (blue), *NEW* (magenta), and *STA* (yellow). Source [46]

(d) Existing distribution grid of gas (yellow), district heating (green) and electricity (red) in the urban neighborhood and its surrounding area. Source: [47]

GUSTO

enerGy commUnity SysTem mOdeling

GUSTO is a mixed-integer linear program (MILP) for energy system modeling. Thanks to the open-source energy system modeling community it is an extension of the existing open-source model (OSM) urbs[1].

Open Source ❤ | Made with Python | License GPLv3 | DOI 10.5281/zenodo.3946098

Objective and scope:

The Horizon 2020 openENTRANCE project aims at developing, using and disseminating an open, transparent and integrated modelling platform for assessing low-carbon transition pathways in Europe. openENTRANCE will analyse the new challenges of the energy transition and demonstrate the ability of the project to answer a wide range of questions linked to the energy transition by carrying out case study simulations. This model (as a merger of the two models HEROS and OSCARS) is part of case study 3, which is described as follows:

CS3: Need of flexibility – storage: Comparison of the flexibility of pumped hydro storage with batteries for future high-variability power systems caused by a large share of variable renewables. Analyses for the Iberian Peninsula and the Nordic region. Impacts on pan-European level. Key aspects covered: variability, flexibility, decentralisation

More information about the case studies of the project can be found here.

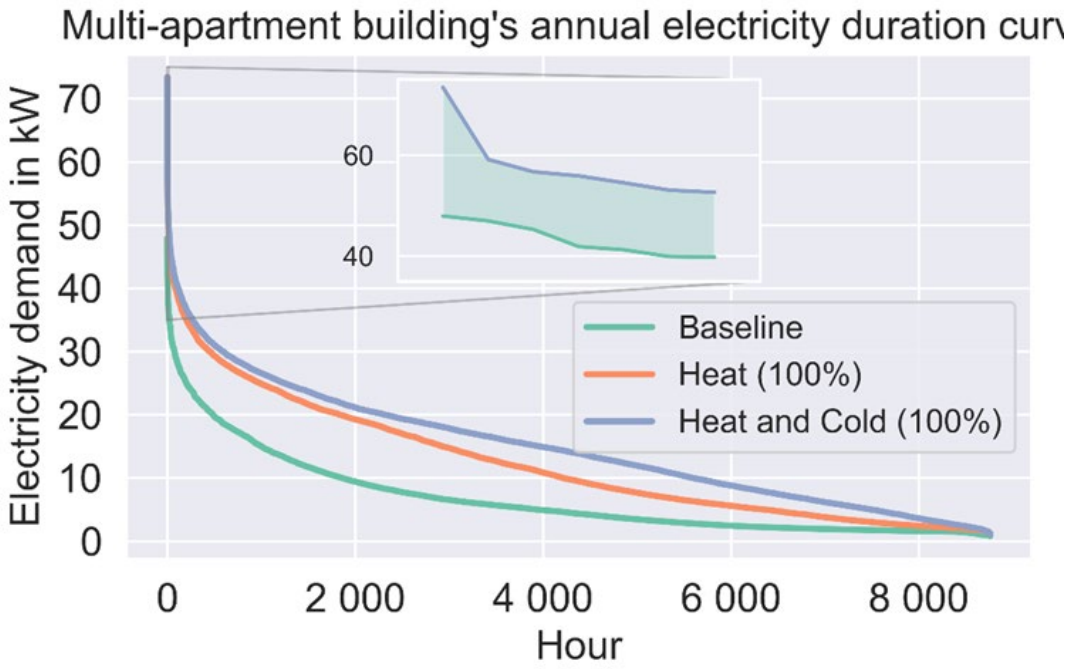
The model provides a tool for investment decisions as well as for the operational utilization of the generation units, technologies and storage units.

