IEA R&D Programme on

"District Heating and Cooling, including the integration of CHP"

District heating for energy efficient building areas

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Preface

Introduction

The International Energy Agency (IEA) was established in 1974 in order to strengthen the co-operation between member countries and reduce the dependency on oil and other fossil fuels. Thirty years later, the IEA again drew attention to serious concerns about energy security, investment, the environment and energy poverty. The global situation is resulting in soaring oil and gas prices, the increasing vulnerability of energy supply routes and ever-increasing emissions of climate-destabilising carbon dioxide.

At the 2005 Gleneagles G8 an important role was given to the IEA in advising on alternative energy scenarios and strategies aimed at a clean, clever and competitive energy future. Two years later, at the Heiligendamm G8, it was agreed that “instruments and measures will be adopted to significantly increase the share of combined heat and power (CHP) in the generation of electricity”. District Heating and Cooling is an integral part of the successful growth of CHP: heat networks distribute what would otherwise be waste heat to serve local communities. The IEA is active in promoting and developing knowledge of District Heating and Cooling: while the DHC programme itself is the major global R&D programme, the IEA Secretariat has also initiated the International DHC/CHP Collaborative which assesses global markets and policies for these important technologies.

The IEA’s latest CHP report, "Cogeneration and District Energy: Sustainable energy technologies for today…and tomorrow", released at COGEN Europe meeting in Brussels on 21 April 2009, identifies proven solutions that governments have used to advance CHP and district energy, setting out a practical ‘’how to’’ guide with options to consider for design and implementation. The report concludes that these technologies do not need significant financial incentives; rather they require the creation of a government ‘champion’ to identify and address market barriers. This makes CHP and district energy ideal investments at a time of tight budgets.

The CHP report follows the IEA’s first report from March 2008, "Combined Heat and Power: Evaluating the Benefits of Greater Global Investment". There are also 11 "Country Scorecards" that evaluate different countries’ success in achieving increased use of CHP and DHC. In November 2009, the IEA joined with the Copenhagen District Energy Summit to issue the first Global District Energy Climate Awards in order to recognize communities that have embraced district heating and cooling as a vital sustainable energy solution.

The major international R&D programme for DHC/CHP

DHC is an integrative technology that can make significant contributions to reducing emissions of carbon dioxide and air pollution and to increasing energy security.

The fundamental idea of DHC is simple but powerful: connect multiple thermal energy users through a piping network to environmentally optimum energy sources, such as combined heat and power (CHP), industrial waste heat and renewable energy sources such as biomass, geothermal and natural sources of heating and cooling.

The ability to assemble and connect thermal loads enables these environmentally optimum sources to be used in a cost-effective way, and also offers ongoing fuel flexibility. By integrating district cooling carbon-intensive electrically-based air-conditioning, rapidly growing in many countries, can be displaced.

As one of the IEA’s ’Implementing Agreements’, the District Heating & Cooling programme is the major international research programme for this technology. Active now for more than 25 years, the full name of this Implementing Agreement is ‘District Heating and Cooling including the integration of Combined Heat and Power’. Participant countries undertake cooperative actions in energy research, development and demonstration.

Annex IX

In May 2008 Annex IX started, with the participation from Canada, Denmark, Finland, the Netherlands, Norway, South Korea, Sweden, United Kingdom, United States of America. Below you will find the Annex IX research projects undertaken by the Implementing Agreement “District Heating & Cooling including the Integration of Combined Heat and Power”.

Annex IX (2008 – 2011) research projects Implementing Agreement “District Heating & Cooling including the Integration of Combined Heat and Power”.

Benefits of membership

Membership of this implementing agreement fosters sharing of knowledge and current best practice from many countries including those where:

- DHC is already a mature industry
- DHC is well established but refurbishment is a key issue
- DHC is not well established

Membership proves invaluable in enhancing the quality of support given under national programmes. Participant countries benefit through the active participation in the programme of their own consultants and research organisations. Each of the projects is supported by a team of experts, one from each participant country. As well as the final research reports, other benefits include sharing knowledge and ideas and opportunities for further collaboration. New member countries are very welcome – please simply contact us (see below) to discuss.

Information

General information about the IEA Programme District Heating and Cooling, including the integration of CHP can be obtained from our website www.iea-dhc.org or from:

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Acknowledgement

The IA DHC/CHP also known as the Implementing Agreement on District Heating and Cooling, including the Integration of Combined Heat and Power, functions within a framework created by the International Energy Agency (IEA). Views, findings, and publications of the IA DHC/CHP do not necessarily represent the views or policies neither of all its individual member countries nor of the IEA Secretariat.

We would like to thank people who helped with preparing figures and provided photographs for the report and in particular the Danish Energy Agency, the Danish District Heating Association and EuroHeat & Power.

Executive summary

Background

The district heating market is facing strong challenges in coming years. As the energy efficiency of buildings, both new and renovated, is increasing, the heat sales and the efficiency of the existing distribution systems are decreasing. Also, the customers in newly built areas are more and more interested in using their own renewable heat sources such as solar energy, biomass or heat pumps based on decarbonising electricity, which accentuate the difference between summer and winter loads making district heating system design more challenging than ever.

However, the combined heat and power (CHP) production remains to be the most efficient technology to convert combustible fuels into usable energy even if district cooling could be included. This fact is unchanged when the use of biomass is increased and is even more attractive than before due to the cost pressure of most biomass based energy production technologies.

This project deals with the challenges by indicating strategies for the operation of district heating systems in the changing environment and the connection of renewable energy sources to new or existing systems. Also, the lower economical and technical limits of district heating applications are studied and compared with alternative solutions, such as individual or local heating systems.

Content of the report

The report consist of 7 chapters, which are

Chapter 1 “*Introduction*” presents the background and describes problems considered later in this report

The Chapter 2 “*Expected development of summer and winter loads including regulation on heat demand of new dwellings in future*” deals with the expected development of loads in district heating systems in the future when more energy efficient building technologies are introduced. Both summer and winter loads are investigated.

The Chapter 3 “*Introduction to designing district heating systems*” gives an introduction to district heating system design in the context of this report.

The Chapter 4 “*The borderline between district heating and individual systems*” sketches the borderline between district and individual heating systems from an economical and environmental point of view using examples from Finland and United Kingdom. In addition, the operational challenges on low heat demand system design are discussed.

Chapter 5 “*Integration of heat sources in district heating areas*” deals the integration of renewable sources of energy in district heating and examples of successful integration are described in different countries.

Chapter 6 “*Conclusions*” contains the conclusions to pay attention in planning. The chapter concludes results in future district heating even more large perspective as results given in the report may give attention.

Chapter 7 “*Recommendations*” give guidelines, which will be important in district heating planning in future.

Conclusions

Future loads

Environmental and economic requirements will slowly change the composition of existing district heating areas towards lower heat density and lower heat-line density.

As the space heating load reduces, the domestic hot water will have a larger share of the total load. DHW is dominating the district heating load in the summer time. However in some areas, heat driven cooling can add a new load to district heating.

The annual load demand curves of networks will, in general, become flatter. There is, however, an uncertainty about the peak load demand. In some places, district heating will be used for peak load (wintertime), which means that high power loads can be necessary for short duration. This concerns especially areas where exhaust/outdoor air heat pumps and/or solar panels have a significant share of the buildings auxiliary heat supply.

The customers may possibly be able to buy dwelling comfort instead of only energy, which also will contribute to even out the load distribution. The comfort means a service of temperature, humidity and pure indoor air.

In some district heating networks, distributed production systems such as solar energy or other renewable heat sources, will also be connected to the grid. This will require careful planning whether the renewable production is to be integrated in an existing system or whether a new system is constructed. Especially with solar energy, district heating flows can exhibit large variability and even change direction.

Future newly built sparse areas will have very low heat densities. This calls for modern distribution technology with very good insulation properties for piping and also improved intelligent control systems.

Consequences of energy efficient buildings on system layout

Energy efficiency in buildings will contribute to decreased heat line density and increased relative heat losses. As a consequence, the temperature drop along the pipes will be an accentuated problem which must be counteracted by improved pipe technology and advanced control strategies.

Existing networks must be operated at as low temperatures and with as high temperature difference as possible. Special consideration will have to be taken for times of low DH load, however; when it may be necessary to maintain a minimum flow in the system, at the expense of low return temperature. If the DH flow is too low, the temperature drop in the supply pipe to distant consumers will become unacceptable.

New networks will generally be designed for lower distribution temperatures, taking advantage of new types of heating systems in the buildings, such as floor or wall heating as well as air heating systems. Depending on the supply temperature, DHW topping procedures based on electric heat pumps or electricity will have to be applied in some cases. PV- technology could also play an important new role in this.

The increased uses of dispersed intermittent heat sources will stipulate the uses of storage-technologies in the systems. Such storage systems can either be installed at the consumers, such as DHW accumulators or centrally at the production unit, for example for storing solar heat or heat from other intermittent sources.

Consequences of energy efficient buildings on operation

Many systems will be designed as a mixture of building-owned production (such as solar energy or fuel cells) and central production and therefore increased requirements for flexible or adaptable heat distribution systems will be demanded.

The distribution temperatures will generally be lower. In some networks, however, they might increase in summertime, due to the increased use of heat-driven cooling systems.

In the future, concepts with increased producer/consumer interaction such as heat-on-demand or heat-when-available will be enabled through the availability of inexpensive control equipment.

On-line energy measurements will inform the user continuously about used energy and applied heating power. This will steer the consumer towards being more active to turn his consumption toward lower total costs. Building automation will help a lot in this aim to save costs.

Integration of renewable heat sources (RES)

The potential for RES in DH systems is very big, primarily in the form of biomass, solar heating and geothermal energy. Already there is a large share of RES in the DH systems, especially in the Nordic countries.

The yearly yield from solar radiation does not differentiate very much in different countries in Northern Europe and Northern America, so the potential is very big for large solar heating plants.

A future without fossil fuels in the DH sector in 2030 – 2050 is possible. It will include RES in the form of large solar heating plants, biomass and use of decarbonised electricity in heat pump systems.

Economic consequences

Future decreased heat demand can be compensated by connecting new buildings with more floors in compacted existent areas. New users can also come from connecting new areas, although they generally will exhibit a lower heat density than has been the case so far. This means that the district heating rates have to be adapted to this situation, with higher fixed prices reflecting the larger investments in relation to operating costs.

The economic border line between heating systems based on district heating and those for individual heating systems is different for existing DH systems and new-constructed DH systems. It is influenced by a range of factors including the relative costs of alternative fuels, the capital costs for DH, the capital costs of individual systems, assumptions regarding maintenance costs, etc.

The general trend is that district heating becomes progressively more economically interesting with increased linear heat density. However, the exact cross-over point depends on the local situation. It is more favourable to connect new areas with low linear heat density (~0.5 MWh/m, a) to existing DH networks up a certain distance of 1000 meters. This conclusion applies for many well developed DH heating countries, such as the Scandinavian countries.

In countries with DH systems to be completely new-constructed, the cross-over point will, due to higher investment costs, be at higher heat densities. An example from UK shows that the cross-over point will be at a linear heat density around 1.5 MWh/m, a, although the crossing interval is very broad.

Convenient and easy district heating

District heating is convenient, carefree and easy way to heat the home. You do not have to pay attention to the DH systems and you do not need any chimney in your house. The noiseless substation takes care of comfortable circumstances in the house together with the building automation system. CO_2 -foot print of district heating is low especially combined to CHP production with low or non CO_2 fuels.

Recommendations

Future district heating systems will consist of a mixture of central and dispersed production systems (hybrid) based on renewable energy sources (RES). The distribution temperature will be lower than now and the flow variable. This means that future systems should be carefully planned as a total system, including production, distribution and use of heat. Simulation and optimisation programmes for such integrated planning are available today.

Dispersed production systems from third parties will be connected to existing or new district heating networks. Operational strategies for the integration of such systems must be further developed.

Existing district heating systems will be complemented with new systems which generally can work at lower temperatures. It is recommended to separate areas with different distribution temperatures in order to facilitate operation.

In order to reduce costs and get more effective operation, new system components and new distribution methods should increasingly be used, such as plastic pipe systems (possibly with super insulation), local or central heat storages, low depth pipeline installations, combined customer/ production substations and heat driven cooling. Guidelines and directives for the application of these components and methods should be developed in order to enable a smooth blend of old and new technologies.

CHP production should be integrated with the future DH system. Power-to-heat ratio can be made higher because of lower temperature demand in DH systems.

Pumping capacity might be reasonable to divide in smaller units and to split under intelligent control in the DH systems.

The district heating business will be more complex in the future, because building owners will want to realize their own ideas about the way to use and to produce energy. This will give district heating companies the opportunity to complement their core business through energy consulting and management of building equipment and systems, thus supporting the customers and finding suitable solutions together, instead of counteracting each other.

