Low-energy district heating in energy-efficient building areas

This paper presents an innovative low-energy district heating (DH) concept based on low-temperature operation. The decreased heating demand from low-energy buildings affects the cost-effectiveness of traditionally-designed DH systems, so we carried out a case study of the annual energy performance of a low-energy network for low-energy houses in Denmark. We took into account the effect of human behaviour on energy demand, the effect of the number of buildings connected to the network, a socio-economic comparison with ground source heat pumps, and opportunities for the optimization of the network design, and operational temperature and pressure. In the north-European climate, we found that human behaviour can lead to 50% higher heating demand and 60% higher heating power than those anticipated in the reference values in the standard calculations for energy demand patterns in energy-efficient buildings. This considerable impact of human behaviour should clearly be included in energy simulations. We also showed that low-energy DH systems are robust systems that ensure security of supply for each customer in a cost-effective and environmentally friendly way in areas with linear heat density down to 0.20 MWh/(m year), and that the levelized cost of energy in low-energy DH supply is competitive with a scenario based on ground source heat pumps. The investment costs represent up to three quarters of the overall expenditure, over a time horizon of 30 years; so, the implementation of an energy system that fully relies on renewable energy needs substantial capital investment, but in the long term this is sustainable from the environmental and socio-economic points of view. Having demonstrated the value of the low-energy DH concept, we evaluated various possible designs with the aim of finding the optimal solution with regard to economic and energy efficiency issues. Here we showed the advantage of low supply and return temperatures, their effect on energy efficiency and that a DH design that relies on low-temperature operation is superior to a design based on low-flow operation. The total primary energy use in the best design was 14.3% lower than the primary energy use for standard, recently designed networks, and distribution heat losses were halved. Moreover, the exploitation of the entire available pressure by means of careful network design decreased the average pipe size required, which slightly lowers the investment costs for purchasing and laying the pipelines in the ground. This low-temperature DH concept fits the vision of the future energy-sustainable society.

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