EuroSun2026

EXPERIMENTAL INVESTIGATIONS OF A LOW-TEMPERATURE-LIFT HEAT PUMP COMBINED WITH AN ICE STORE FOR COLD DISTRICT HEATING SYSTEMS

Summary

This contribution presents experimental investigations of a central low-temperature-lift heat pump prototype in combination with an ice store and emulated solar air-brine collectors as part of a concept for a new generation of cold district heating and cooling systems. The investigation focuses on the heat transfer within the ice store and its effects on the overall system efficiency when combined with the central low-temperature-lift heat pump.

Keywords: heat pump, ice store, seasonal thermal energy store, solar thermal, district heating and cooling systems, system efficiency, 5GDHC

Field of application for the findings: Solar thermal heating and cooling systems with seasonal thermal energy store

Addressed audience: Researchers and engineers in solar thermal energy and thermal energy storage, HVAC and energy system planners, decision makers of municipalities.

1. Introduction

Since the emergence of district heating networks, the temperatures within such networks have been lowered further and further over time. While the first generation of heating networks used steam as heat transfer medium, the more modern networks of the fourth generation use liquid water at 30 to 70 °C temperature (Lund et al. 2014). The driving factors for decreasing the network temperature are a reduced heat loss at lower temperatures and a higher efficiency of the heat generators such as e. g. condensing gas boilers, solar thermal collectors and heat pumps. With the use of decentral heat pumps, it is even possible to have network temperatures much lower than what is required by a heating installation. The current fifth generation of heating and cooling networks (5GDHC) runs at network temperatures between -15 and 30 °C, sometimes even resulting in heat gains of the network from the environment instead of heat losses. The lower temperatures also make it possible to use the network for cooling purposes.

The fact that network temperatures may go below 0 °C however, requires the use of antifreeze agents in the heat transfer medium to prevent freezing leading to potentially bursting pipes. This raises new challenges for installation, operation and environmental safety of such networks, as antifreeze agents are generally harmful to the environment. Depending on the individual requirements of the country, such a network requires double walled pipes, an automatic system for leakage detection, as well as collecting basins for the transfer medium in case of a leakage. Those additional requirements and higher investments costs for using antifreeze mixtures compared to water decrease the economic efficiency of such systems.

2. New Generation of Cold District Heating Systems

A proposed new generation of cold district heating networks as shown in Fig. 1 uses a central heat pump in order to ensure network temperatures above the freezing point of water. This enables the use of water without antifreeze as heat transfer medium in the network. Since the heat transfer circuit on the source side of the system still requires antifreeze due to source outlet temperatures lower than 0 °C, the central heat pump should be positioned close to the thermal energy sources such as solar thermal air-brine-collectors and the ice store. The central heat pump then raises the temperature level of the heat transfer medium by approximately 20 K to be distributed by the network to the respective buildings where decentral heat pumps raise it further to the required temperature level for the heating systems. Since the central heat pump can operate in a relatively narrow range around its optimal operating point, the overall system efficiency in this concept is expected to be higher compared to a system without central heat pump.

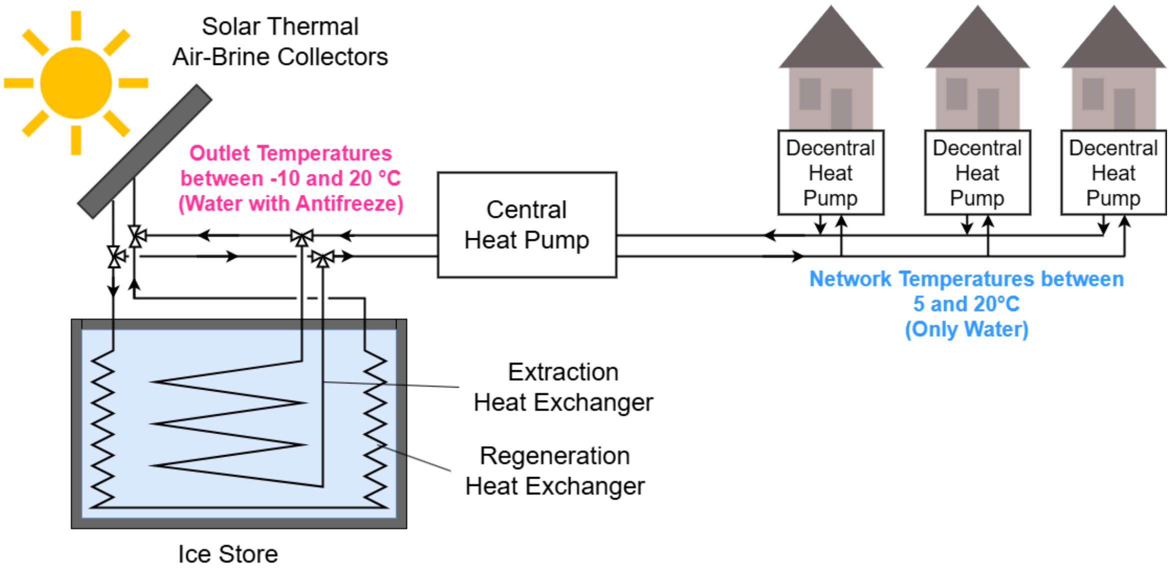

Fig. 1: Schematic set-up of the new generation of a cold district heating system supplying heat with water as heat transfer medium in the cold district heating network

3. Experimental Investigations and Selected Results

This paper will present experimental investigations of a laboratory-scale prototype of a central heat pump with around 25 kW_{th} in combination with an ice store and emulated air-brine-collectors. The heat pump uses R-290 as refrigerant and consists of a five-component cycle with a scroll compressor, condenser, inner heat exchanger, expansion valve and evaporator. The central heat pump has a low temperature lift in its application: the temperature ranges are -10 to 5 °C on the evaporator side and 5 to 20 °C on the condenser side. This means that the temperature differences in heat transfer significantly influence the overall efficiency of the heat pump. The investigation focuses particularly on the influence of an increasing state of icing in the ice store, which reduces the heat transfer capacity and thus the overall system efficiency.

Preliminary investigations examined the heat transfer in the ice store by measuring the heat transfer capacity across varying configurations of heat exchangers with increasing and decreasing state of icing. The configurations include one or two heat exchangers in the ice store: heat extraction via one heat exchanger and regeneration via the other heat exchanger compared to extraction and regeneration via a single heat exchanger. Results showed that the heat transfer capacity could be improved for this particular type of ice store by using only one heat exchanger for both heat extraction and regeneration. Another investigation included a circulation pump that caused artificial convection flow within the ice storage medium, increasing the heat transfer capacity significantly during regeneration. Further planned investigations include a dynamic operation of the heat pump with simulated load profiles, focusing on the effects on the ice store and overall system efficiency.

4. References

Lund, H. et al., 2014. 4th Generation District Heating (4GDH). Energy, Vol. 68.