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Sensitivity analysis of the conception of small scale district heating networks on the thermal conductivity of the surrounding soil

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Abstract

Heat distribution via pre-insulated plastic bonded piping systems will become of major importance for covering the primary energy consumption of EU and will be of vital importance for the energy and heat turnaround. Utilizing efficiency potentials of combined heat and power (CHP) and integrating (industrial) waste heat and renewable energy contents within these grids, low temperature (and low-ex) heat sources might be exploited. Thus, energetic contents unsuitable for electrical energy supply are utilized in order to diminish greenhouse gas emissions and minimize primary energy needs.
Distribution of heat requires accurate planning and network design for the expected service time of several decades. This applies for existing networks as well as for future networks. During planning and conception different load scenarios (of today and in future) must be considered. Since the design of existing networks was done in the past, this paper focusses on the requirements for the conception and planning of heating networks in the near future. Because of low temperature (and low-ex) heat sources, the expansion of district heating networks in EU will be linked to modifications in the network design and planning. A sensitivity analysis was carried out for relevant input parameters in low temperature networks. The analysis showed a significant influence of the conductivity of the bedding material as well as the overburden height on heat losses. For the given set of reference parameters, the energy efficiency potential of systems for heat distribution is approximately 10 %.

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Keywords: district heating (DH); pipe statics; heat losses; optimization

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1. Introduction and methodology

District heating (DH) networks steadily expanded throughout the last decades. Within this context, additional heat customers are attached to existing DH networks in EU countries, in order to counteract diminishing heat demands of the buildings attached (due to energetic renewals). On the other hand, new DH networks are developed in suburban and rural areas at medium and low temperature levels (e.g. low-ex networks).

In order to run DH networks on a long term perspective and most reliable, piping systems must be assessed according to operational loads occurring. Incorrect engineering, static calculations, technological configurations and construction of these networks will lead to an interruption in supply and severe economic losses. In addition, the public image is corrupted. Therefore, knowledge on the necessity of a computational design according to normative standards of engineering and the “state of the art” is of inestimable value. Nevertheless, different models and theories utilized, simplify real life boundary conditions. Designing DH networks, the interaction of a correct engineering, technological configuration and construction with these simplifications and a sustainable and feasible long-term operation must be considered and recognized.

Within this contribution, an overview on realistic ranges of variation for different boundary conditions of the piping systems for DH will be given and the sensitivity of the expected results will be discussed.

Nomenclature

$\dot{V}$	dV/dt Volume flow, m³/h
$\dot{Q}$	dQ/dt Heat flow, kW
ΔT	Temperature increment, K
d_i	Inner pipe diameter, m
v	flow velocity, m/h
ρ	density of the water, kg/m³
c_p	heat capacity of water, J/(kgK)
h_{s1}	geometrical factor for the heat transfer geometry, according to Fig. 2.
λ_{bed}, λ_{ins},	heat conductivities of the bedding material and insulation, according to Fig. 2.
T_1, T_2, T_0	temperatures of the supply (1) and return (2), as well as the temperature on the terrain surface (0)
H, R, r, B, D_a	geometric dimensions, according to Fig. 2.

2. Conception of Heating Networks

Heat demands and related thermal loads in the infrastructure for heat distribution are the fundamental input of any calculation of DH networks. Prior to the calculation, a strategic conception regarding future developments of the area (residential area, industrial quarter, etc.) is necessary. Thus, future developments of the heat demand, heat load and feasibility of the DH network and its operation are evaluated. For this purpose, registers for the heat demands are developed covering smaller or bigger heat supply quarters in very different levels of detail.

In order to cover the heat demand of the customer, the DH network operator distributes heating water via the DH piping network. The common thermo-hydraulic principle may be described as follows:

- The supply of the DH network provides volumetric flow of hot water dV/dt, which then is
- Cooled down (e.g. for heating or tap water purposes) at the customer’s site by ΔT and which finally
- Returns to the heat source in order to be heated up again.

The operational temperature of the network depends on most different interacting aspects, such as (i) the structure of heat sources attached (e.g. new, low energy buildings or older building using high temperature radiators for heating), (ii) heat sources available (e.g. fossil fuels or solar-thermal heat sources), (iii) topology of the DH location, (iv) piping technology in focus for heat distribution or the (v) heat losses occurring throughout operation (depending on the