Table of content

1 Introduction

District heating in energy efficiency building area

The district heating market is facing strong challenges in coming years. As the energy efficiency of buildings, both new and renovated, is increasing, the heat sales and the efficiency of the existing distribution systems are decreasing. Also, the customers in newly built areas are more and more interested in using their own renewable heat sources such as solar energy, biomass or heat pumps based on decarbonising electricity, which accentuate the difference between summer and winter loads making district heating system design more challenging than ever.

However, the combined heat and power (CHP) production remains to be the most efficient technology to convert combustible fuels into usable energy. This fact is unchanged when the use of biomass is increased and is even more attractive than before due to the cost pressure of most biomass based energy production technologies.

This project deals with the challenges by indicating strategies for the operation of district heating systems in the changing environment and the connection of renewable energy sources to new or existing systems. Also, the lower economical and technical limits of district heating applications are studied and compared with alternative solutions, such as individual or local heating systems.

Content of the report

Chapter 1 presents the background and describes problems considered later in this report

The following Chapter 2 deals with the expected development of loads in district heating systems in the future when more energy efficient building technologies are introduced. Both summer and winter loads are investigated.

The Chapter 3 gives an introduction to district heating system design in the context of this report.

The Chapter 4 sketches the borderline between district and individual heating systems from an economical and environmental point of view using examples from Finland and United Kingdom. In addition, the operational challenges on low heat demand system design are discussed.

This is followed by Chapter 5 in which the integration of renewable sources of energy in district heating is investigated and examples of successful integration are described in different countries.

The chapter 6 gives the conclusions based on the results in the report and even more extensive sights on district heating.

The report in wrapped up in the final Chapter 7 containing recommendations to pay attention in district heating planning in future.

Expert group

As mentioned in the preface, this project was performed as one of the projects within the IEA District Heating and Cooling Program, Annex IX. In the project an Experts group supported the project team with ideas and a wealth of experience. They form a panel that helps to develop the essential concepts of the project. They also assisted the researchers of the project group in getting all the technical details understandable and right, also looking at problems from all countries viewpoint. Such a counsel is an invaluable help in this type of project. Therefore, we are very grateful to the following members of the Experts group for their assistance:

Li Lövehed, E.ON Värme Sverige AB, Sweden
Per Kristensen, Braedstrup District Heating Company; Denmark
Jaakko Luhtala, Fortum Heat, Finland
Terje Strøm, BKK Varme AS, Norway
Mark Howell, Vital Energy Utilities Ltd, United Kingdom
Bard Skagestad, FVB Energy, Canada
Mark Spurr, FVB Energy Inc., USA

Co-operation

The project has been made in co-operation between the following four institutions:

The research institute **Technical Research Centre of Finland (VTT)** in Espoo, Finland was a project organiser with Kari Sipilä as the project manager and the editor of the report text as well as the main writer in chapt.3. In addition Miika Rämä was a co-worker and he was responsible of DH-network simulation in Finnish case study in chap. 4 and he made up also the outlook of the report.

Dr. Heimo Zinko and Ulrika Ottosson at **FVB Sverige AB (FVB)** in Nyköping; Sweden worked with heat load profile forecasting in town and rural areas in different types of buildings. They are mostly responsible of the chap. 2 in the report. Ulrika Ottosson has written also a part of the chapt.3.

Jonathan Williams and Antonio Aguiló-Rullán at **Building Research Establishment Limited (BRE**) in Watford, UK worked with case studies in three places in UK in chap. 4. They simulated DH systems in those three places and find out in which conditions district heating systems are feasible in those places. They make research also to find the border line between district heating and individual house heating systems.

Dr. Benny Bøhm at **BB Energiteknik (BBE)** in Virum, Denmark worked with integration of RES heat sources connected to district heating systems. The RES sources are mainly biomass, solar, wastes and geothermal energy. He find out also successful integrations of RES in DH systems in Europe He was responsible of chapt.5 in the report.

2 Expected development of summer and winter loads including regulation on heat demand of new dwellings in future

2.1 Development of loads in different areas of district heating networks

A district heating area can be composed in a variety of ways. There is diversity in types of buildings as well as age of the connected properties. Some buildings are more attractive to connect to the district heating grid, due to their heat density and/or suitable temperature requirements. Some industries, for example, require higher temperatures than what is normally found in a district heating network and are therefore often excluded from connection to the net. Figure 1 shows the distribution of district energy use for different sectors in Sweden 2006. Multi-residential buildings and non-domestic buildings are the main users of DH. About 85% of all multi-residential buildings and 70% of non-domestic buildings in Sweden are heated by DH[1].

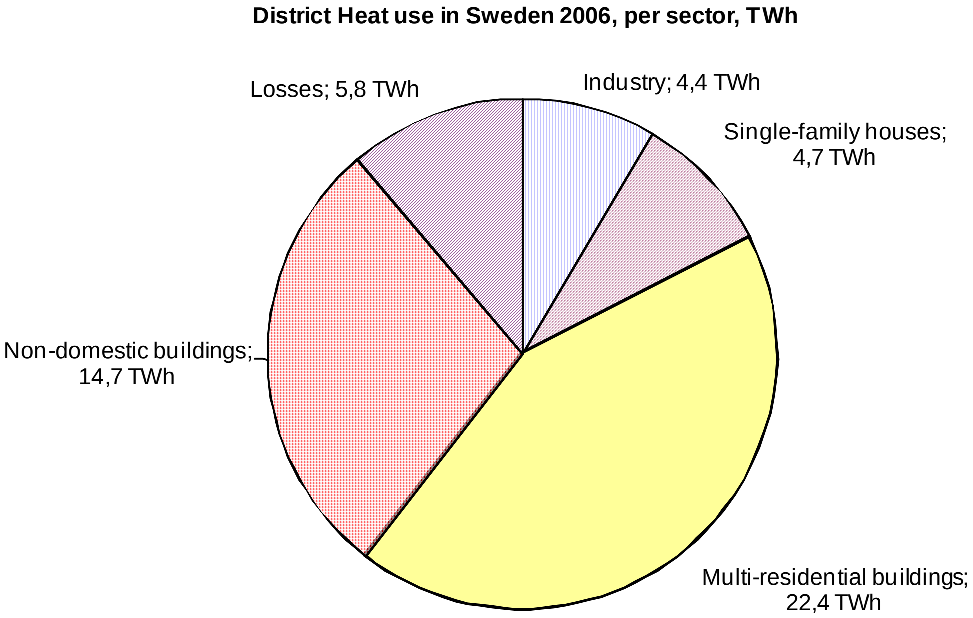

Figure 1. Use of district heating in Sweden 2006. (Source: Swedish Energy Agency)

2.1.1 Heat demand for different types of buildings

Residential buildings have a heating demand with an almost linear dependence on outdoor temperature, up till the buildings balance temperature (also known as base temperature). The balance temperature is the outdoor temperature when no heat needs to be supplied to the building in order to provide a comfortable indoor temperature. Published degree days in the UK are calculated to a base temperature of 15.5ºC for general use with most buildings (and 18.5ºC for hospitals). In Sweden, published degree days usually are calculated to a balance temperature of 17°C. For a well insulated house, such as a passive house, the balance temperature is significantly lower than average, though.

Approximately 20%[2] of the yearly supplied heat to a residential building is to accommodate the hot water demand. This load is more user-dependent and peek loads in DH nets are often found in mornings and evenings, partly due to DHW use[3].

Non-domestic buildings usually have a lower heat demand relative building area and a lower balance temperature than residential buildings. There is usually a lot of electrical equipment which generates internal heat. Non-domestic buildings are not as homogenous as residential buildings are. Neither are industrial buildings. Some industries has a heating demand that widely exceeds the space heating

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[1] 2006, Swedish Energy Agency

[2] 20% in Sweden; 25% in Finland

[3] In the morning, the start-up of ventilation in non-domestic buildings and industry, as well as returning to normal indoor temperature after trying to lower it in night-time, will also have a significant impact.

load, while others produce waste heat that at times will not only fill, but even surpass the buildings' heat demand. Although industries can have a significant impact on the heat load of a district heating net, they will not be included in the calculations in this chapter since that impact is so dependant on site-specific heat profiles.

2.1.2 Influence on future district heating load

The age of the building will usually give an indication on how energy-efficient the building is. As energy prices have risen and also awareness of environmental impacts from energy use, buildings have increasingly become better insulated. The economic incentives for low energy building have increased, but also, national regulation has become sterner.

Buildings will, in the future, consume less energy than they do today. Many European countries abide by the EU goal of 20% less energy use by 2020[4]. The methods for lowering energy use are several:

Improving building envelope. There are a number of ways in which the building envelope can be improved. Adding insulation to walls, floors or roofs is one way. Another is to seal gaps around windows and doors or reduce thermal bridges. Changing to windows with lower transmission is also a method worth mentioning. All these measures will lead to a decrease in the space heating load. With colder outdoor temperature, the saving gets larger. Domestic hot water is not affected by this.

Improving control of heating system. A lot of energy can still be saved by improved heat regulation and thus avoiding over-temperatures in the building. This measure would have a positive effect on the peak load.

Switching to energy-saving appliances. Low-energy light bulbs, freezers and fridges, among other appliances, will lead to lower electricity consumption. A side effect of this will be a slightly higher need for additional heating. There will be no effect on the summer load, but space heating load will increase somewhat.

Heat pumps. In countries with relatively low electricity prices compared to alternative energy sources. In Sweden, for example, heat pumps have become a popular way of providing heat with low energy input. Common heat sources for the heat pumps are outdoor air, exhaust air, ground, sea water or groundwater. Depending on the type of installation, the heat pump can cover the total heat load or merely a part of it. In an area where, for instance, exhaust air heat pumps are used to lower the use of energy, this will affect the use of district heating in the area. If an outdoor air heat pump is used, the annual heat load will be lower, but dimensioning district heating load will stay the same[5]. Some, but not all, heat pumps are also used for providing domestic hot water. This means that the district heating company will have the same installation costs for piping and production units, but lower income (unless the build-up of their energy fees reflect the actual costs).

Building integrated solar heat panels are becoming increasingly popular, especially in new developments with eco-friendly profiles. They have a similar impact on the district heating net as heat pumps; the annual heat consumption goes down, but dimensioning heat flux is not affected much. Usually, solar panels also provide domestic hot water, so summer load will be slim.

In retrofitted or newly built houses there will probably be a combination of energy-saving measures listed above, which will affect the district heating net in different ways.

2.2 Hot tap water versus space heating profiles

As mentioned before, residential buildings have a heating demand with an almost linear dependence on outdoor temperature, for as long as the outdoor temperature does not exceed the buildings balance temperature. Domestic hot water, on the other hand, is dependant on the behaviour of the buildings residents. For a single dwelling, the DHW tapping is very sporadic and the flow can vary considerably. With more dwellings, connected to the same system, there will be a coincidence of the tapping, so the maximum flow will not be the sum of all individual design flows, but lower. Figure 3 shows the DHW flow during 24 hours for a building of 110 apartments. The maximum flow is only a little bit more than 10 times the flow of a single apartment. The correlation between number of dwellings and design flow is shown in Figure 4.

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[4] Compared with the energy used 1990 (20 20 by 2020)

[5] Most outdoor air heat pumps switch to direct electricity heating at outdoor temperatures below -5°C. In any case, COP for the heat pump will be close to 1 or lower at subzero temperatures.

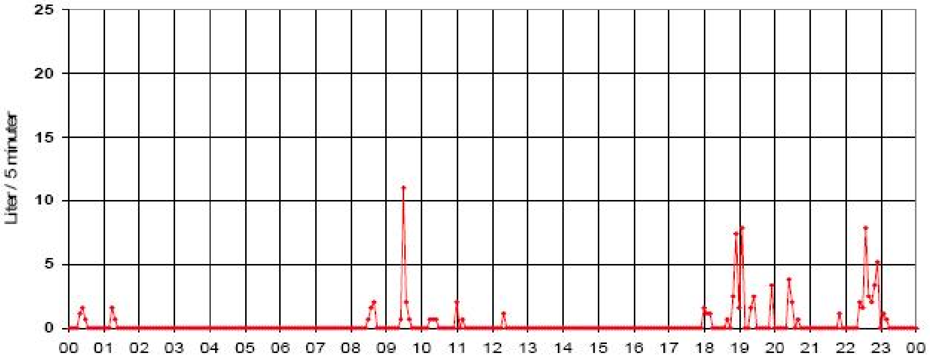

Figure 2. Example of domestic hot water tapping in an apartment during 24 hours (liters/5 minutes), week day. Source: Swedish Energy Agency (ER 2009:26).

