District Heating Distribution in Areas with Low Heat Demand Density

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Summary

The following measures leading to improved system economy were analysed, according to the following main sections of the project:

a. Techniques for reduction of piping costs and heat losses from heat distribution networks (DK)

b. Increased use of district heat instead of electricity in households (SE)

c. Load profiles and operational analyses of areas with low heat demand density (FIN)

The project was organised in such a way that each of the partners had the main responsibility for one of the areas of interest indicated above. However, all project partners of the other countries are supporting the responsible lead partner with relevant input from their own countries, thus covering a broad district heating experience.

Background

In many countries with long district heating tradition, such as is the case in Scandinavia, district heating is well developed and the market development has been slowed by increased use of energy efficiency measures in buildings. When available at all, district heating reaches often about 80 -90 % of the central city area. In the areas with lower heat demand density surrounding the city centre, often only 10-15 % of the buildings are connected to the district heating system. One way to allocate an increased market share to district heating is to apply new measures/techniques for supplying heat into areas with lower heat demand density that to date have not been considered economically suitable for district heating. Among the investigated alternatives are measures for making heat distribution more efficient as well as new heating applications. As a result, heat distribution in areas with low heat demand density could be done more effectively and at lower cost.

The objective of this project is to propose and to analyse measures for improving the economy of heat distribution in areas with low heat demand density. The consequent application of these measures will not only reduce distribution costs but also the environmental impact of energy use in these areas.

Systems with low heat density are struggling with relatively high investment costs and high heat losses. One way to reduces these costs would be to make components smaller and lower the amount of groundwork in the distribution net. Another way is to distribute more energy in the same piping structure, hence decreasing the relative amount of fixed costs of the delivered energy. Therefore, in this report we are first presenting new technologies that are on the frontier for application in district heating systems. This holds as well for the heat distribution system as for systems using heat. We describe technologies that have been used in demonstrations projects or in real projects such as new types of pipes (i. e. triple pipes) or only just in the laboratory (egg-shaped pipes). For the same purpose, we present new distribution methods, such as small service pipes with booster pumps or small pipes in combination with heat storage units. In addition, we describe components and measures, which can gain worldwide interest for their capability of replacing electricity by heat, in our case district heat.

Cost analyses are critical for the outcome of this report. By analysing real systems, we were able to calibrate other programs used for cost calculations. Because project costs can be very site-specific and costs of different systems on different places are usually very difficult to compare, we concentrated in this project on the cost comparison of systems constructed with comparable cost structures. These system comparisons were applied on the systems analysed from Finland and Denmark, leading to some general conclusions about the systems to be used in areas with low heat density.

Concerning the use of energy, we are presenting measures for increasing district heating loads without wasting energy. We give example of systems in which the use of district heat is increased at the expense of electricity use. Households can be provided with equipment such as heat driven washing machine, dishwasher and tumble-drier. In the future, people may want to increase their comfort by using air-conditioning, pools and spa-tubs and possibly other equipment such as car heaters and greenhouses, all of those supplied with district heat instead of electricity. This saves not only electricity for other and exergetically more favourable applications, it will also help to compensate for decreasing heat loads and to maintain heat distribution efficiency.

Content of the report

The report contains the following main chapters dealing with the questions of heat demand, distribution systems and new loads suitable for areas with low heat demand density.

Chapter 1 - "Introduction" presents the background and introduces the problem area.

Chapter 2 - "Heat demands for district heating" - discusses after the Introduction the basic load conditions for practical district heating networks and describes the relation of heat density and line heat demand. It also shows examples for the lower limits of heat density in district heating and elucidates how measures for energy saving on the one hand and new district heating loads on the other hand can shift these limits.

Chapter 3 - "Examples of applications with low heat demand" describes examples from sparse district heating applications realised in Sweden, Finland and Denmark. The intention of this chapter is to show how district heating is used in areas with low heat demand density, and which losses and other typical system conditions are prevailing for such systems.

