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Energetic and Exergetic Performance of short term thermal storages in urban district heating networks

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Abstract

Meeting the heat demand of all customers attached, is the main objective for the operation of district heating (DH) systems combined with combined heat and power (CHP) plants. On the other hand, the economic ratification for the operation of CHP plants strongly depends on highly volatile electricity prices on the market. This trend will be reinforced in future, due to the additional integration and exploitation of renewable energies. Within this techno-economic field of most different operational objectives, DH systems and CHP plants must find a way for a cost-covering and efficient operation in future.
Against this background, time shifts in producing and allocating heat supplied in parallel with electricity, are most attractive for DH system and CHP plant operators. Thus, margins on the electricity market could be maximized. On the other hand, heat amounts produced in parallel should be decoupled from the production of electricity as efficient as possible. Thus, thermal energy storages enter the limelight of interest for DH system operators. However, aspects concerning most different mechanisms for energetic and exergetic losses have to be considered for an optimized operation of these systems.
Within this paper, the energetic and exergetic performance of sensible thermal storages will be examined. Underlying loss mechanisms of typical urban thermal storages are described qualitatively and quantified energetically and exergetically. For this purpose, existing models from literature are combined with practically relevant operational parameters for simulations.

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Keywords: District Heating; Thermal Storages; Thermal Losses

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1. Introduction

CHP is a widespread and robust system for efficiently delivering electrical power and heat to customers. Thus, within urban areas of northern European countries, CHP is and will be a major partner for the energy turnaround [1]. Running these systems, the main focus of operation has been on meeting the heat demands occurring in the district heating (DH) network attached. On the other hand, revenues at the energy markets are mainly responsible for running these systems economically and profitable.

Against this background, measures for a more flexible and, in best case, a market-price-oriented operation of CHP, enter the limelight of interest for DH supply companies. Thus, the utilization of thermal storages (thermal accumulators) within urban areas is widely discussed for enhancing the economic performance and full-load hours of CHP, s. [2 to 7], whereas operational cost diminish due to raising efficiencies, s. [8].

However, knowing the energetic and exergetic contents utilizable within large scale thermal storages (hot water contents > 10,000m³) is the main prerequisite for an optimized, efficient and economic operation of these systems. As these contents are diminished by a multitude of thermodynamic processes, the contents of [9] are refined, improved and developed further. Therefore, the impact of different heat transfer and loss mechanisms on the energetic and exergetic contents utilizable as well as the thermal stratification within large scale thermal storages are described and quantified. Thus, potentials of CHP and thermal storages within the context of an overall DH system may be evaluated and analyzed.

Basing on relevant literature [2 to 16], typical operational parameters of sensible thermal storages within urban DH systems are defined. Regarding these studies, heat loss mechanisms of thermal storages are of major interest concerning operational efficiency and effect the energetic and exergetic contents of these systems, cf. [17 to 20]. However, the transferability of these results is not necessarily given for large scale applications. Against this background, approaches for approximating these mechanisms are refined and combined with operational parameters of large scale thermal storages. Regarding practically relevant operational parameters, energetic and exergetic losses are calculated and quantified for typical urban storage systems.

Nomenclature

A	Surface area [m²]
C	Heat storage capacity [J/K]
D	Diameter [m]
H	Height [m]
Q	Heat Amount [MWh]
$\dot{Q}$	Heat Loss [kW]
s	Strength of wall/ insulation, etc. [m]
T	Temperature [°C]
V	Volume [m³]
λ	Heat Conductivity [W/mK]
θ	Typ. Timescale for (dis-) charging [h]
Ξ	Typ. Time-Shift charging-discharging [d]

2. State-of-the-art

Thermal storages will play a major role for an efficient and feasible operation of DH networks. Geometrical and operational parameters of these systems, mainly implemented as sensible, stratifying systems operating at atmospheric pressures, are closely connected to the operational parameters of the DH grid attached. Furthermore, technological key-performance indicators (capacity, flexibility of operation, operational temperature, quality of thermal stratification, etc.), non-techological aspects (space required for installation, inherent operational safety, etc.), have to be considered Table 1**Error! Reference source not found.** summarizes the relevant literature and gives typical geometric, energetic and operational parameters of these systems [2 to 20].