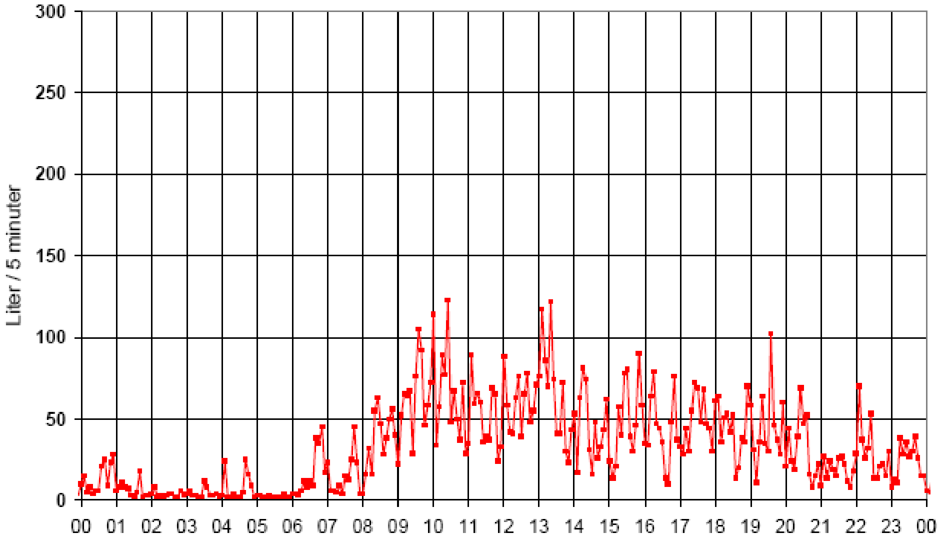

Figure 3. Example of domestic hot water tapping in a building of 110 apartments, during 24 hours (liters/5 minutes), Saturday. Source: Swedish Energy Agency (ER 2009:26).

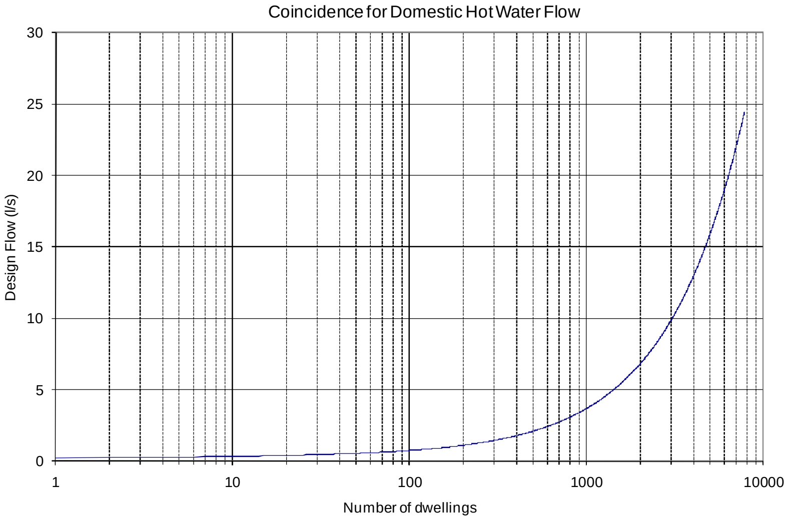

Figure 4. Coincidence for domestic hot water design flow, as recommended by the Swedish District Heating Association.

In today’s residential buildings the DHW load is often assumed to be 20%[6] of the total heat load on an annual basis. As the space heating load reduces, when more energy efficient buildings are being

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[6] 25% in Finland

built, the domestic hot water will have a larger share of the total load. Today, DHW is already dominating the summer load of the district heating net.

2.2.1 Cooling of supply temperature

For areas with low demand and/or low heat density, there's a risk in the summertime of the district heating flow becoming so low that the feed temperature drops too much and the consumer is unable to maintain desired DHW temperature. It is very important to keep this in mind during the design phase, so that pipe diameters in the network is kept as slim as possible in order to avoid this problem. If the pipes are dimensioned to the actual heat demand of the properties, this problem might be avoided. For areas with existing buildings, where the space heating load of the building is much larger than the DHW load, the supply pipes will also have to be larger though, which might cause the supply temperature in summer to cool down in long pipe segments. For such areas, or areas with existing networks that suffer from low supply temperatures during summer, the solution can be to install bypass valves at selected places in order to increase the pipe flow. These valves should have some sort of temperature control, in order to avoid excess flow during the heating season.

2.2.2 Domestic Hot Water Load

Energy efficiency measures throughout Europe will strive to decrease the hot water load in households. On the other hand, recent reports suggest that DHW loads will increase in the future, when people install bath tubs, Jacuzzis and outdoor pools or tubs at a higher rate than before. That would make the DHW load a more significant part of the district heating network. In this study, we have assumed that the DHW load stays at the same level over the 20 year period. Figure 5 presents daily hot water use per capita for some European countries. A daily DHW consumption of 40 litres corresponds to 8.2 kWh/day or 3.0 MWh annually.

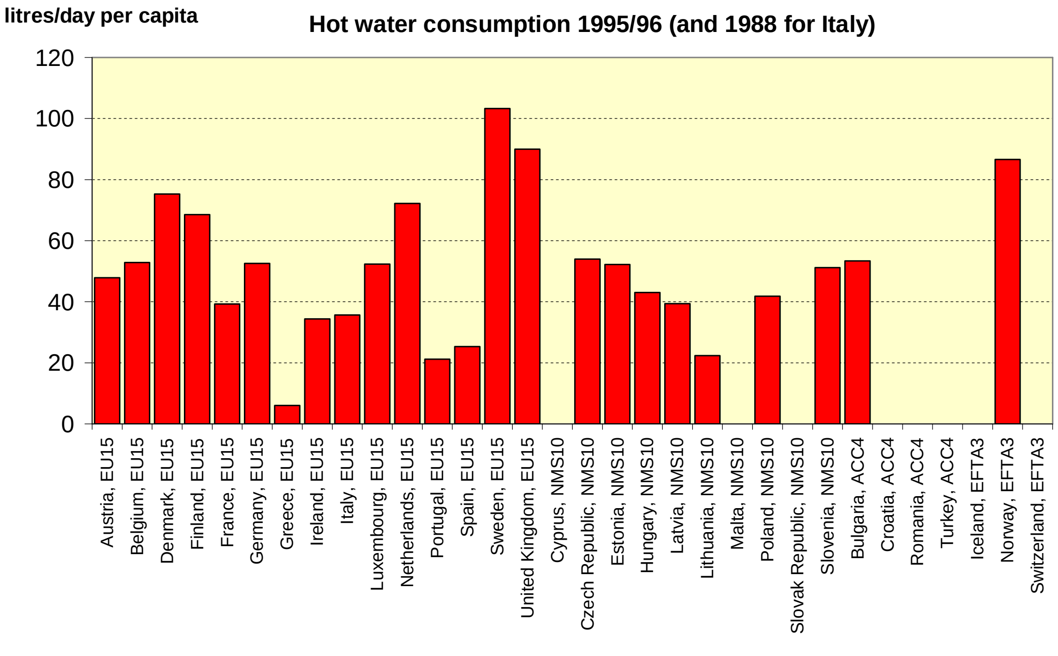

Figure 5. Example of estimated hot water consumption in some European countries. The hot water consumption has been estimated by assuming a temperature increase of 50ºC. Source: Ecoheatcool Work Package 1.

Aronsson, S (1996), has measured the domestic hot water consumption in 50 buildings, both single-family houses and multi-family buildings. According to the report, the annual DHW load is about 30 kWh/m^2. A more recent report by the Swedish Energy Agency[7] presents measured domestic hot water consumption from 44 dwellings, of which 35 one- and two-family buildings and 9 apartments (Figure 6). The average annual DHW load was a little less than 1000 kWh per resident.

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[7] Energimyndigheten 2009, Mätning av kall- och varmvattenanvändning i 44 hushåll, Delrapport i Energimyndighetens projekt Förbättrad energistatistik i bebyggelsen och industrin (ER 2009:26)

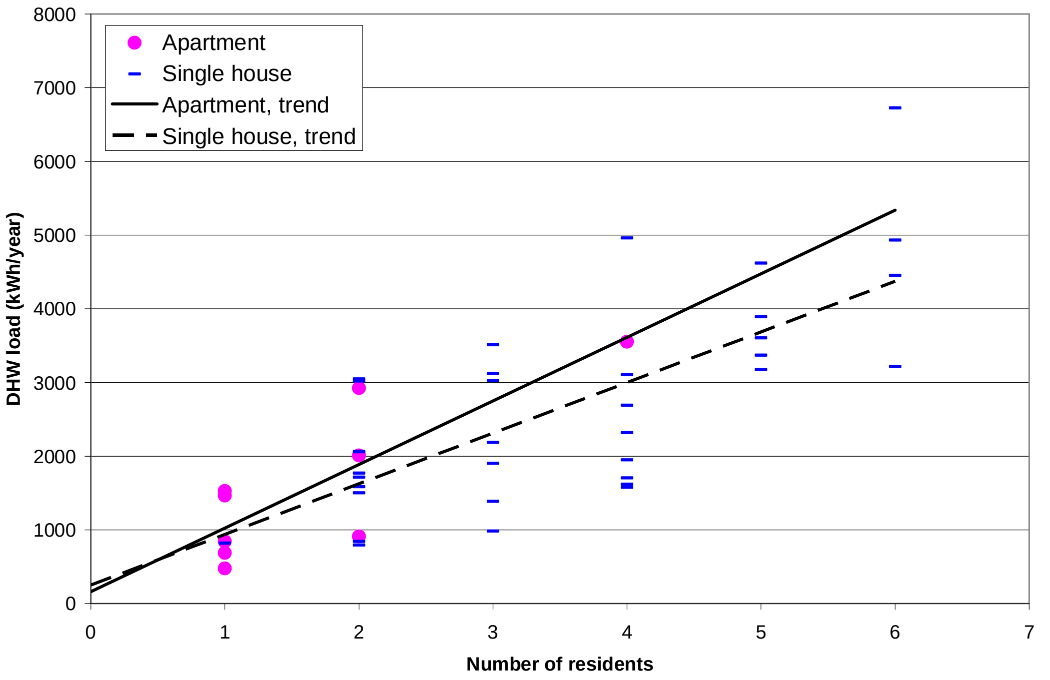

Figure 6. Measured hot water consumption in 44 Swedish dwellings. The X-axis represents number of inhabitants in each dwelling and the Y-axis represents the annual DHW load for the dwelling. The hot water consumption has been calculated by using monitored temperature increases for each dwelling (34°C-55°C) Source: Swedish Energy Agency (ER 2009:26).

2.3 Load examples from different countries

The load examples described in this segment are provided with the help of measured data from a boiler house or district heating substation. The consumption of DHW is included in the total load, and, for larger schemes, also distribution heat losses. The examples are representative for the areas and the building types they stand for, but are not necessarily the average or norm for that type of load.

Figure 7 shows the load duration for a residential area in the London area for the year 2010. The area serves around 3000 older purpose built flats plus a few non-domestic buildings. The data used for the graph are daily average values for the heat demand at boiler plant, which means that distribution losses are included in the heat demand. As data for a complete year was not available, missing values have been estimated. Nevertheless, provides a good example for a large residential led scheme in the UK. Figure 8 displays the monthly heat demand for the area the same year. The outdoor temperature fro London 2010 is included in the figure, for reference (source; Wunderground.com). It’s evident that the heat consumption for this area goes up significantly when the outdoor temperature goes below 5°C and even below 0°C.

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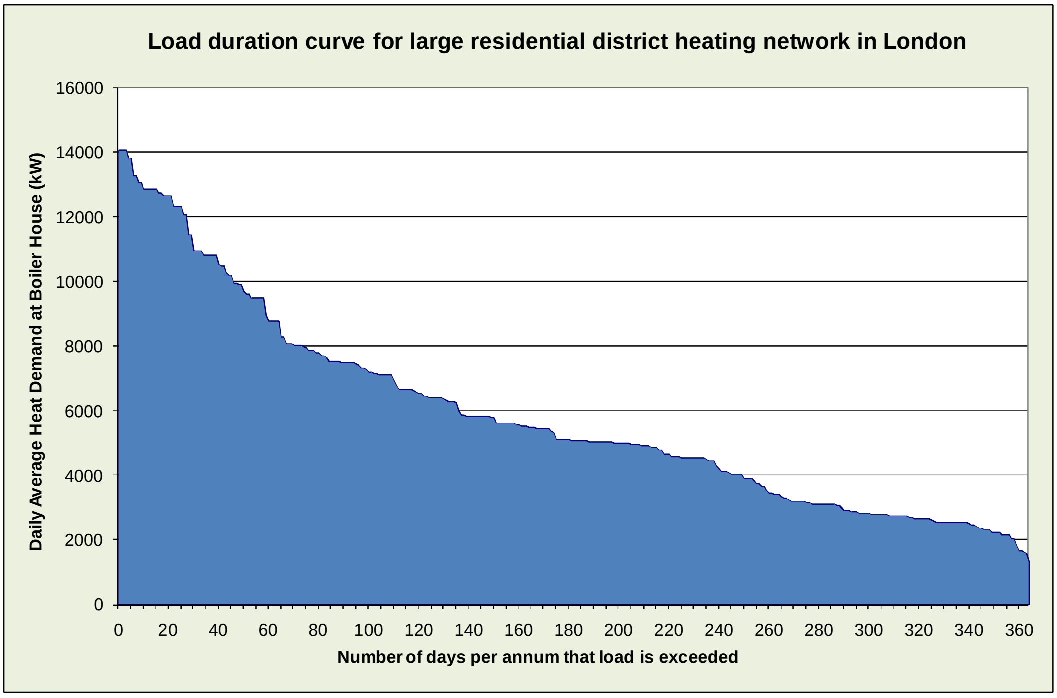

Figure 7. Load duration curve for a residential area in London. Net losses are included in the measured data.

