Is the decarbonization of the European energy system driving district heating in Norway?

Energie-/Klimapolitik, Versorgungssicherheit

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Motivation and Core Objective

The scope of this paper deals with a (strong) simplification frequently made in the representation of the heat sector in large-scale energy system models. We elaborate here on district heating and its role in large-scale energy system models, as this centralized heat supply option is often neglected and not explicitly considered in those models. That is also, why most of the model-based decarbonization pathways have difficulty making robust estimates about the heat supply by district heating. Even if large-scale energy system models consider district heating, it usually results in quantitative values at the country level, which has proven to be an insufficient spatial resolution for analyzing district heating as, at this resolution, a realistic account of infrastructure-related investments is significantly limited or even impossible. Undisputedly, most decarbonization pathways show a strong trend toward electrification of the heat sector. Nevertheless, this trend does not necessarily say anything about district heating, which is essentially a heat transport infrastructure on the one hand, and can also be electric on the other (e.g., large-scale heat pumps). In the foreground here is, therefore, the trade-off between district heating (centralized) and building heating (decentralized). The issue in large-scale energy system models is that they cannot separate these two types of heat infrastructure.

Against this background, the core objective is to examine district heating in Norway at the regional levels until 2060. For this, we consider the cost-optimal network expansion and energy technology dispatch of district heating in each of the five Norwegian electricity price zones (NO1 to NO5). We build upon two existing optimization models and combine them to get a single framework given the typical approach to minimize total system costs over time (from the network operator's perspective). We consider the existing district heating infrastructure (i.e., energy generation capacities and network pipelines) as a starting point. Additionally, we introduce tailor-made restrictions and constraints to the model framework about vital determining parameters derived from the cost-optimal solution at the European level of the large-scale energy system model EMPIRE [1]. Mainly, these parameters include electricity and carbon emission prices, maximum energy technology capacities, and total heat delivered. Therefore, this work uses a novel approach for testing the implement-ability of cost-optimal but aggregated heat supply from the European as well as country to the district heating level.

Methodology

Generally, the used modeling framework consists of two model types derived from their spatial scope. The first type is used for the optimal infrastructure planning of district heating at the local level, the second for the decarbonization of the European energy system and thus aggregated level. The two model types are linked in this modeling framework by introducing values of the cost-optimal solution as a restriction (more precisely as parameters) in the first model type.

We use a multi-nodal unit commitment (UC) model as the district heating planning tool. This tool builds upon the two optimization models described in [2] and [3]. In the work here, the optimization model is formulated as a linear program as considering additional linear constraints allows us to replace binary decision variables present in most multi-nodal UC models when representing the grid in detail. The model is implemented in *Python* 3.8.12 using the modeling framework *Pyomo* version 5.7.3. It is solved with *Gurobi* version 9.0.3. We use the standard data format template the Integrated Assessment Modeling Consortium developed using the open-source Python package *pyam* [4].

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The model calculates investment decisions and the dispatch to cover the heating demand in every node. Figure 1 shows the heating density in the Oslo district on the left side, then the model uses this data to cluster the heat density to nodes and calculate connecting pipelines.
The objective function of the model z is to minimize the total systems costs of the district heating network operator. The key results encompass the optimal investment decision into heat generation technologies and transport pipelines, represented by the value of installed capacity $Cap_{i,t}^{ins}$ per heat infrastructure i (i.e., heat technology and heat transport pipeline) and time step t in the optimal case: $Cap_{i,t}^{*} = \underset{Cap_{i,t}^{ins}}{\operatorname{argmin}}\, z$.

Expected Results and Conclusions

First preliminary results show that under the current cost structure the existing transport infrastructure is economically profitable and thus will not be decommissioned. The heating generation to cover the load is centralized in this district heating system. External areas will not be connected to the district heating infrastructure and are supplied decentralized.

The implemented approach is so far applied for one Norwegian electricity price zone, the application for all five electricity price zones will be part of future work. Furthermore, the quantification of flexibility provided from the district heating to the electricity system is going to be examined.

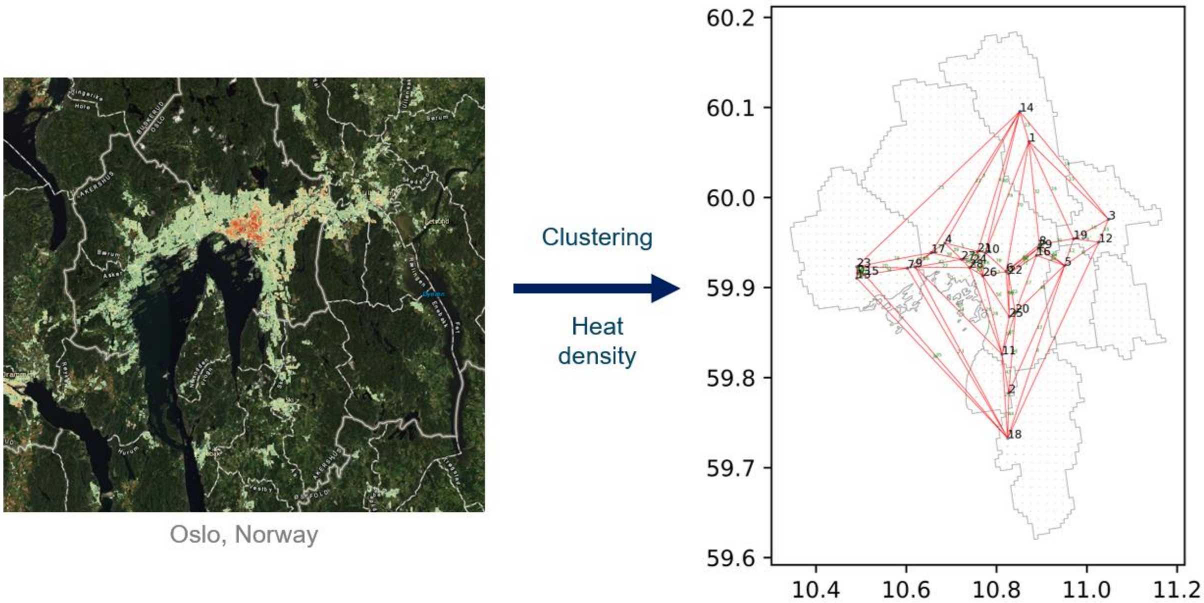

Figure 1: Illustration of the applied methodology:
(left) heat demand and related heat densities obtained from the HOTMAPS project[2] as main input for the modeling; (right) representation of the heat demand in the model using clustering algorithms

Literatur

[1] Backe, Stian, et al. "EMPIRE: An open-source model based on multi-horizon programming for energy transition analyses." *SoftwareX* 17 (2022): 100877.
[2] Zwickl-Bernhard, Sebastian, and Hans Auer. "Demystifying natural gas distribution grid decommissioning: An open-source approach to local deep decarbonization of urban neighborhoods." *Energy* 238 (2022): 121805.
[3] Auer, Hans, and Sebastian Zwickl-Bernhard. "Designing a model for the cost-optimal decommissioning and refurbishment investment decision for gas networks: application on a real test bed in Austria until 2050." The Future of Global Energy Systems, 17th IAEE European Conference, September 21-24, 2022. International Association for Energy Economics, 2022.
[4] Huppmann, Daniel, et al. "pyam: Analysis and visualisation of integrated assessment and macro-energy scenarios [version 2; peer review: 3 approved]." *Open Research Europe* 1 (2021).

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[2] Source: https://www.hotmaps.eu/map