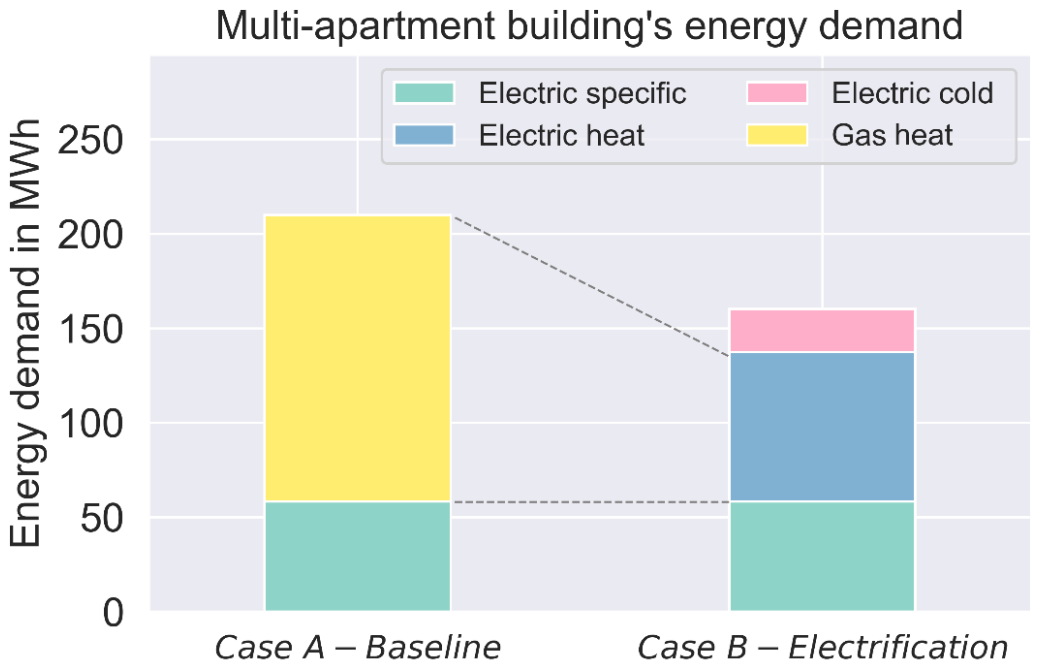
https://github.com/sebastianzwickl/GUSTO

https://doi.org/10.1016/j.apenergy.2020.116166

GUSTO enables high temporal resolution

Split existing building stock into different characteristic building types

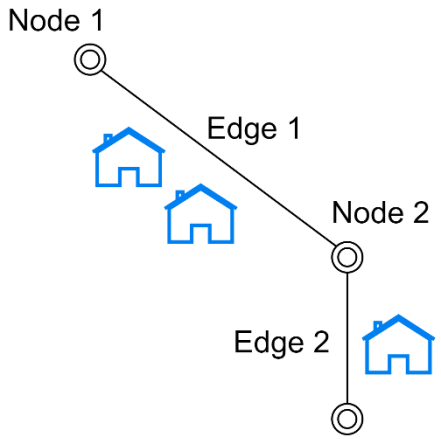


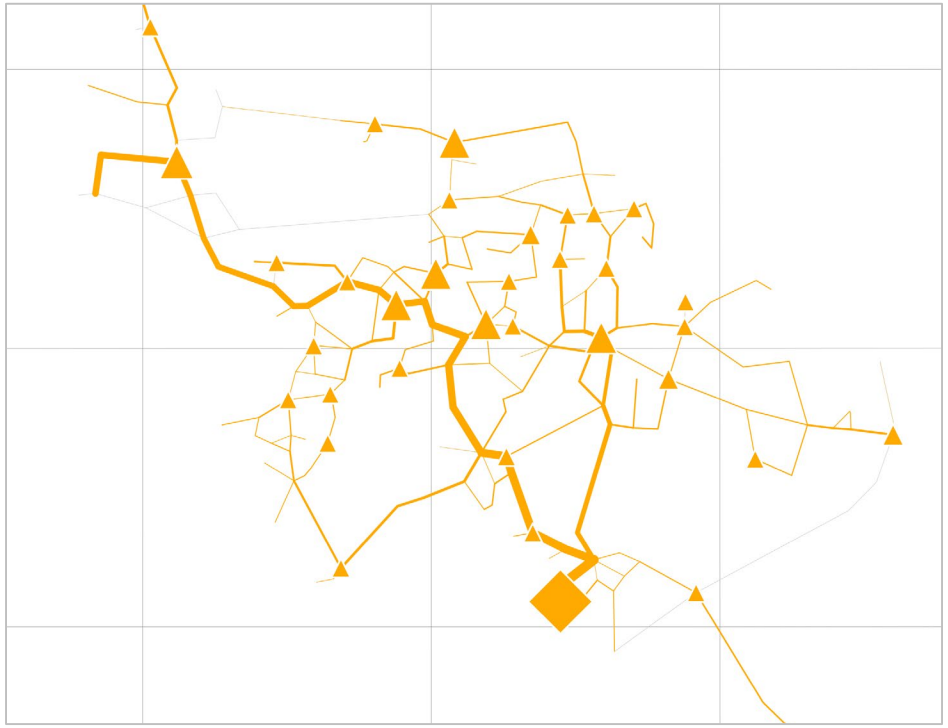


GUSTO‘s peak load results are inputs for *rivus*

rivus is an open-source model delevoped by Dorfner (TU Munich) available on GitHub (https://github.com/tum-ens/rivus)