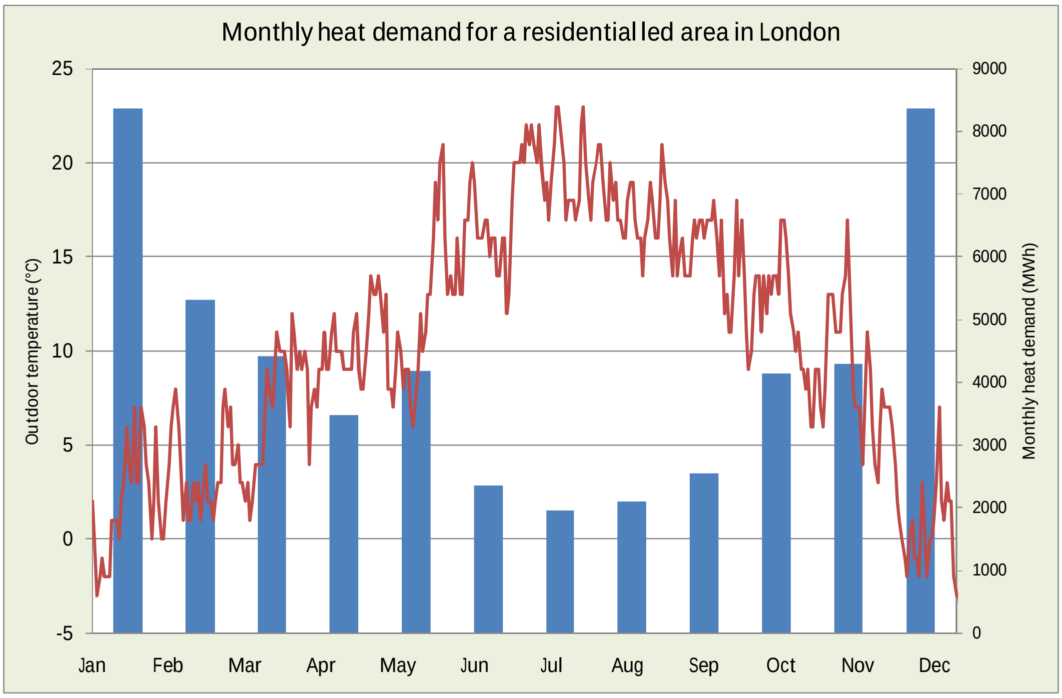

Figure 8. Monthly heat demand 2010 for a residential area in London. Net losses are included in the measured data.

The load duration curve for specific heat loads (W/m^2) for a modern detached house (built in 2005) in the Helsinki area, Finland, is found in Figure 9. The graph is made with daily average values for the heat load for the year 2006. Figure 10 shows the corresponding graph for a block of flats in the same area, built the same year (about 20 apartments). The specific monthly heat consumption for the block of flats is substantially higher than for the detached house, which can have a number of explanations. DHW is included in this consumption, and there are more residents per m^2 in the flats than in the detached house. Some of the flats are constructed as row houses, with a secondary heat distribution system, where the heat losses from that system are included in the total heat load. Furthermore, studies have shown that identical built houses can greatly vary in energy consumption, depending on the residents' habits.

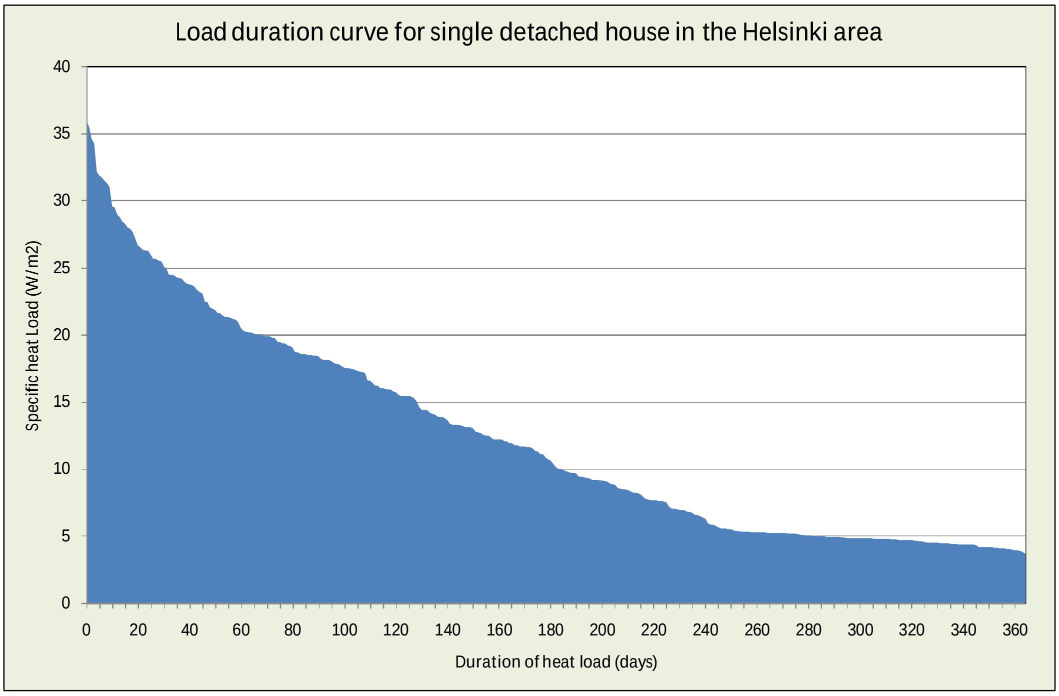

Figure 9. Load duration curve for a single detached house in the Helsinki area, Finland.

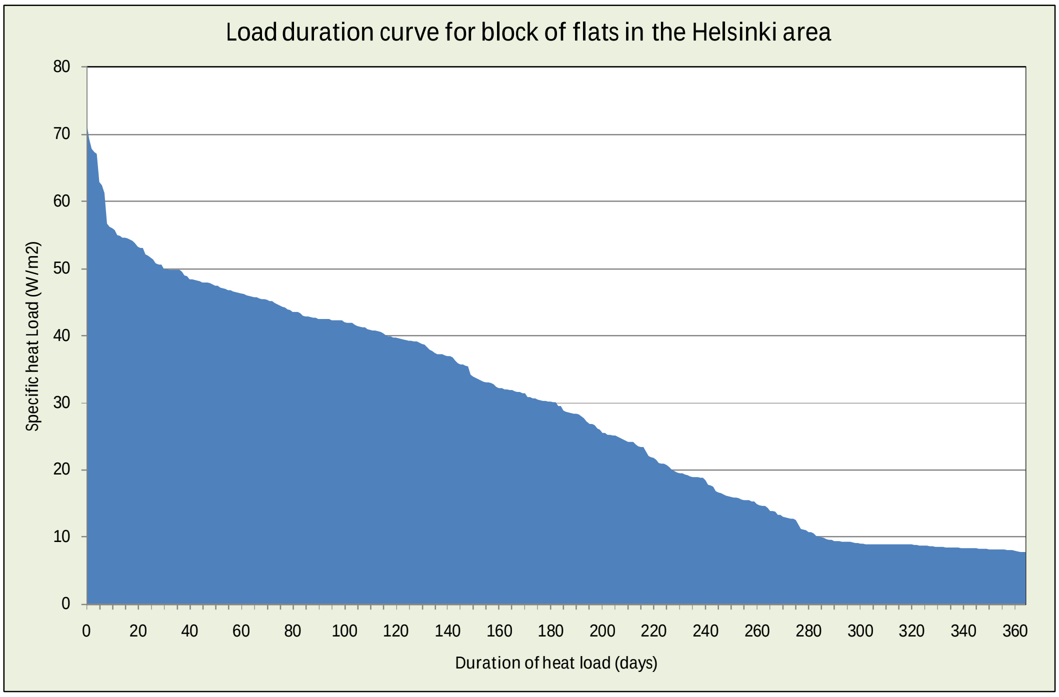

Figure 10. Load duration curve for a block of flats in the Helsinki area, Finland.

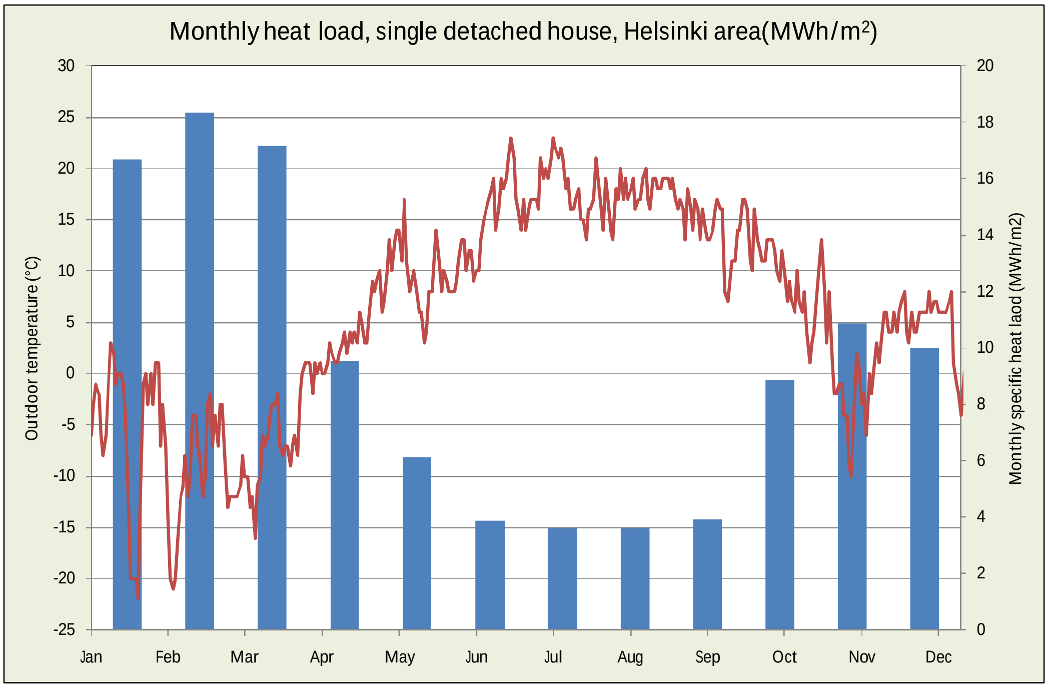

Figure 11. Monthly heat loads 2006 for a single detached in the Helsinki area, Finland.

