Annex X Final report

Toward 4th Generation District Heating: Experience and Potential of Low-Temperature District Heating

Short title: Toward 4th Generation District Heating

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Executive Summary

Background and Objective

The evolution of district heating (DH) has gone through three generations since the first introduction of distirct heating. It is characterized by the type of transport media and the network temperature levels: the 1st generation DH system is steam-based system, the 2nd generation DH uses high network supply temperature above 100°C, and the 3rd generation DH represents the current DH system with medium network supply temperature between 80°C to 100°C. Up until now, the 4th generation DH as the low-temperature district heating (LTDH) is emerging as a new system which is going to replace the existing 3rd generation DH system. Comparing with the existing DH system, the LTDH reduces the network supply temperature down to consumer required temperature level, thus greatly improves the quality match between the energy supply and the energy demand. Meanwhile, LTDH coupling with reduced network temperature and well-designed DH network can reduce network heat loss by up to 75% comparing with the current system. This makes DH economically competitive comparing with local heat generation units in the areas with low heat density or with low-energy buildings.

The traditional approach to evaluating a DH system often focuses on the production/supply aspect and only afterwards on the final users. The LTDH concept switches the perspective, starting from end-user thermal comfort and a quality match between energy supply and energy consumption, and aiming to find the best and most economical way to satisfy the heat demand through efficient distribution networks and supply systems based on waste heat and RE. The new concept therefore starts by identifying suitable in-house substations for low-energy-demand buildings at low supply temperature, goes back to design efficient and reliable networks, and finally considers environmentally-friendly heat production units.

This report describes the concept of LTDH, collects and discusses successful examples of implementation LTDH in the building heating sector.The objective of this report is to raise awareness and provide insights that will stimulate the research, development and implementation of LTDH systems. It will help to increase public recognition and assist policy makers and energy planners, both at local and governmental level, in promoting cost-effective and environmentally friendly DH systems, and in planning and realizing long-term sustainable urban area development. To this end, the report addresses the following research issues:

1. What are the main advantages of LTDH?
2. What technology options are available for LTDH, and what are the associated challenges to consider?
3. How can the risk of Legionella be mitigated in LTDH?
4. What lessons can be learned from early LTDH projects?
5. What heat distribution costs are associated with LTDH?

Content of the Report

In this report, the relevance of the new generation DH concept is emphasized and the related technologies are described. The report consists of the following chapters mainly dealing with the relevance of LTDH, the DHW regulation and risk of Legionella, the DHW installations, the supply of LTDH to low-energy buildings and existing buildings, the optimal design of a DH network, the renewable and low temperature heat source and case studies from early LTDH projects.

In chapter 1, the basic terminology used in the report is presented. The background, objective and the structure of the report are described. The five basic research issues are stated.

In chapter 2, the role of DH is discussed with respect to the specific distribution cost, the strategic planning of DH in the overall energy system for a future low-energy-demand society, and the balance between investment for building energy reduction and renewable heat source exploitation.

In chapter 3, the DHW regulations that address potential Legionella issues are summarized. Statistical analysis of Legionella contamination in DHW installations is presented. Various types of Legionella treatment methods are discussed, and proper design methods to reduce the risk of Legionella in single-family houses and multi-storey buildings are introduced.

In chapter 4, various types of DH substation specifically designed for low-temperature operation for single-family houses and multi-storey buildings are described.

In chapter 5, the supply of LTDH for low-energy buildings is discussed through building performance simulation, with emphasis of the consumer thermal comfort and the internal heat gain.

In chapter 6, the potential to supply LTDH for existing buildings is evaluated. Various building renovation strategies are suggested to fit the low-temperature operation.

In chapter 7, the performance of energy-efficient DH networks with pre-insulated flexible twin pipes is examined and the idea of optimal network design and operation is discussed. Strategies to reduce network bypass heat losses are illustrated, and the concept of the Comfort Bathroom is introduced.

In chapter 8, the use of a renewable-energy-based energy conversion system is discussed. The concept to use micro-heat pump for DHW in the individual residential building and decentralized heat pump used in the distribution network are discussed.

In chapter 9, the experience from early LTDH projects around the world is drawn upon with regard to efficient low-temperature supply, the integration of low-energy buildings, and renewable energy supply. A comparative analysis is carried out with existing MTDH systems with respect to performance indicators and heat distribution costs.

In chapter 10, the concepts and technologies for the new generation LTDH system are summarized by providing our answers to the research issues we started with.

In Appendices, seven case studies are collected to document the early experiences for LTDH projects.

Final Conclusions

LTDH Advantages

The main advantages of LTDH in heat distribution are reduced heat losses, improved harmonization between heat supply temperatures and heat demand temperatures, reduced thermal stress in steel pipes, the possibility of using other pipe materials, reduced boiling risk, and reduced risks for scalding.

The main LTDH advantages in heat supply are improved power-to-heat ratios in steam CHP plants, greater heat utilization from flue gas condensation when using fuels with moisture, higher coefficients of performance in heat pumps, greater utilization of low-temperature industrial excess heat, increased utilization of geothermal heat, higher conversion efficiencies in central solar collector fields, reduced heat losses, and greater utilization of thermal storage.

The current barriers for LTDH are high-temperature heat demands, legionella growth at low hot-water temperatures, substation faults, and shortcut flows in distribution networks.