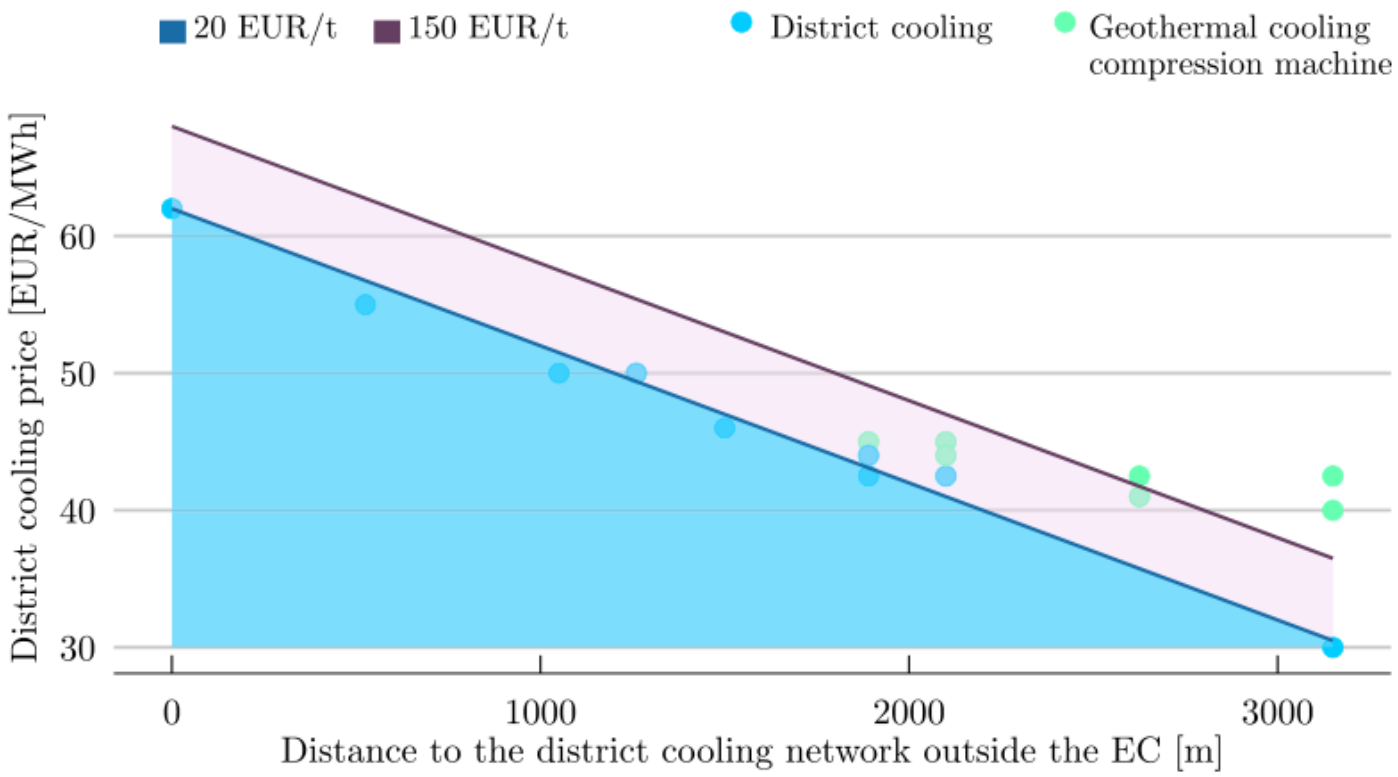
- Bases on graph theory
- Mixed-integer linear program
- Cost-minimizing multiple-energy carrier network expansion





Profitability of network-based energy supply

Consumer connection and network-based energy service provision depends significantly on the distance between consumers and existing networks



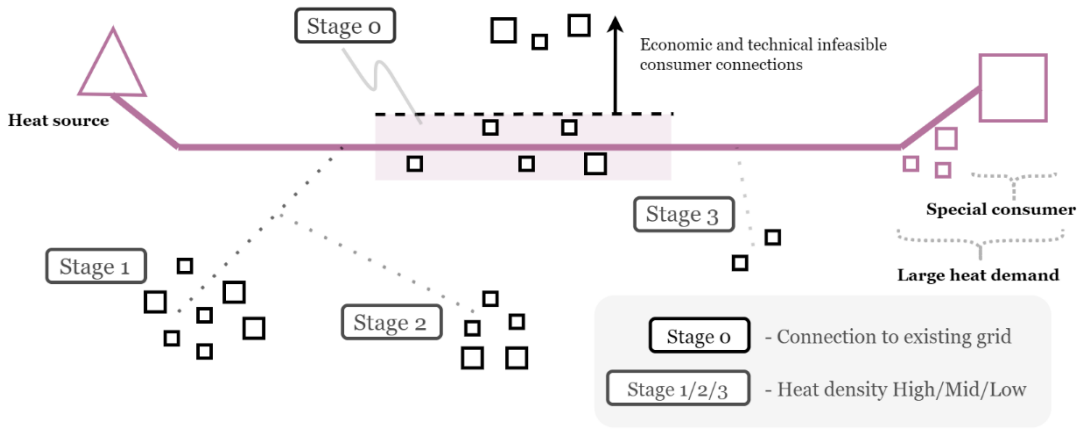
„Non-discriminatory right“ to be connected