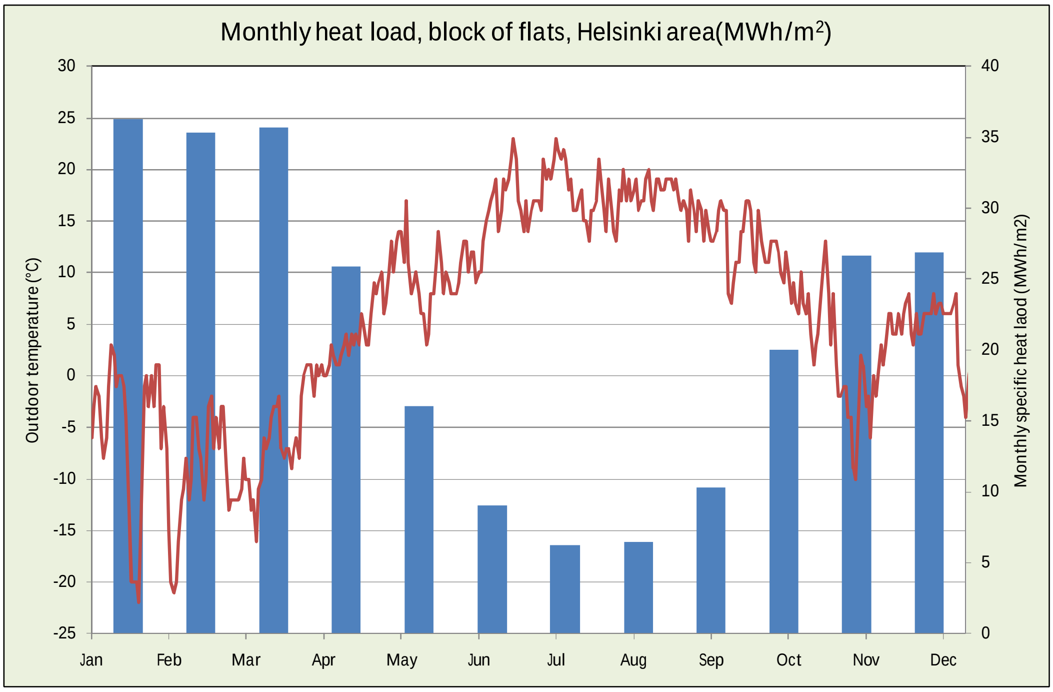

Figure 12. Monthly heat loads 2006 for a block of flats in the Helsinki area, Finland.

Figure 13 shows the load duration curve for an older purpose built apartment building (17 flats) that also contains a few smaller non-domestic premises. The building has a total area of about 1000 m^2. Monthly heat consumption is displayed in Figure 14, together with the outdoor temperature for the same period. The load duration curve resembles the curve in Figure 10; load duration for a block of flats in Finland, although the summer load in this example is lower.

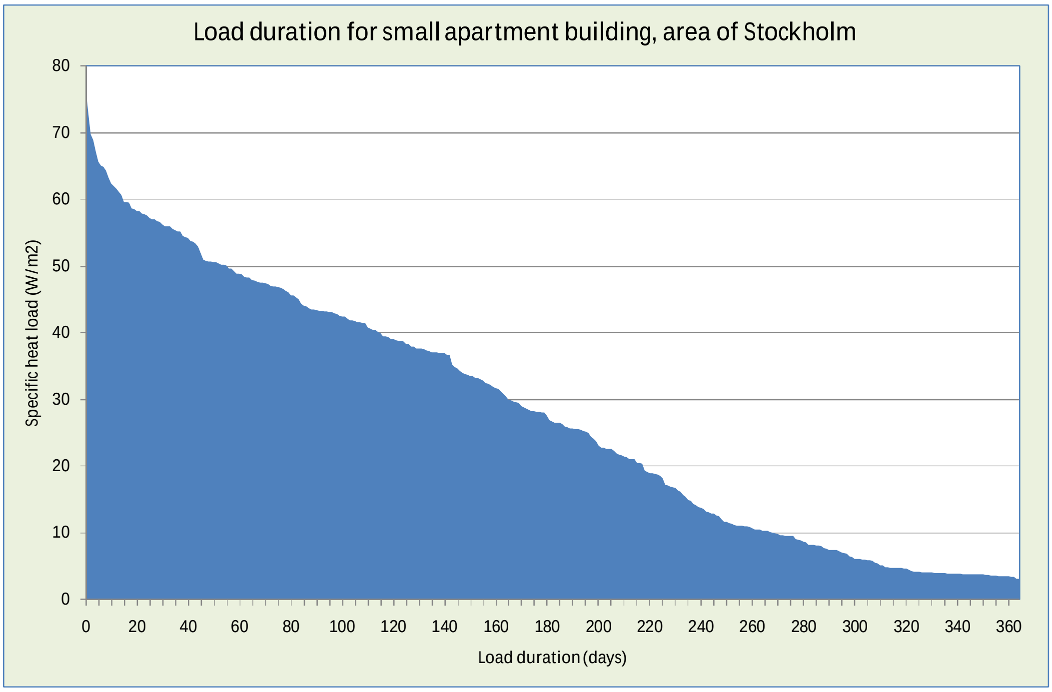

Figure 13. Load duration 2010 for a small apartment building in the Stockholm area, Sweden.

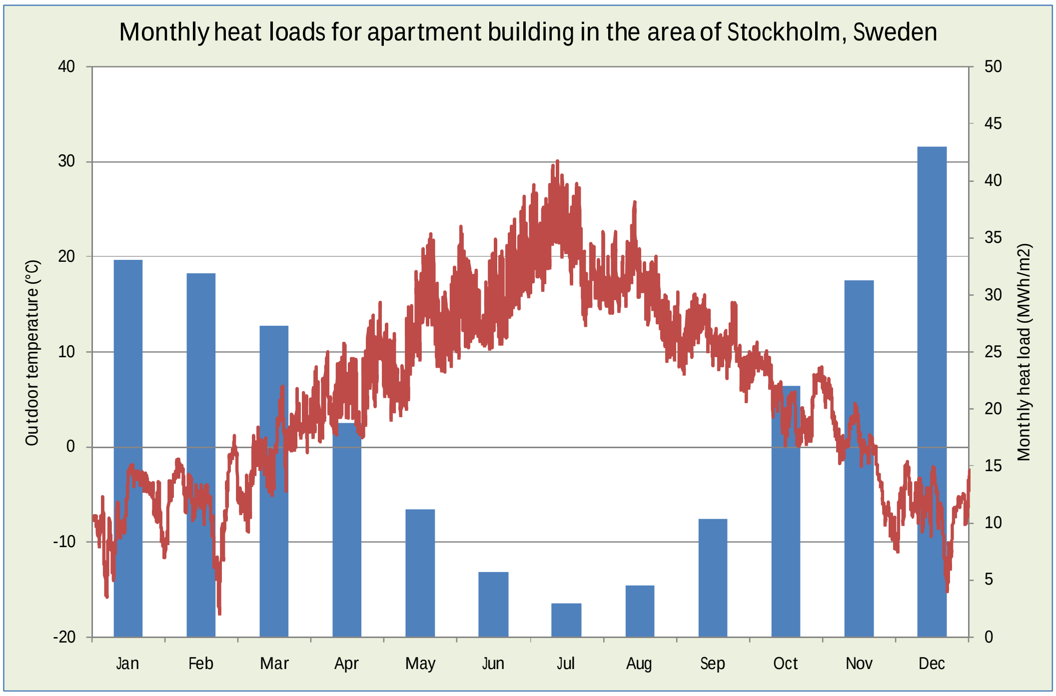

Figure 14. Monthly heat loads 2010 for a small apartment building in the Stockholm area, Sweden.

2.4 Load scenarios for this study

2.4.1 Definition of building types

In Scandinavia, the UK and other European countries, many existing buildings are quite old. In Sweden, for example, over 40% of buildings that are in use today are built before 1960. Future buildings will either be built according to standard regulations or with even better quality. Low energy houses and passive houses are becoming increasingly popular. There are also cases of existing buildings being retrofitted to a low energy standard. Gradually converting to low-energy systems will lead to a continuous change of loads.

For each building type some defining characteristics must be set in order to determine the heating load;

- Dimensioning outdoor temperature (same for all buildings in an area)[8]
- Balance temperature (varies according to building type)
- Indoor temperature (varies according to building type)
- Dimensioning heat load (W/m^2)
- Annual heat use (kWh/m^2)

For non-domestic premises special consideration will have to be taken. Figure 15 demonstrates that the average heat load for the newer premises is lower than for the older, but the difference is less than for residential buildings.

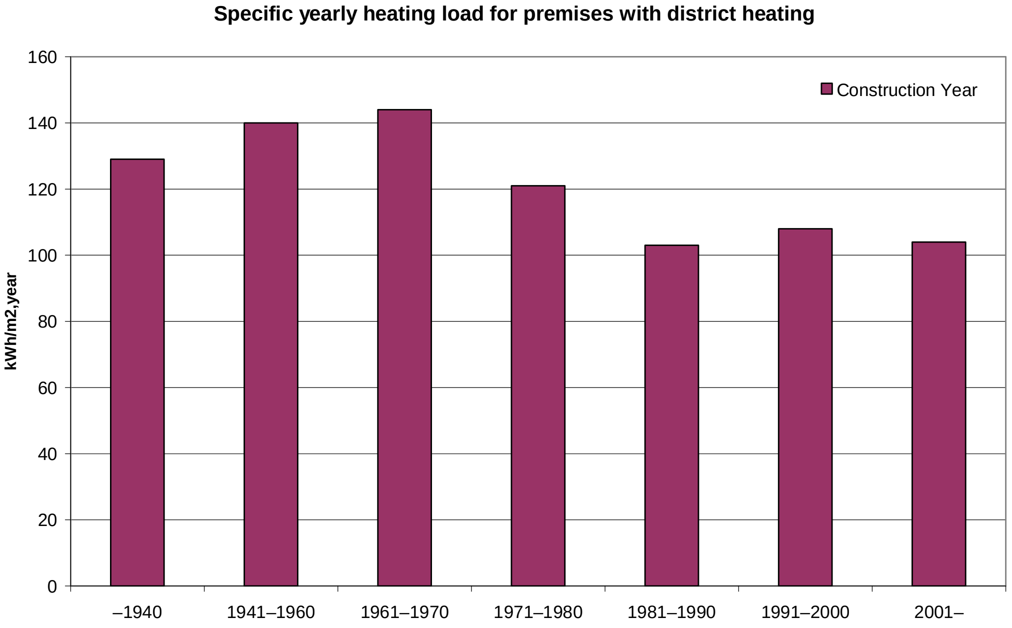

Figure 15. Yearly district heat load 2001-2007 (both heating and DHW) for premises in Sweden depending on their construction year. Source: SCB (Statistics Sweden)

Four overall building types for residential use are defined for the purposes of this report; existing building, new building, low energy building and passive house. For non-domestic buildings one or two types per geographic area is also included (see Figure 16, Figure 17 and Table 1).

Table 1. Dimensioning heat load and yearly heat demand for different building types in Sweden and UK, respectively

Building type, Sweden	**Heat load kW**	**Heat loss coefficient W/°C*m^2**	**Yearly heat demand kWh/m^2,a**
Existing building; estimated average of existing buildings connected to DH net	60	1.82	140
New building; built according to today's building regulations[9].	35	1.13	80
Low energy building; half the heat demand defined in today's building regulations[3].	20	0.69	55
Passive building; built according to Passive House standards	10	0.38	15
Non-domestic building, Existing	85	3.70	120
Non-domestic building, Low Energy	25	1.74	40

Building type, UK	**Heat load kW**	**Heat loss coefficient W/°C*m^2**	**Yearly heat demand kWh/m^2,a**
Existing building; estimated average of existing buildings connected to DH net	50	3.03	140
New building; built according to today's building regulations	25	1.79	45
Low energy building.	15	1.20	25
Passive building; built according to Passive House standards	10	0.91	15
Non-domestic building	30	-	80

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[8] The praxis is to use the same dimensioning outdoor temperature for a specified geographic area, i.e. a city. Some studies have argued that for a building with higher building density the dimensioning outdoor temperature should be higher than for a lighter building. This is not taken into account in this report, however.

[9] Swedish building regulations, National Board of Housing, Building and Planning (Boverkets byggregler, BBR)

For the purpose of this report, building area is defined as all area enclosed by insulated walls; i.e. common rooms, staircases and elevators within apartment buildings, but not cold storage spaces, glazed balconies or unheated garages.

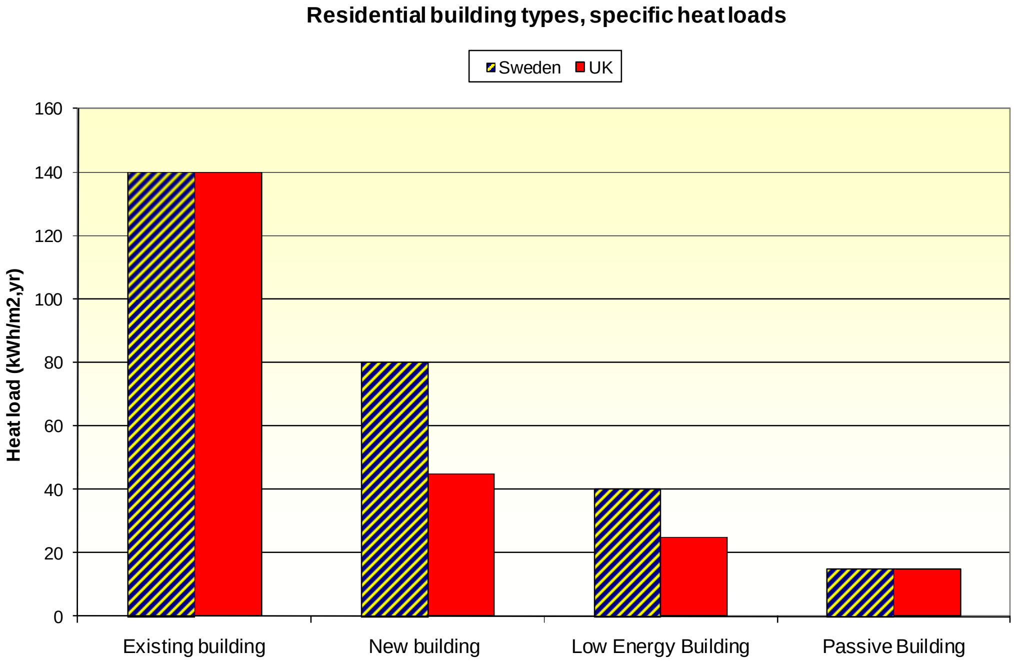

Figure 16. Four residential building types that have been used as heat loads in the load profile simulations.

