TEMPERATURE-LEVEL DEPENDENT MODELING OF ENERGY FLOWS AT THE QUARTER LEVEL

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Introduction

Alongside the ecological necessity for decarbonization, economic arguments for an accelerated phase-out of importing fossil fuels have come into focus due to increasing uncertainties in the energy market. The statutory incorporation of mandatory minimum shares of renewable energies in heat supply [1] brings about further changes, rendering a classical sectoral approach (electricity, gas, heat) is no longer effective for planning supply infrastructures in new quarters. Due to legal limitations on the use of fossil fuels and studies indicating a limited future availability of green methane or hydrogen [2], the planning of gas networks for heat supply is under critical review. The overarching goal, considering the altered regulatory and technical conditions, is to develop cross-sectoral planning and operational principles for energy networks explicitly tailored to the planning of new quarters. Modeling and optimizing the occurring energy flows hold a central significance in this context.

Methodology

Embedded within the overall quarter planning is the energy-based optimization, which is conducted using a bottom-up approach. Initially, individual consumer units such as residential and non-residential buildings are considered, and subsequently, the results are juxtaposed with a clustering process across larger system contexts. This involves the use of year-long time series data for both consumption and generation.

Through the process of system modeling, it becomes evident that the temperature level of heat demands holds critical significance for the overall system optimization. This is primarily attributed to the respective efficiency profiles. Efficiency profiles, in this context, are defined as efficiency rates/performance coefficients at different operational points of various technologies used for heat provision.

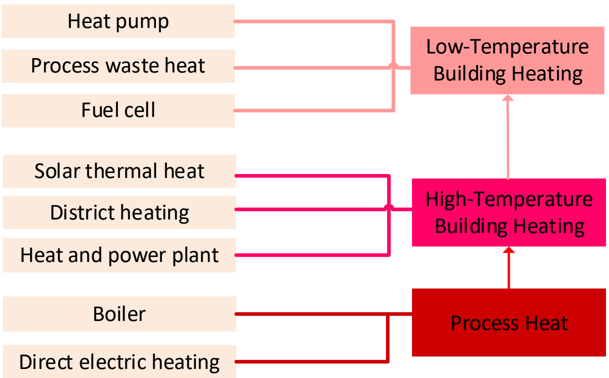

Figure 1: Overview of temperature level modeling

This represents a significant departure from the established supply planning for heat infrastructure, which is primarily based on the demand for kilowatt-hours and the transportation of corresponding energy quantities. A distinction is made between levels for low-temperature building heating, high-temperature building heating, and process heat. Additionally, there is a backward compatibility designed among these temperature levels (see Figure 1)

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In this way, a systematic modeling of energy demands in the quarter is carried out, considering specific requirements regarding the necessary temperatures. Supply possibilities through external infrastructure, such as existing district heating systems, are also considered. For the execution of energy-based optimization, the python-based Open Energy Modeling Framework (OEMOF) is used, which includes a toolbox for modeling energy systems. This allows the representation and parametrization of various generation, conversion, and storage facilities with relevant technical and economic parameters [3]. The existing technical characteristics and dependencies between different technologies are interconnected and modeled across classical sectors during this process. The subsequent optimization can be parameterized considering various optimization goals such as economic efficiency, CO2 optimization, or degree of autonomy.

Results

It is computationally demonstrated that the primary energy usage of heat pumps for decarbonizing the building heat sector is significantly lower compared to efficient combustion systems powered by hydrogen or synthetic natural gas [4]. Combined with an analysis of regulatory requirements for decarbonization, it is inferred that planning gas networks in the low-pressure range to supply residential buildings in new quarters is no longer conducive. This results in a reduction in complexity and costs.

The developed methodology, considering three temperature levels in heat demand, also allows for a more detailed examination of the markedly different efficiency profiles of various heat generation technologies. This method effectively models the possibilities and limitations of the employed technologies, calculating energy flows based on specific quarter requirements and optimization goals.

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