Planning and Technical issues

The Planning of DH

DH systems have a long lifetime and can be operated with a strategy that combines reduced network supply temperature with extension to adjacent areas which are supplied with individual heating units. The profitability of extending an existing DH network and the threshold for DH market share can be indicated through the specific distribution cost.

To find an optimal energy supply structure and identify the role of DH in the energy supply system of the future, a strategic energy planning approach can be applied to optimize the entire energy infrastructure to achieve the target for a low-carbon economy and minimize total long-term investment.

The transition from current DH systems to the next generation DH system requires coordinated efforts for building energy reduction and wide exploitation of low-grade waste heat and RE. With a significant building energy reduction, the heating demand will be levelled out throughout the year, which means DH utilities profit from savings in peak-load facility investment. The level of building energy saving and the reduction in renewable-based heating plant installed capacity will depend largely on the decisions on socio-economic criteria made by policy makers through regulations and incentives.

Domestic Hot Water Installation

A well-designed and functioning DHW system must fulfil the requirements for hygiene, thermal comfort and better energy efficiency. One of the major barriers to implementing LTDH is the increased Legionella risk with supply temperatures close to 50°C. In small residential buildings, the DHW system can be operated below 50°C without using external treatment or recirculation if the water volume in each DHW supply line, including the water content on the secondary side of HE, can be limited to 3 litres. The same design philosophy can be used in multi-storey buildings if a station unit is installed in each apartment.

There are different types of in-house DHW installations, typically including district heating storage tank unit (DHSU) or instantaneous heat exchanger unit (IHEU). Storage tanks have the advantages to shave the peak heating load and allow a reduction in the diameter of distribution pipes, such advantages should be further justified by considering the size of the tank and using a more realistic simultaneous factor to design the distribution pipes. IHEU is a comparatively simple and cost-saving solution. It has better cooling than DHSU. The negative side of IHEU is that it has larger service pipe diameters. Meanwhile, novel HEs with an increased unit heat transfer rate and more accurate fast-response thermal control is required for LTDH.

LTDH Supply to Residential Buildings

The low-temperature SH system should be selected to fit the low-energy building demand with regard to various criteria such as energy consumption, the ability to shave the peak heating demand, the network return temperature, and consumer thermal comfort.

The large-scale implementation of LTDH relies on its use in existing buildings. The studies show that with the aid of varying network supply temperature and light building renovation, it is possible to supply LTDH to existing buildings prior to extensive building renovation.

DH Network

To reduce the network heat loss, which accounts for a significant portion of annual operational cost, the performance of the advanced pre-insulated DH twin pipes designed for high pressure in the distribution network has been studied. Triple pipes which can deliver supply water with two different diameter pipes and at two different temperature levels were suggested for service pipes to reduce pipe heat loss. Alternatively, they can be used for the 'minimum cooling' bypass strategy.

The operation of a DH system normally has a much higher relative heat loss in summer than in winter due to the use of thermal bypasses. The Comfort Bathroom concept redirects the bypass water through bathroom floor heating, which on one hand improves consumer thermal comfort and on the other hand further cools down the bypass water.

Heat Sources

The use of the various forms of renewable energy should be evaluated in the local energy framework, taking into account heating, cooling, electricity and transportation. The development of DH will move from the highly hierarchical, large-scale heating plant heat generation towards small-scale, more flexible and more controllable decentralized heat generation. The energy at different temperature levels will be used in a cascade way to match different energy demand requirements. To further reduce network heat loss, the DH supply temperature can be reduced to ultra-low level and boosted on-site or close to the consumption point with the aid of heat pumps.

Legionella issue

One of the major barriers to implementing LTDH is the increased Legionella risk with supply temperatures close to 50°C. A literature survey was conducted for this report to identify DHW supply regulations around the world. We have reported a statistical study on the growth of Legionella in different DHW installations at different temperature levels. Various treatment solutions have been introduced to reduce or eliminate Legionella bacteria.

Lessons learnt from early projects

The main lessons learnt from the case studies are:

*Generation compatibility:*Fourth generation technology requires the application of more realistic and accurate design conditions with respect to heat demands, costs, and operating conditions. It is also possible to extend traditional networks into new areas using fourth generation technology.

*Temperature level:*The design and operation of low-temperature in DH network requires customer heating systems with low temperature demands, no shortcut flows in distribution networks, and continuous commissioning of the systems to identify new faults that give higher temperature levels.

*Heat losses:*As a result of LTDH operation, acceptable annual heat distribution heat losses of 10-15% can be achieved in areas with low-energy houses by cutting the temperature level in half and by doubling the pipeline heat resistances compared to current third generation technology, and by using twin pipes.

*Heat supply:*Future heat supply will be more diversified and will give opportunities for power system interaction, renewables, and heat recycling from local excess heat resources. The role of heat storages will increase due to the need to make fluctuating renewables more flexible to satisfy customer heat demands.

Independence: The case studies were often demonstration areas with installations supported by research grants. They have a high degree of independence achieved by using renewable energy sources and major heat storages. They represent a new market segment for district heating, which has previously been more associated with large-scale citywide systems in concentrated urban areas.

Heat distribution costs

Both distribution capital cost and distribution heat loss are proportional to the inverse of the heat density. So these two important system parameters depend on a combination of specific heat demands and the concentration of buildings, expressed by the plot ratio. The case studies show that both acceptable distribution capital costs and acceptable distribution heat losses can be achieved for low-energy buildings with low specific heat demands, if these buildings are concentrated. High distribution costs will, however, mean that DH is not viable for low-energy buildings located in areas with low plot ratios.

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