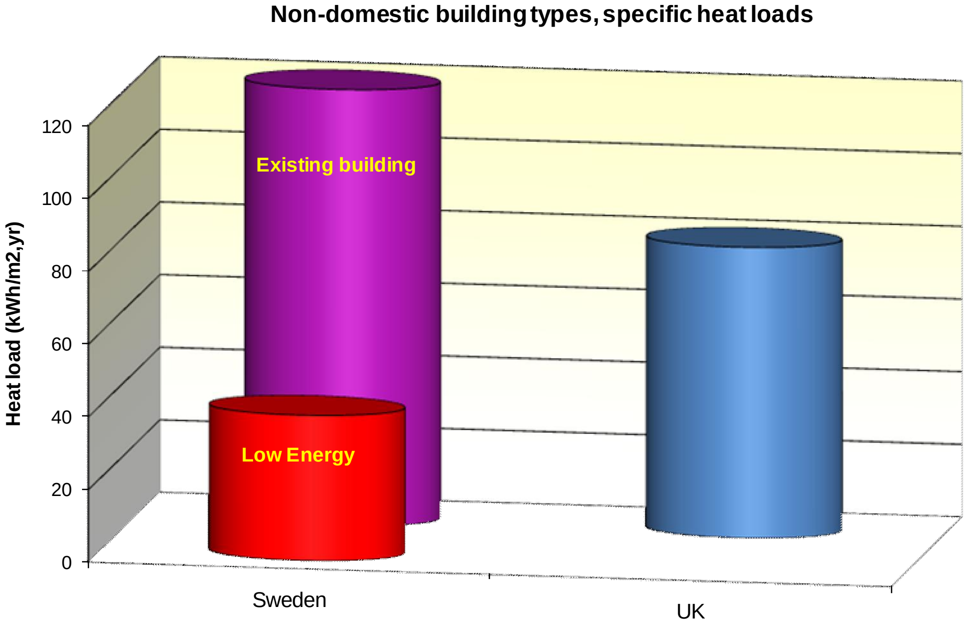

Figure 17. Non-domestic building types that have been used as heat loads in the load profile simulations.

In order to calculate load profiles there is also a need of climate data input for the geographic area that is simulated. In this report, temperature data from Stockholm will represent Scandinavian climate and temperature data from London will represent British Isles climate. For Stockholm, temperature data from 2006 have been used. This year is considered to be close to a standard year. For London, temperature data from different years have been assembled to form a test reference year (TRY).

For each building type used in the different district heating areas described later in this chapter, a load profile has been calculated. Figure 18 and Figure 19 displays the individual load profiles for the building types defined in Table 1. Combining the individual building profiles will then result in a load profile for the whole distribution net. For reference, these load profiles correspond[10] with load profiles for Hamnhuset, Gothenburg (see Figure 20).

For the Swedish case, a dimensioning temperature of -15°C was chosen, which corresponds to the climate in the middle of Sweden. For UK, the dimensioning temperature is -1°, which is a reasonable value for southeast of England. For the Swedish case; the dimensioning temperature is not achieved during the test reference year (TRY). In UK, the dimensioning temperature is transcended during the TRY. This indicates different dimensioning strategies for the two countries.

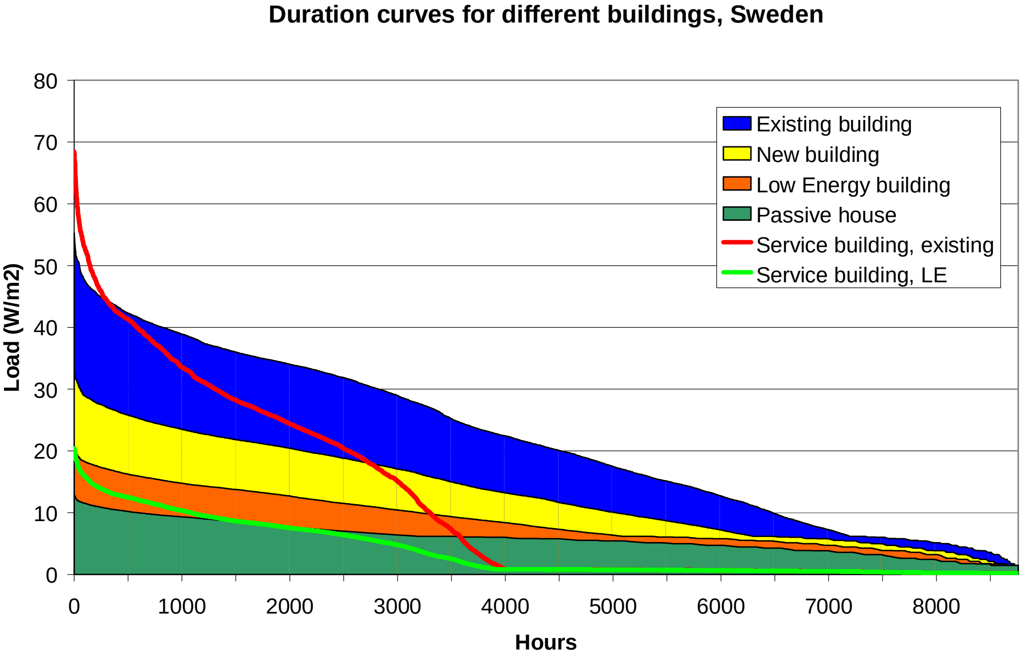

Figure 18. Duration curves for the heat load (space heating and DHW) in Sweden for the building types in this study.

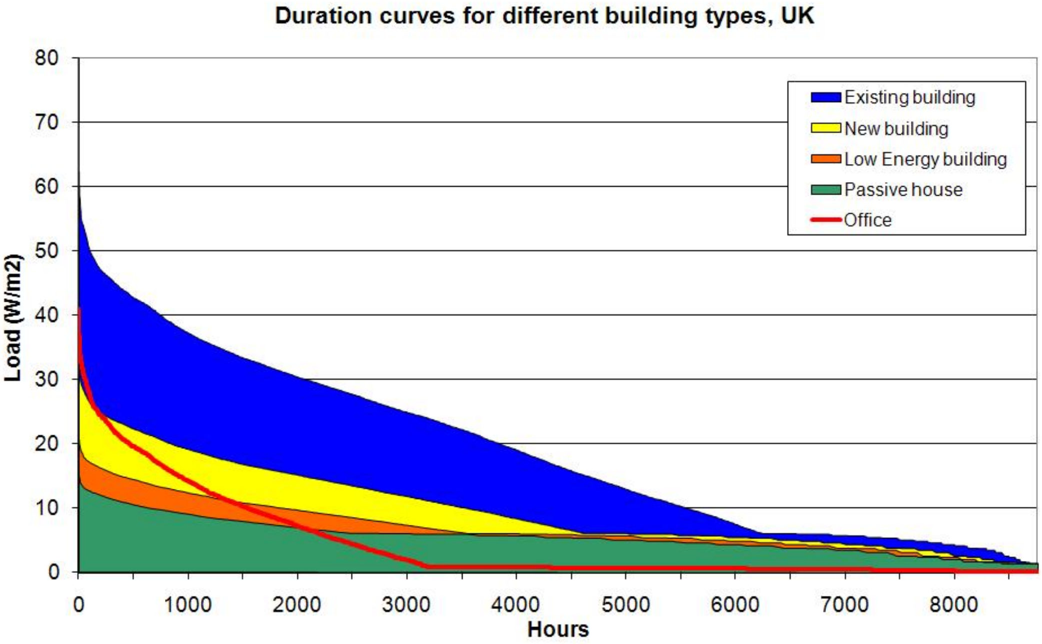

Figure 19. Duration curves for the heat load (space heating and DHW) in UK for the building types in this study.

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[10] No data for Hamnhuset has been used in our calculations, however.

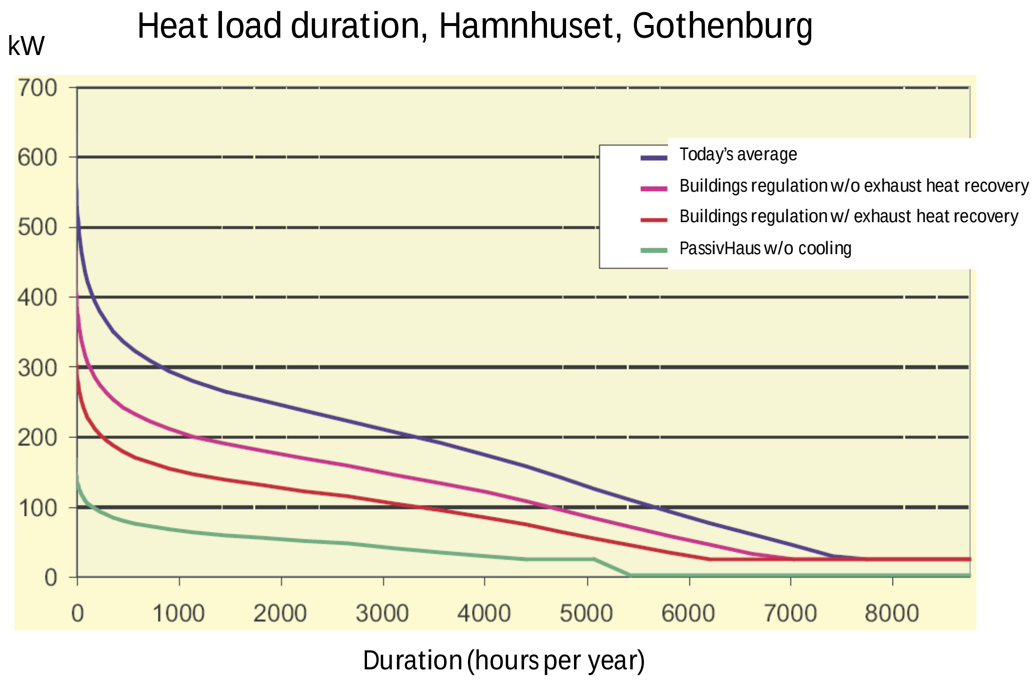

Figure 20. Heat load durability for different house standards, applied to Hamnhuset in Gothenburg (today's average on top, passive house without or with cooling at bottom). Area: 15021 m^2. Werner, S, Fröling, M, et al (2007)

2.4.2 *Different types of areas for load simulation*

TCPA[11] & CHPA[12] in UK has published the report "Community Energy: Urban Planning for a Low Carbon Future" (Dodd 2008). The report identifies seven *Character Areas* with different opportunities for renewable energy and/or CHP. Five of those *Character Areas* would be sustainable for district heating and are used as bases for the type areas in this study:

City Centre	With their mix of uses town and city centres create the most significant opportunity for the large-scale deployment of Combined Heat and Power (CHP).
Inner City Districts	The improvement, remodelling and selective demolition of properties to achieve Housing Market Renewal, investment in new mixed tenure housing and programmes to deliver improved community facilities create a range of opportunities from the communal scale to individual buildings.
Edge of Centre	The heat densities of university and hospital sites, as well as new residential and mixed use developments will support CHP/district heating, with the potential to be supplemented and complemented by other communally deployed renewable technologies, such as solar thermal collectors.
Suburban Districts	The low density of suburbs makes them more challenging for DH. For suburbs with very low heat density micro generation technologies or renewable energy schemes may be deployed instead.
Urban Extensions	Large new urban extensions and settlements provide some of the best opportunities in the UK for putting the principles of low carbon, decentralised energy generation into practice

For these character areas typical load profiles are defined, based on an average distribution of different buildings in a DH net (Figure 1 and Figure 49). Calculations/ simulations on these areas are then performed in order to predict how the load profile will change over the next 20-30 years. *City Centre*, *Edge of Centre* and *Inner City Districts* are combined to represent a larger city area with over 100 000 inhabitants.

The build-up of DH consumers in Sweden (Figure 21) has served as a starting point for the area building mixes. The configuration of the areas has been adjusted to suit the character of each area.