Chapter 4 - "Evaluation of loads in district heating systems with low heat demand density" describes the evaluation of two systems with low heat demand density: Neidonkallio near Espoo, Finland and Peter Freuchenvej in Nykøbing/Falster, Denmark. In Neidonkallio, the energy for space heating is delivered via substations with two heat exchangers in parallel, one for space heating and one for hot water preparation. In the Peter Freuchenvej-system, this solution is used in a couple of buildings, whereas the majority of the buildings have direct-connected radiators and a hot water storage tanks fed by district heating.
Chapter 5 - "Techniques for reduction of piping costs and heat losses from heat distribution networks" discusses methods and techniques that in recent years have been developed especially for areas with low heat demand density. A great deal of the development has been achieved in development projects in Denmark, Sweden and Finland. Compared to standard technology, these achievements concern new material for pipes and insulation, new design of pipes, methods for routing district heating pipes, and in addition how to reduce heat losses by other measures, i. e. reduction of pipe diameter in combination with advanced flow control.
Chapter 6 - "Cost model for heat distribution systems in areas with low heat demand density" presents a simple cost model for local district heating systems to be used for applications with low heat density. The model itself is based on spreadsheets created in Excel that are constructed so that they show system costs for alternative construction layouts applied on the same system. This cost model is applied on the two system analysed in detail for this report, i.e. and Neidonkallio and Nykøbing.
Chapter 7 - "Increased use of district heat instead of electricity in households" shows how the load of detached houses can be increased, partially by shifting the energy use from electricity to district heating. The chapter describes methods for increased utilisation of district heating that were demonstrated in a project in Gothenburg, Sweden. It also describes how the total load would change if some of these loads were to be used in row houses in Neidonkallio.
Chapter 8 - "Improved system solutions" describes results of system analyses performed to illustrate eventual cost saving that can be received by careful system design. Essentially, the main changes are use of twin pipes instead of single pipe systems, use of smaller pipe dimensions, eventually with booster pump, varying insulation thickness, new routing (house-to-house) and the use of hot water tanks instead of directly connected hot water preparation. Two systems, one in Finland (Neidonkallio) and one in Denmark (Nykøbing/Falster) are investigated.
Chapter 9 - "Connection of future areas with low heat demand density". This chapter summarises the most important items for achieving cost-effective connection of buildings in areas with low heat demand density, for example small customer loads such as detached houses. The chapter presents a checklist of items that are important for cost reduction when planning a district heating distribution net, either for an area with existing detached houses or for new development. Minimizing pipe dimensions and groundwork is important in any case. In addition, different ways to connect substations are discussed. Finally, the importance of reaching a high degree of connection for local district heating net is underlined.
Chapter 10 - "Conclusions" summarises the quintessence of the work and gives recommendations for future applications.
Chapter 11 collects all *"References".*
Additional information about how to calculate heat losses and further costs comparisons for alternative system solutions are collected in the *Appendices*.

Final conclusions

A main conclusion of this report is that a number of techniques and measures are available to help reduce costs for heat distribution in areas with low heat demand density. Expressed in terms of heat densities, we believe that areas with a heat density of 10 kWh/m^2,yr or with line heat demand of 0.3 MWh/m,yr can be economically served by district heating.
Based on a number of projects, it has be determined that district heating, in order to achieve good economy for low heat demand density, requires more careful planning than traditional district heating. In many cases, alternative solutions that do not follow the traditional district heating manuals can be successfully applied and will give lower costs. Some of these alternative solutions may in the future find their way into handbooks for sparse district heating design, while others for now must be considered as unusual measures and analysed carefully before being applied.
The first preinsulated networks were in use in the late 1960'ties and thus many old systems are in need for renovation. The recommendations given here for better design and reduced heat losses in new DH systems are of course also valid for the renovation of old systems.
The following provisions have been found to affect the total costs of connection to district heating:

System design

- Examples from Denmark have shown that *low pressure and low temperature systems* with direct connection of the radiator system can reduce costs. Such systems can either be used in small local networks or as secondary systems connected to main district heating systems.
- System design that *reduces pipe dimensions* is important in design of systems for detached houses. Such systems can be systems with *hot water accumulators* instead of directly connected heat exchangers, or service pipes with reduced diameter and ultimately even a *booster pump* for adequate heat supply.
- House-to-house connection is already a classical way to connect detached houses. However, it is difficult to get the customer interested due to larger impact on their premises. On the other hand, in connection with lower system costs and rewards for own work, it is possible to implement this method of reducing connection costs.
- The *degree of connection* is an import issue for both the utility and the customer, because the fixed costs decrease with the number of customers. This accentuates the importance of investment in marketing and dissemination of information to the potential customers from the very beginning of a project dealing with new connections to an area.