- Electricity supply: coverage and connection obligation for each consumer
- Connection costs socialized into the grid tariff and paid by all consumers

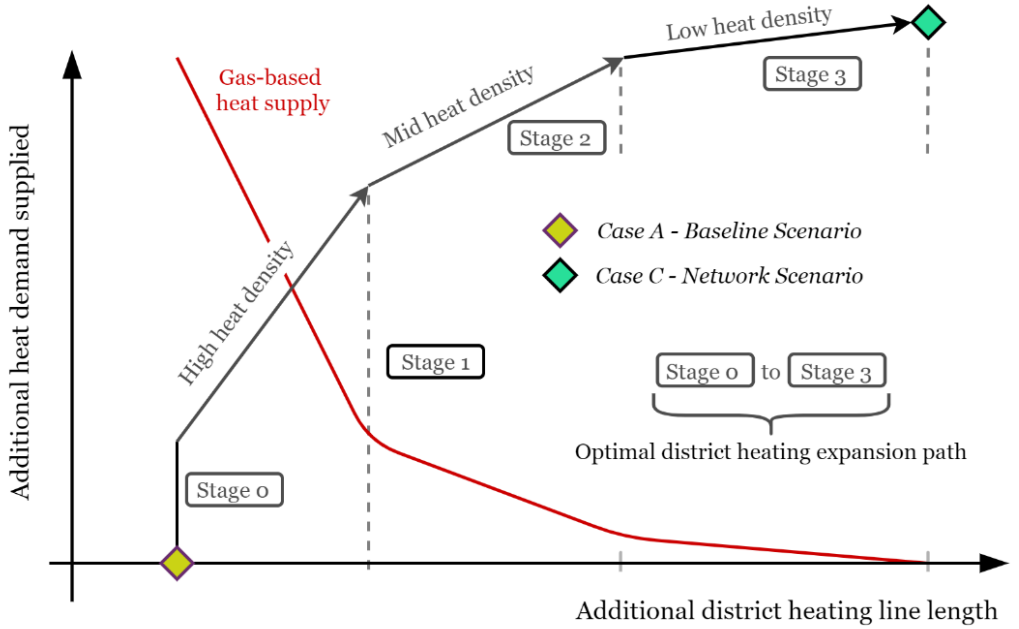
dreamstime.com

Extension: Non-linear network expansion path

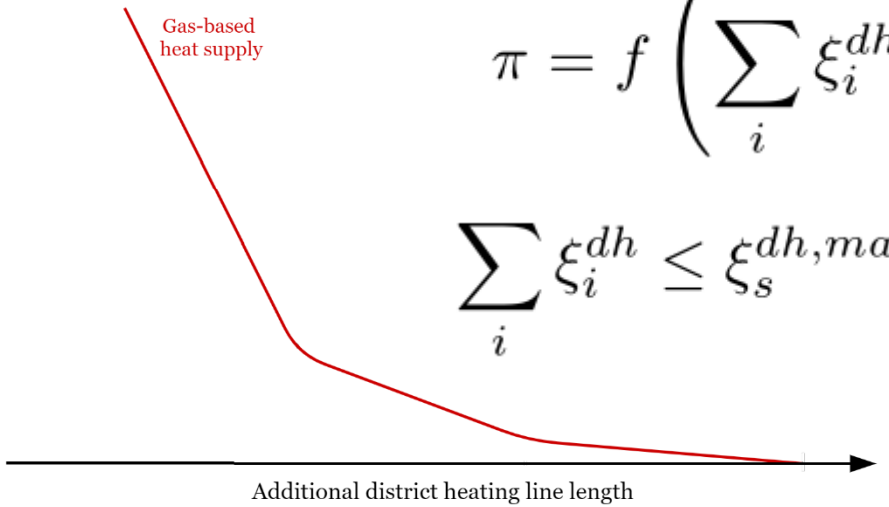
(a) District heating network expansion path depending on heat density



(b) Non-linear relation between the district heating network and gas-based heat supply



Objective function extension by penalty costs



$$\pi = f\left(\sum_i \xi_i^{dh}\right)$$

$$\sum_i \xi_i^{dh} \leq \xi_s^{dh,max}$$

➔ Non-linear relation between district heating network and gas-based supply

➔ Discrete district heating network expansion (=optimal pathway)