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[11] The Town and Country Planning Association (www.tcpa.org.uk)

[12] The Combined Heat and Power Association (www.chpa.co.uk)

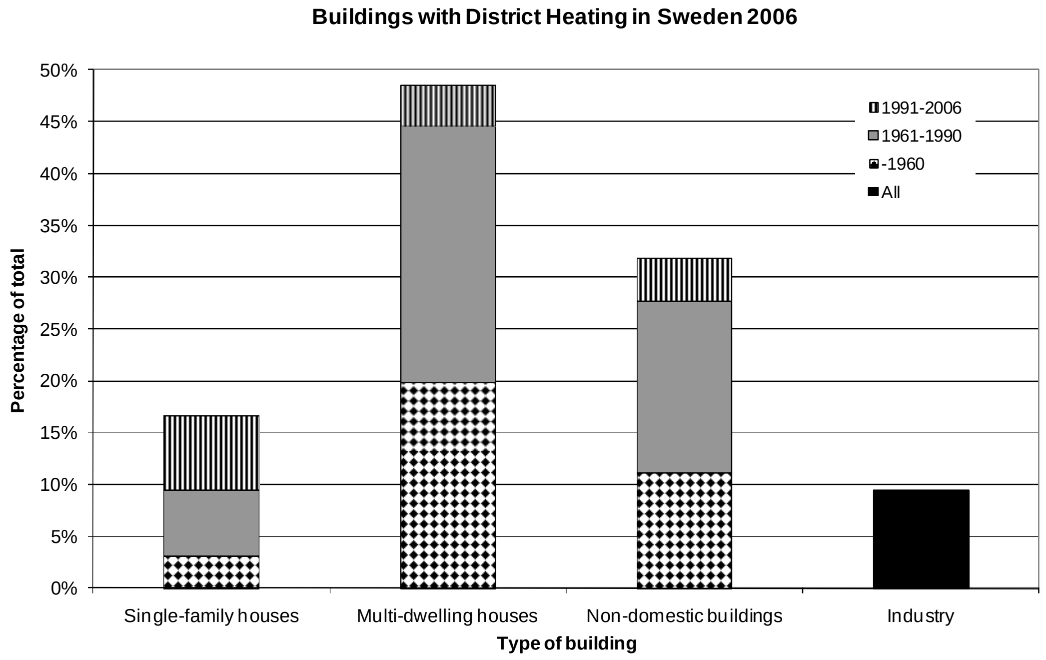


Figure 21. Distribution of the DH load that different customer categories have. Residential and non-domestic buildings are in turn divided into construction years. For industries that data is not available. Source: SCB (Statistics Sweden)

Table 2. Building mix for three district heating type areas. The mix represents existing area build-up.

Suburban district
Single-family houses mixed with multi-family dwellings. Some schools, nursing homes and/or commercial buildings

Building mix (percentage of heat load)

Building type	**Single-family houses**	**Multi-dwelling houses**	**Service buildings**
Existing	17,5%	58,2%	21,1%
New	0,5%	1,8%	0,9%
Total	18,0%	60,0%	22,0%

City Centre, Edge of Centre and Inner City Districts
Office buildings, shops (high heat density), restaurants, hotels, some apartment buildings
100 000 Inhabitants

Building mix (percentage of heat load)

Building type	**Single-family houses**	**Multi-dwelling houses**	**Service buildings**
Existing	6,3%	55,8%	34,6%
New	0,2%	1,7%	1,4%
Total	6,5%	57,5%	36,0%

Urban Extension
New developments; low energy housing where DH may or may not be
included in early stages of planning
1000 Inhabitants

Building mix (percentage of heat load)

Building type	**Single-family houses**	**Multi-dwelling houses**	**Service buildings**
Low Energy	8,0%	46,0%	36,0%
Passive		10,0%	

In 20 years time, the areas are assumed to have expanded somewhat, while, at the same time, some of the buildings have been retrofitted or replaced. New construction and retrofitting is assumed to keep about the same pace as in previous years (Figure 22). Expected changes in the building sector is 0.25 – 0.5 % new construction per year and 1 – 3 % renovation per year. The same pace is assumed for both Sweden and UK. Based on these figures, the areas will in 20 years time have a building mix according to Table 3.

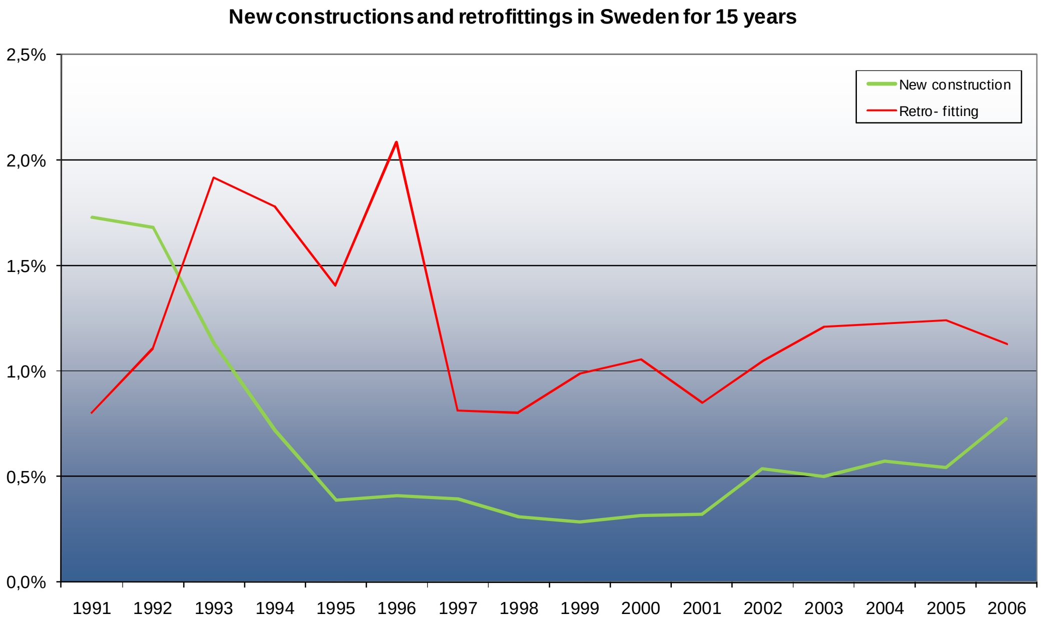
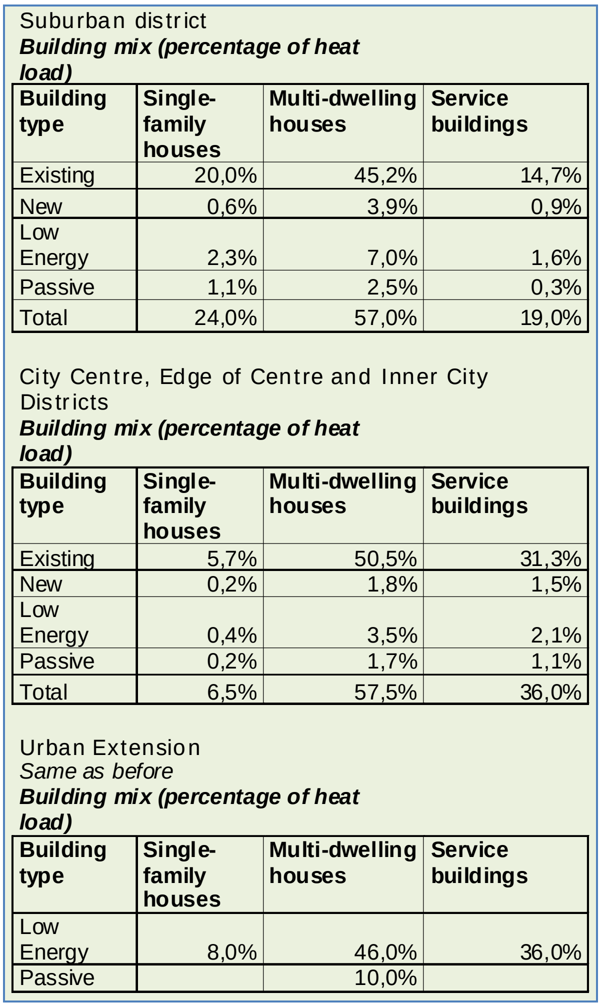


Figure 22.Percentage of the total building stock in Sweden that are retrofitted and built new, respectively for the years 1991 to 2006 Source; Statistiska Centralbyrån, SCB (Statistics Sweden)

Table 3. Building mix after 20 years for the three type areas



Suburban district

Building mix (percentage of heat load)

Building type	**Single-family houses**	**Multi-dwelling houses**	**Service buildings**
Existing	20,0%	45,2%	14,7%
New	0,6%	3,9%	0,9%
Low Energy	2,3%	7,0%	1,6%
Passive	1,1%	2,5%	0,3%
Total	24,0%	57,0%	19,0%

City Centre, Edge of Centre and Inner City Districts

Building mix (percentage of heat load)

Building type	**Single-family houses**	**Multi-dwelling houses**	**Service buildings**
Existing	5,7%	50,5%	31,3%
New	0,2%	1,8%	1,5%
Low Energy	0,4%	3,5%	2,1%
Passive	0,2%	1,7%	1,1%
Total	6,5%	57,5%	36,0%

Urban Extension

Same as before

Building mix (percentage of heat load)

Building type	**Single-family houses**	**Multi-dwelling houses**	**Service buildings**
Low Energy	8,0%	46,0%	36,0%
Passive		10,0%	

2.4.3 Suburban area

The suburban area is the home of approx. 1000 people. They live in single-family or multi-family houses. There are also a couple of non-domestic facilities in the area. An average of 75 inhabitants per multi-family house and 2.5 inhabitants per single-family house is assumed. The build-up of the area is shown in Figure 23. It consists mainly of existing buildings with a few new buildings, built according to today’s building regulations. In twenty years time, some buildings are assumed to have been retrofitted and others to have been replaced. There are also some new buildings in the area. All retrofitted and new buildings are abiding the EU energy efficiency guidelines. The area will still have a major part of the existing buildings connected to the distribution net, but there will be a larger portion of new buildings, as well as low energy buildings and passive houses (Figure 24).

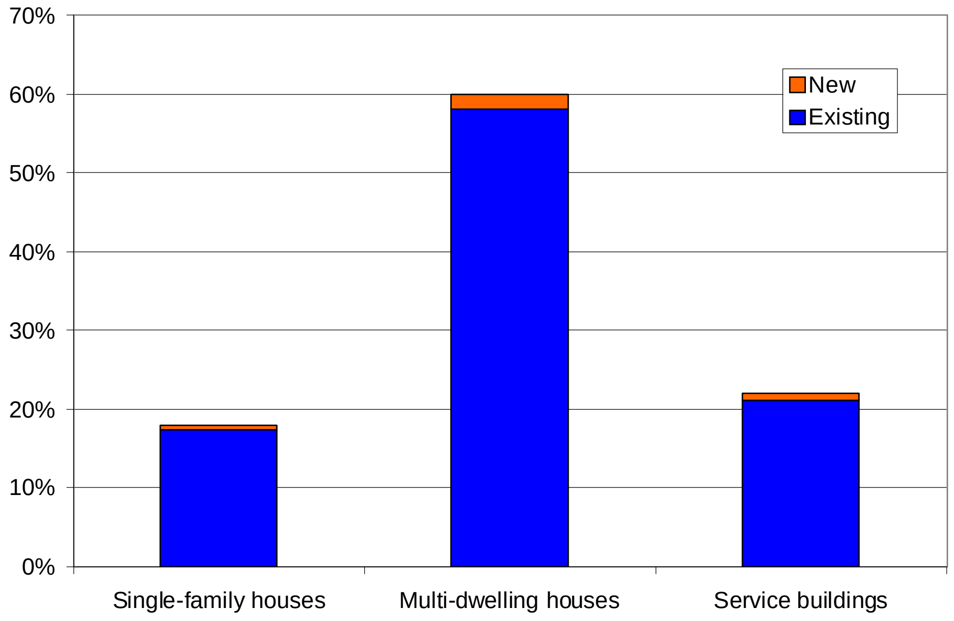


Figure 23. Build-up of the suburban area district heating system, year 0. The graph shows each building type’s share of the total heating load.