District heating pipes

Pipes have a twofold impact on the system costs: *Investment and heat losses*. All measures that can reduce one of these are of interest, such as good *insulation performance* and *advanced pipe design.*

- The thermal conductivity of polyurethane insulation depends on the temperature as well as on the time elapsed since the foam was produced (ageing). Heat losses and heat loss coefficients can be accurately calculated for single, twin and triple buried heating pipes.
- New types of pipe systems are compared in respect to their possible installation costs and heat losses. *For an 80 mm (nominal) distribution pipe,* we compared a pair of single pipes with a *circular twin pipe* and with an *egg-shaped twin pipe*. We found that the egg-shaped pipe reduces the heat loss by 37 % and the investment index by 12 % compared with the pair of single pipes.
- For *service pipes* a pair of single pipes ø 25/77 mm is the reference case. We found that the *triple pipe* (a system with two smaller supply pipes and one return pipe, one of them used in the case of high hot water consumption) reduces the heat loss by 45 % compared with the reference case and by 24 % compared with a *circular twin pipe*. The reduction in investment index can be up to 20 %. New altern-ative designs of service pipes, involving a combination of co-insulation, asymmetric insulation, and dissimilar dimensions of two or three media pipes, have the potential to achieve saving of roughly 50 % compared with traditional pair of pipes.
- *Service pipes* should be as small as possible and no reserve capacity should be calculated for. Similar holds also for the distribution pipes. Taken future energy saving measures into account, reserve capacity should only be taken into consideration if it is obvious that additional loads will be connected in the future.

Civil works

The classical trench design is for double pipes with drainage bed. In accordance with local conditions, the trench can be made smaller with corresponding reduction of excavation work and handling of soil volumes. The following measures are possible:

- The use of twin pipes is mandatory in systems with low heat demand density. The reduction of excavation work is a clear cost advantage.
- Reduction of pipe dimension may in many applications result in a smaller trench, which should be taken advantage of if possible.
- Reduced ground cover can be applied in piping without traffic loads. Hence, the routing should take advantage of such possibilities (parks, gardens, sidewalks).
- Drainage bed pipes can often be omitted, especially in trenches for service pies.

New loads

District heating systems should be marketed to new customers with an additional benefit: District heating can deliver part of the energy, which to date has been supplied by electricity. Eventually, this could cover a broad spectrum of applications. In the beginning, new applications could be the white goods *washing machine*, *disk washer* and *tumble dryer*. Small absorption cooling for air conditioning systems and heating of pools and spa-tubs are other potential applications.
An example is a demonstration of new loads in Gothenburg (Sweden): There it was shown that 7500 kWh of district heating could replace 5500 kWh of electricity. This application resulted in 35 % reduction of primary energy (based on power generated from a coal condensing power plant).

Evaluation and system analysis

System analyses have been verified with system simulations for Neidonkallio and Nykøbing/Falster. The analyses compare the total cost for different pipe systems and district heating solutions, such as: single pipes, twin pipes, triple pipes, reduced pipe dimensions, systems with booster pumps in service pipes and systems with hot water accumulator instead of direct hot water heat exchanger. The results of these analyses conclude that costs could be reduced by about 25 % in smaller systems (Nykøbing/Falster) and by 40 % in larger systems (Neidonkallio).

Reference

Heimo Zinko et al: District Heating Distribution in Areas with Low Heat Demand Density. IEA-Report. IEA-DHC Annex VIII, 2008:8DHC – 08-03.