➔ SOS2 variables

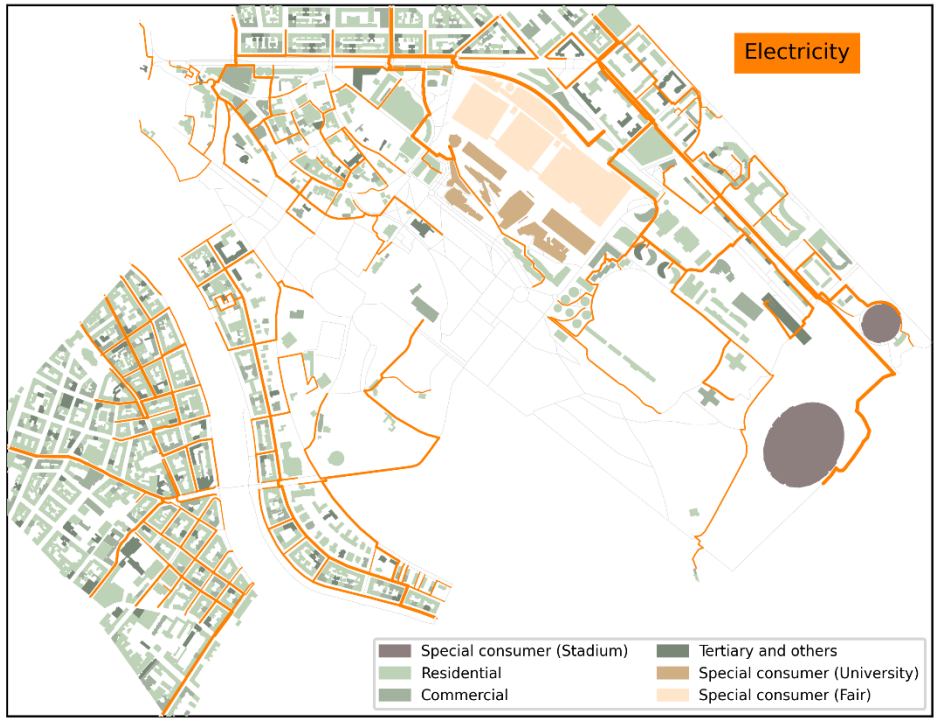
$$\bar{costs} = costs^{cap} + costs^{eos}$$

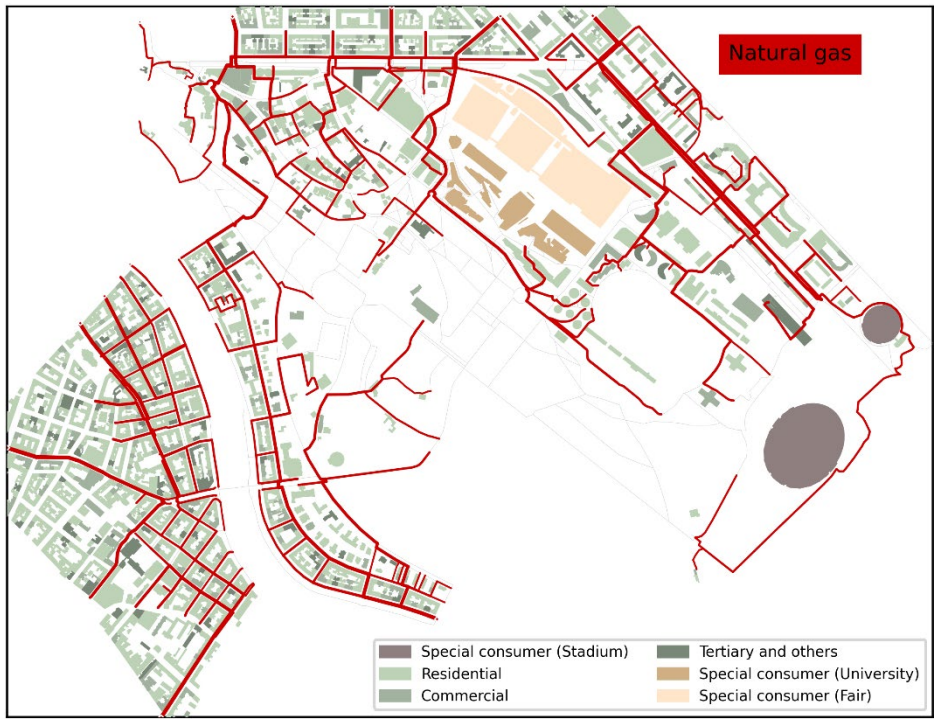
➔ Extension of the objective function by economies of scale

$$costs^{eos} = \sum_\tau \alpha_\tau \cdot \pi \cdot h \cdot r^\tau \cdot \Delta_\tau^{CO_2} \cdot p_\tau^{CO_2}$$

