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Space heating with ultra-low-temperature district heating – a case study of four single-family houses from the 1980s

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Abstract

District heating is predicted to play a large role in the future fossil free energy system. Apart from providing energy savings by utilizing surplus heat, the district heating system also provides flexibility to fluctuating electricity generation by bridging the electricity and the heating sector. These benefits can be maximized if district heating temperatures are lowered as much as possible. In this paper we report on a project where 18 Danish single-family houses from the 1980s were supplied by ultra-low-temperature district heating with a supply temperature as low as 45 °C for the main part of the year. The houses were heated by the existing hydraulic radiator systems, while domestic hot water was prepared by use of district heating and electric boosting. This paper evaluated the heating system temperatures that were necessary in order to maintain thermal comfort in four of the houses. First the four houses were modelled in the building simulation tool IDA ICE. The simulation models included the actual radiator sizes and the models were used to simulate the expected thermal comfort in the houses and resulting district heating return temperatures. Secondly measurements of the actual district heating return temperatures in the houses were analysed for different times of the year. The study found that existing Danish single-family houses from the 1980s can be heated with supply temperatures as low as 45 °C for the main part of the year. Both simulation models and test measurements showed that there is a large potential to lower the district heating temperatures.

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Keywords: Ultra-low-temperature district heating; radiator; IDA ICE; heating power; heat demand

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1. Introduction

District heating (DH) covers approximately 13% of the heat demand in the EU at the current state. This share is expected to increase in the future, as expansion of the DH networks has been found to be an economically beneficial tool in the transition to a low-CO2 energy system [1]. The efficiency of the new DH systems can be increased significantly, if they are operated with low supply and return temperatures, according to the principles of 4th Generation District Heating [2]. A reduction of the DH temperature has two positive effects on the energy efficiency of the heat supply. Firstly, when the DH temperatures are reduced, the heat losses from the pipe networks are also reduced. This can generate significant energy savings, as the reductions in heat loss can be estimated to 30 % when supply and return temperatures are reduced from 80 °C/40 °C to 60 °C/30 °C. Secondly the efficiency of the heat production is increased for heat sources such as geothermal heat, heat pumps or solar heating. The efficiency of the heat production is estimated to increase by approximately 10 % in solar thermal plants and 30 % in heat plants supplied by heat pumps, if supply and return temperatures are lowered from 80 °C/40 °C to 60 °C/30 °C. Additionally the heat production efficiency is increased when return temperatures are lowered in heat plants with flue gas condensation supplied by natural gas or wet biomass. Consequently a reduction in the DH temperatures can amount to significant total energy savings.

Danish DH is characterized by a large outspread, and relatively low supply and return temperatures. However recent research has shown that there is further potential to lower the DH temperatures. Currently, approximately 47 % of the total Danish heat demand is covered by DH [3]. Even low-density areas are at times supplied by DH, for example approximately 40 % of the Danish single family houses are heated by DH [4]. Current supply and return temperatures are as low as 70/40 on average [5]. Nevertheless a large effort is currently taking place to reduce the temperatures further. This is done by the DH companies, through installation of automatic temperature optimization software [6] or through research projects that investigate the opportunity to lower the DH supply temperatures to 55 °C or 60 °C in both new and existing buildings [7].

The temperature reductions in the DH networks are limited by the demands and technical requirements in the buildings. In houses or commercial buildings these limitations are generally set by either the domestic hot water (DHW) requirements or the design of the space heating installations. The supply temperature in current Danish DH networks is generally limited by the DHW systems, which are typically designed for preparation of hot water at a temperature above 60 °C. When DHW is stored at this temperature, the risk of Legionnaires' disease is reduced, as the Legionella bacteria mainly grow at lower temperatures. If DH temperatures go below 55 °C, the DHW must be prepared through for example an instantaneous heat exchanger, to avoid Legionella growth in the DHW [8]. By use of the direct heat exchanger, or other solutions as described by Yang, Li & Svendsen in [9], the DH supply temperature can be lowered to around 50 °C, which is enough to deliver DHW at the required comfort temperature of 40-45 °C. This type of DH is commonly referred to as low-temperature district heating (LTDH).

The DH temperatures can be lowered further if the DHW is heated through a combination of DH and electricity. This is also referred to as ultra-low-temperature district heating (ULTDH). DH is used to heat the domestic hot water to a temperature of e.g. 35 °C and the temperature is then further raised to 40-45 °C by for example a micro heat pump [10] or an instantaneous electric heater. In this case the space heating systems are the limiting factor with regards to temperature reductions. For example it may not be possible to lower the supply temperature to 40 °C in old buildings where the heat loss is large and the heating elements are small. However recent research has shown that many existing buildings can be heated by low-temperature heating without problems. This is partly due to the fact that the supply temperature in a LTDH system can be increased in peak periods during cold winter times when the space heating requirements are higher. Ultimately the lower limit for the DH supply temperature could be as low as 30 °C in new buildings with floor heating. Fig. 1 summarizes the different types of DH based on the technical limitations and in correspondence with earlier definitions as described in [2,6,11].