➔ Penalty costs for failing to meet climate targets

Result representation in the baseline scenario



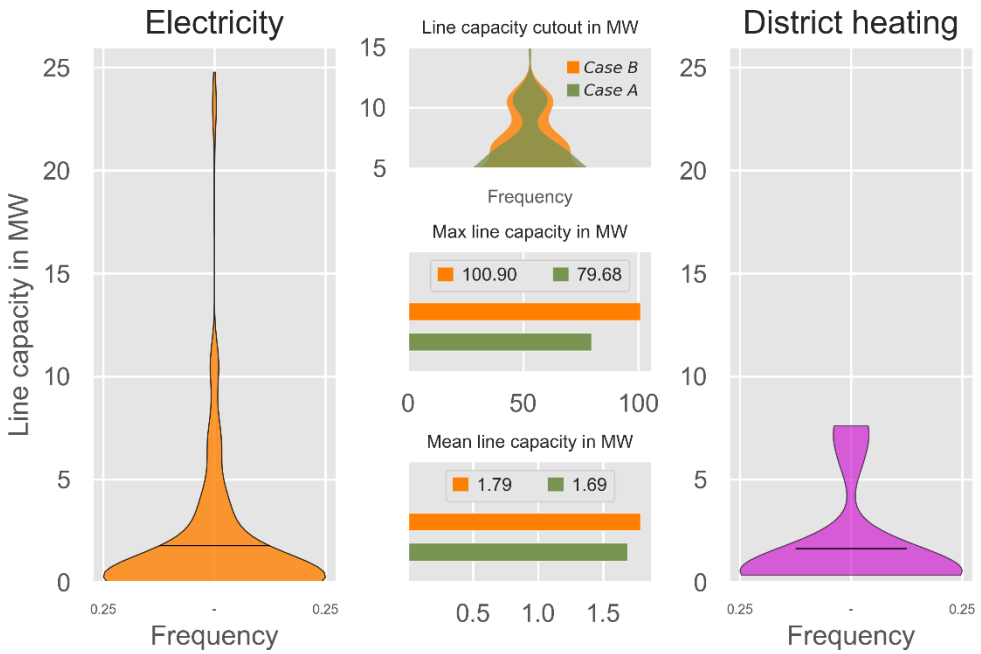


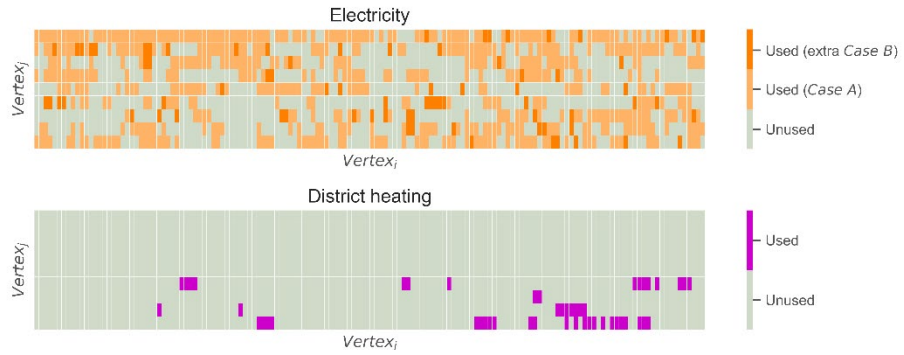
Decarbonization pathway results

Violinplot

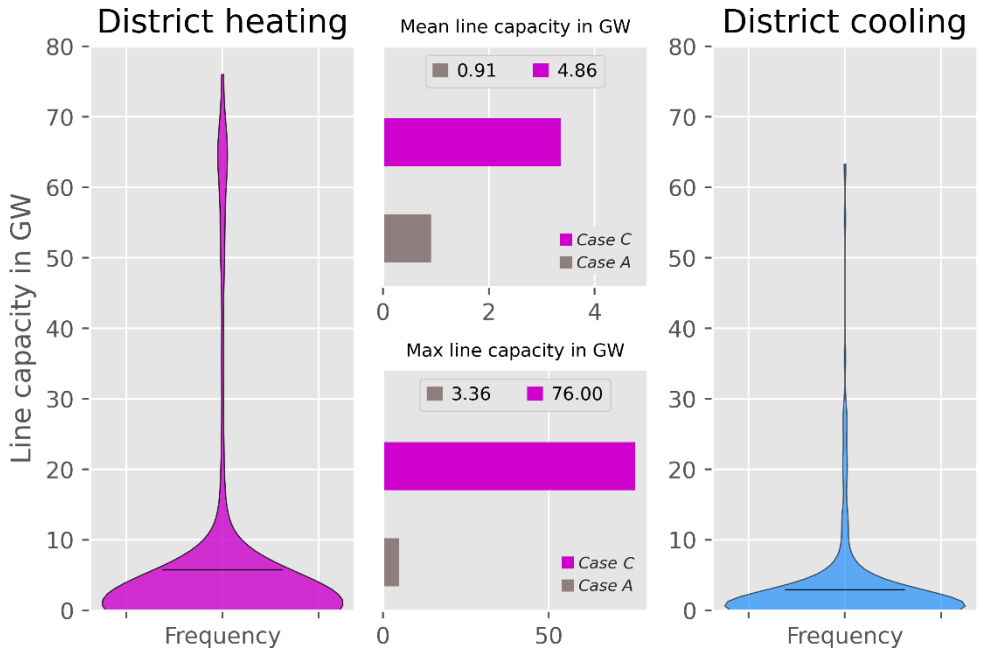
Heatmap

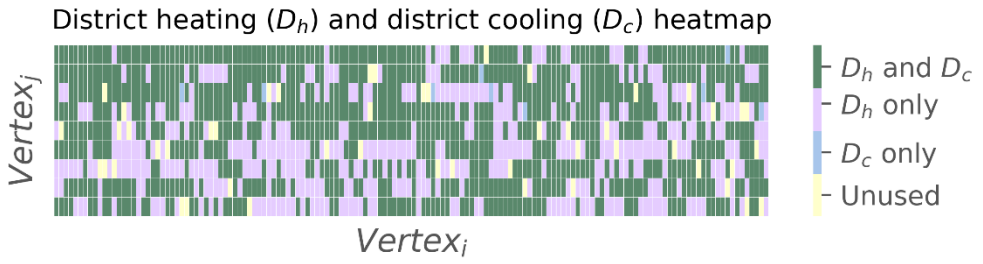
Case B – High Electrification



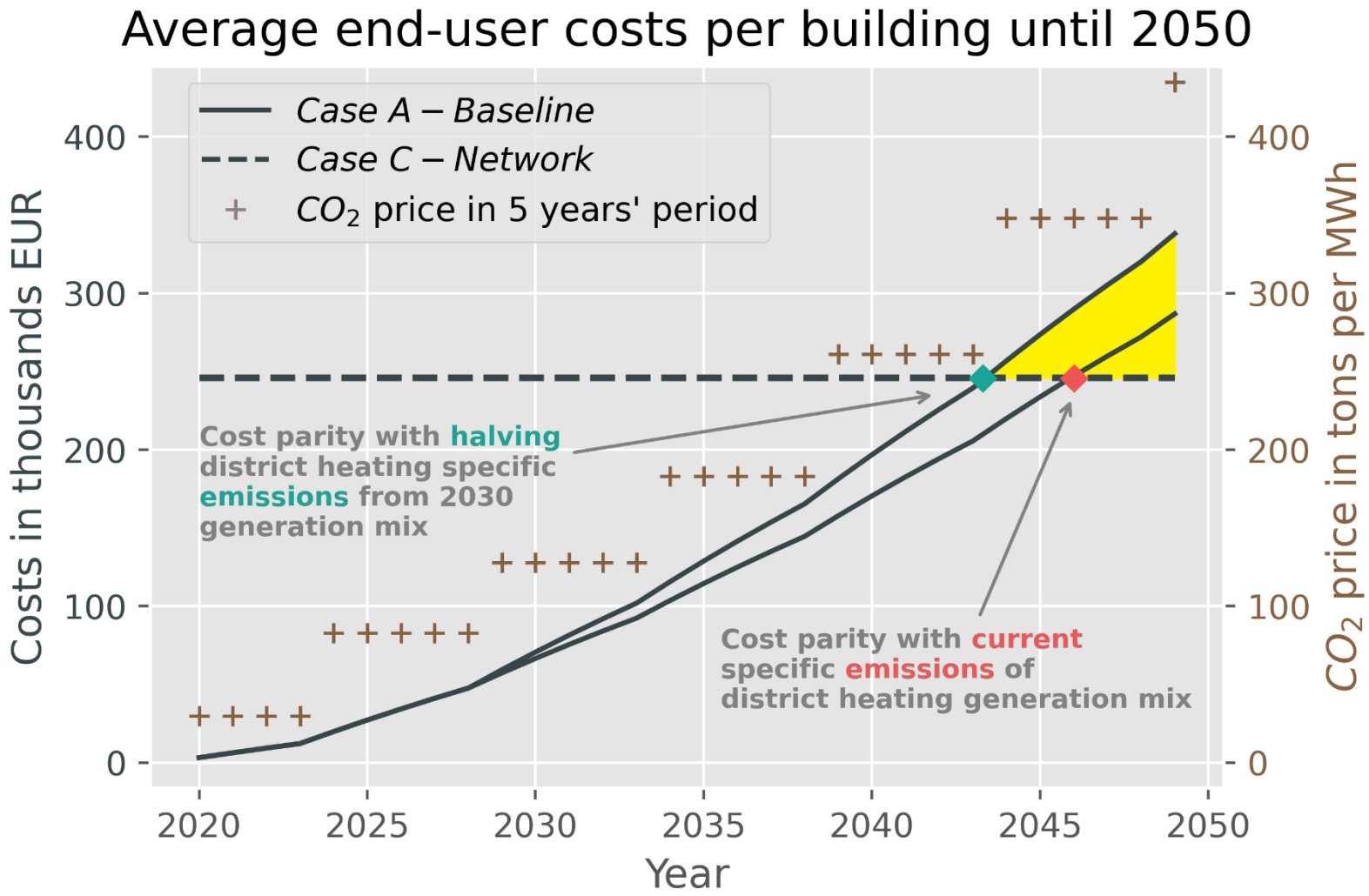


Case C - Network

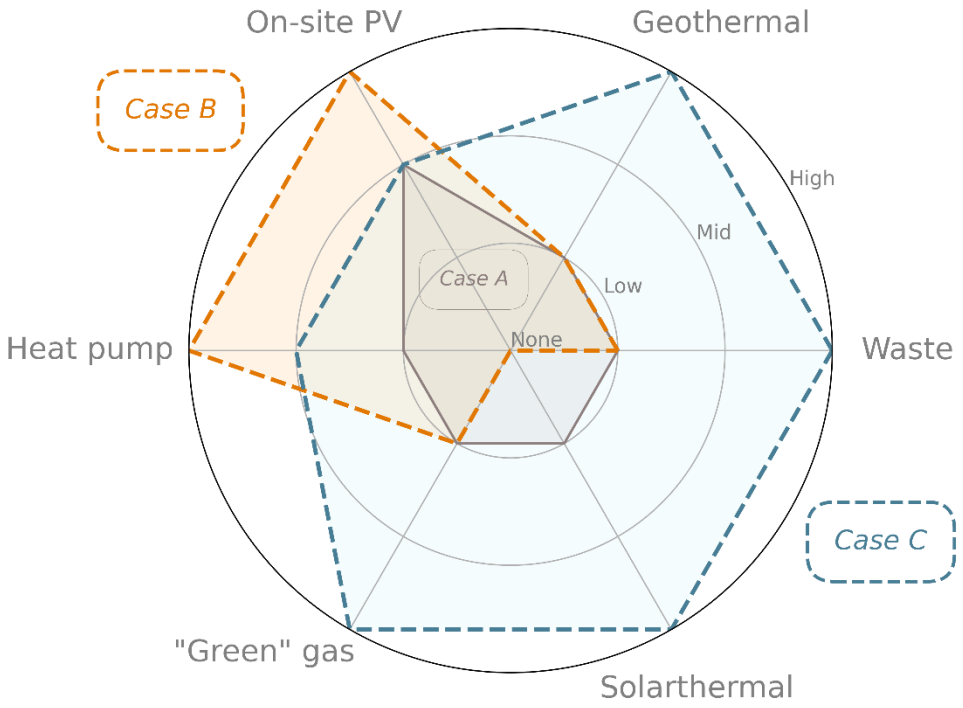


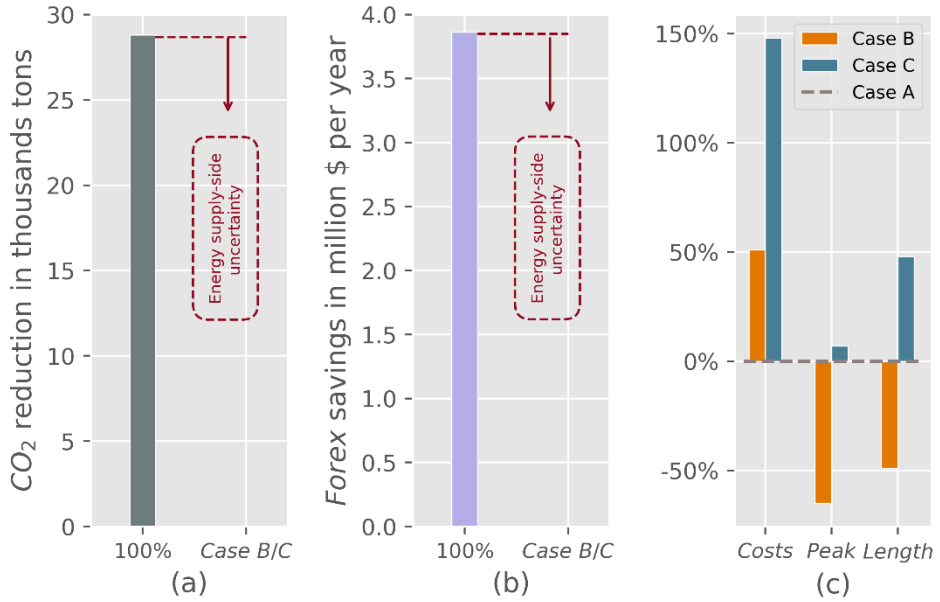


End-user cost parity between 2043 and 2046



Result comparison with benefit indicators





Conclusions and outlook

- Deep decarbonization of local multiple-energy carrier systems is possible, without being dependent on the existing gas network infrastructure
- Possible stranded assets (also at the gas end-user level) must not play a decisive role, especially since the trade-off analyses in this work show that alternative scenarios of lower/zero-emission energy service provision are even more economical in the longer term since the CO2 price is expected to increase in the next decades
- Future work: energy generation technology mix feeding into the district heating grid (waste incineration + seasonal heat storage) and the local mobility service needs

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