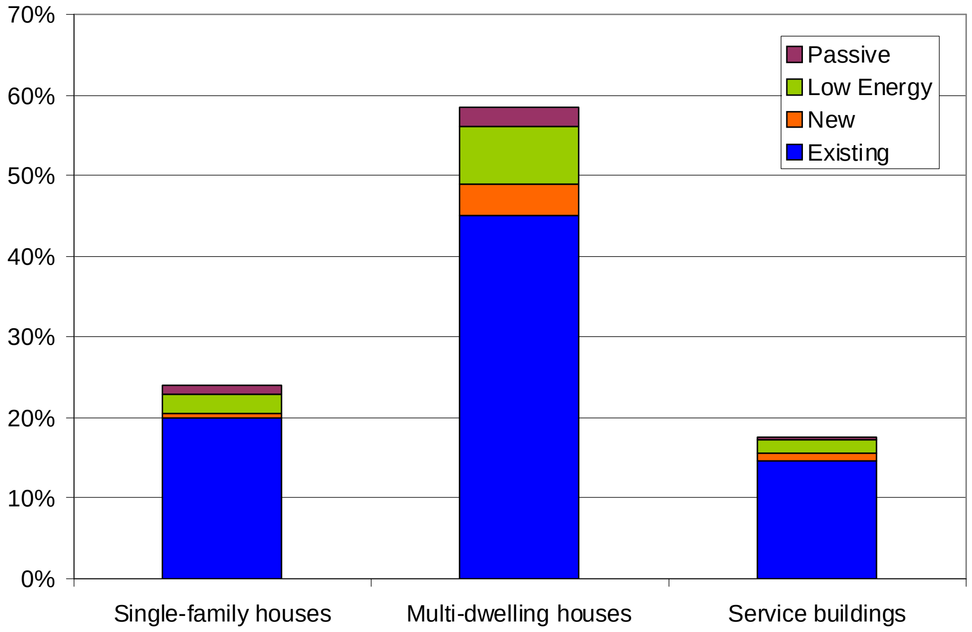


Figure 24. Build-up of the suburban area district heating system, year 20. The graph shows each building type’s share of the total heating load.

2.4.3.1 Distribution net

For each building, an average service pipe length of 15 m and an average distribution pipe length[13] of 25 m is assumed. As most existing district heating nets are over-sized, the dimensions are assumed to be larger than what is necessary for the installed load. A heat loss factor is also added to account for

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[13] Equals the buildings ”share” in the distribution net.

bypass and auxiliary losses. Yearly average heat loss for year 0 (suburb) is calculated to 9%, which would be considered a rather effective distribution net.

For year 20, the net is assumed to have been kept in shape, i.e. specific heat losses are maintained. Buildings connected during the period are assumed to have service and distribution pipes of small dimensions. Heat losses for these pipes are added to the overall heat loss calculation.

Table 4. Pipe lengths and dimensions for Suburb area, year 0 and pipe added to network year 20.

Dim	Distribution pipe	Service pipe	Type	Material
DN25	25 m	1095 m	Twin	Steel
DN32	50 m		Twin	Steel
DN40	75 m		Twin	Steel
DN50	50 m	180 m	Twin	Steel
DN65	125 m	30 m	Twin	Steel
DN80	275 m		Twin	Steel
DN100	460 m		Single	Steel
DN125	560 m		Single	Steel
DN150	200 m		Single	Steel
DN200	183 m		Single	Steel
DN300	175 m		Single	Concrete (old)
Total	2178 m	1305 m		

Pipe added by year 20

Dim	Distribution pipe	Service pipe	Type	Material
DN20		300 m	Twin	Steel
DN25	600 m		Twin	Steel
DN40	300 m			
DN65	250 m			
Total	3328 m	1605 m		

The distribution of different house types in the suburb area starting year and after 20 years is presented in Table 5.

Table 5. Number of houses and total floor area of the buildings in the suburb areas.

	Building type	Average Heat Load per Building	Number of Houses			
			Existing	New	LE	Passive
Sweden	**Multi-dwelling**	203,4 kW	11	1		
Suburb	**Single**	9,5 kW	71	2		
Year 0	**Service building**	333,6 kW	2			
	Total area		57129 m2	3754 m2	-	-
Sweden	**Multi-dwelling**	181,4 kW	6	1	3	2
Suburb	**Single**	8,5 kW	54	3	18	18
Year 20	**Service building**	280,9 kW	1	0	1	0
	Total area		33241 m2	3914 m2	17181 m2	9747 m2
UK	**Multi-dwelling**	169,1 kW	10	1		
Suburb	**Single**	7,9 kW	67	4		
Year 0	**Service building**	280,0 kW	2			
			53055 m2	4074 m2	-	-
UK	**Multi-dwelling**	149,7 kW	5	1	3	2
Suburb	**Single**	7,1 kW	54	3	20	15
Year 20	**Service building**	244,0 kW	1	0	1	0
			29808 m2	3914 m2	17501 m2	9267 m2

2.4.4 *City area*

The city area is the home of approximately 100 000 people. Most of them live in multi-family houses, although there are still some smaller houses in the district heating net. An average of 75 inhabitants per multi-family house and 2.5 inhabitants per single-family house is assumed. There are more non-domestic facilities in the city area than in the suburb. Most buildings are of the type “existing building”, but there are also some that are built according to today’s buildings regulations (Figure 43).

After 20 years, some buildings are assumed to have been retrofitted or replaced. There will also be some new buildings in the area. All retrofitted and new buildings will at least follow building regulations, and many will also be low energy or passive houses (Figure 26).

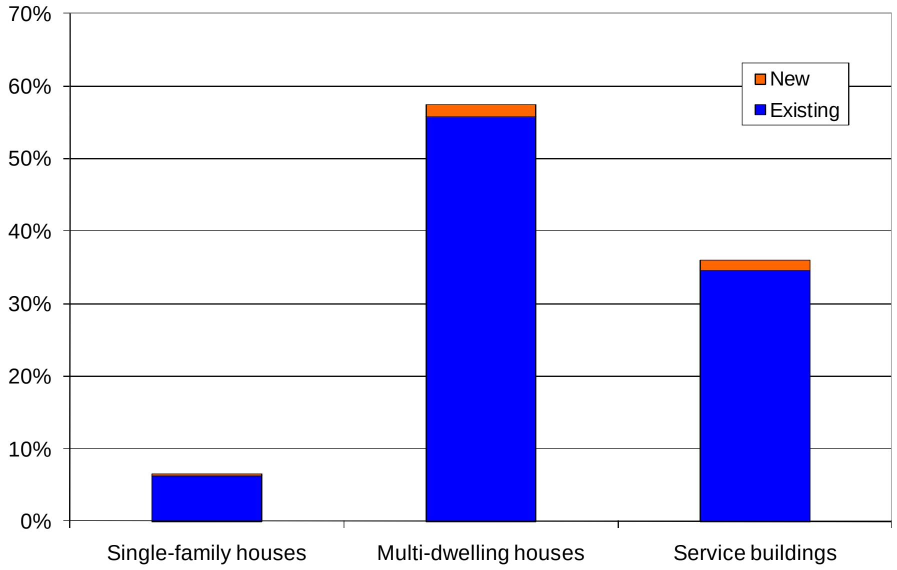

Figure 25. Build-up of the City area district heating system, year 0. The graph shows each building type’s share of the total heating load.

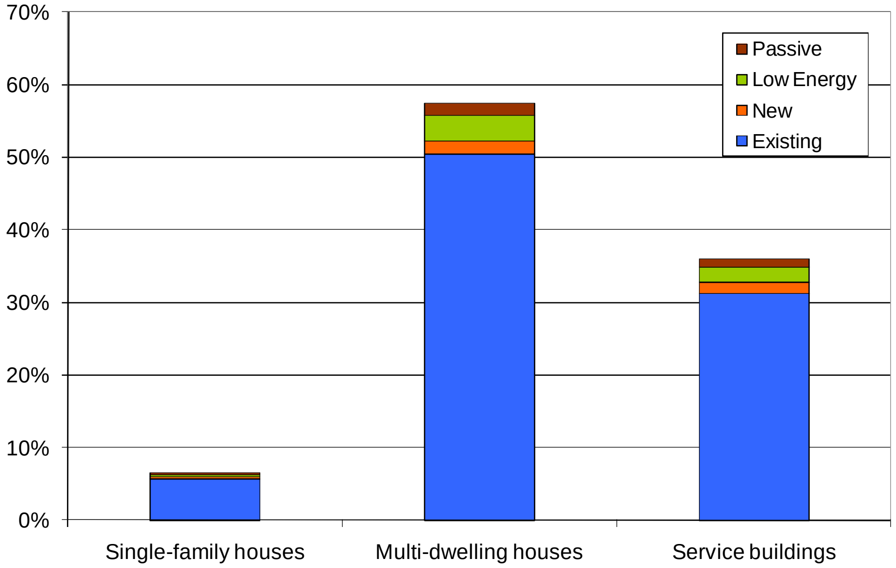

Figure 26. Build-up of the City area district heating system, year 20. The graph shows each building type’s share of the total heating load.

Table 6. Pipe lengths and dimensions for City area, year 0.

	Distribution pipe (m)	**Service pipe (m)**
DN20		
DN25	1250	35820
DN32	2500	
DN40	3750	
DN50	2500	14772
DN65	6250	5268
DN80	3750	
DN100	12500	
DN125	18000	
DN150	8760	
DN200	12400	
DN300	8750	
DN400	5300	
DN500	9500	
DN600	570	
DN700	1650	
DN800	2000	
DN900	600	
DN1000	8300	
Total	**108330**	**55860**

2.4.5 *Urban development area*

As in the suburban area, the urban development area is also the home of approximately 1000 people. They live in single-family or multi-family houses. An average of 75 inhabitants per multi-family house and 2.5 inhabitants per single-family house is assumed. There are also a couple of non-domestic facilities in the area. This urban development area is assumed to be a low energy area, with only low energy buildings or Passive House buildings (Figure 27). There will be some single family houses in the area connected to the district heating network, but mainly multi-family buildings and non-domestic buildings.

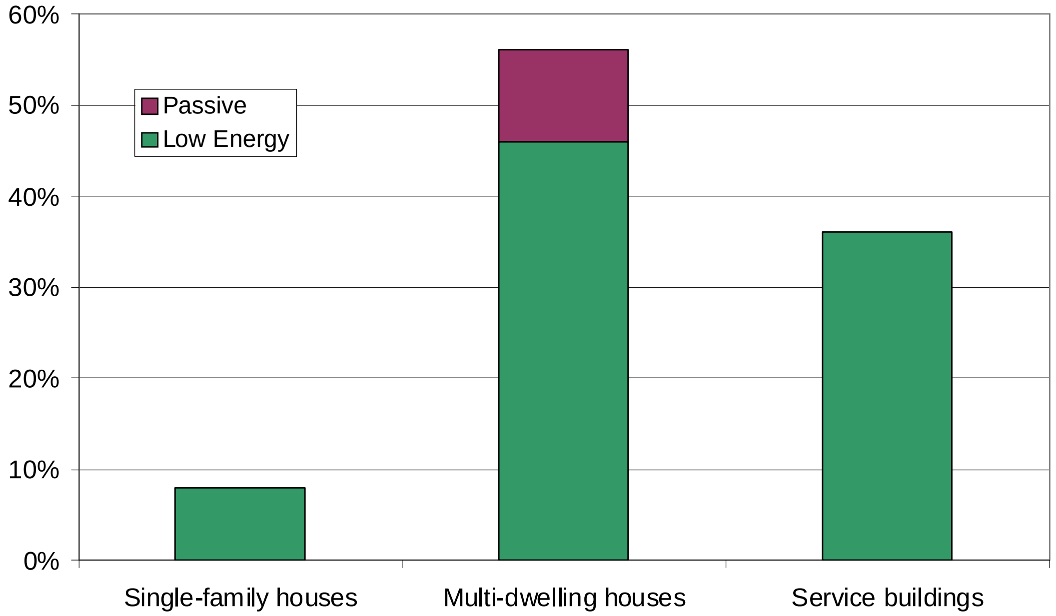

Figure 27. Build-up of the urban development area district heating system. The graph shows each building type's share of the total heating load.

2.4.5.1 Distribution net

The distribution of different house types in the urban development area is presented in Table 5. The area is assumed to stay more or less the same for the next 20 years. The average distribution pipe length per building is 20 m and the average service pipe length is 30 m, see Table 7.

Table 7. Pipe lengths and dimensions for urban development area

	Distribution pipe	Service pipe	Type	Material
DN20		640 m	Twin	Steel
DN25	100 m	80 m	Twin	Steel
DN32	85 m	280 m	Twin	Steel
DN40	175 m		Twin	Steel
DN50	155 m		Twin	Steel
DN65	285 m		Twin	Steel
DN80	300 m		Twin	Steel
DN100	400 m		Single	Steel
Total	1500 m	1000 m		

2.5 Heat load profiles

2.5.1 Suburb

Duration curves for Swedish suburb, starting year and after 20 years, are presented in Figure 28 and Figure 29. In Figure 30 the heat load duration before and after 20 years are presented in the same graph. The corresponding durations curves for UK are presented in Figure 31,
Figure 32 and Figure 33..

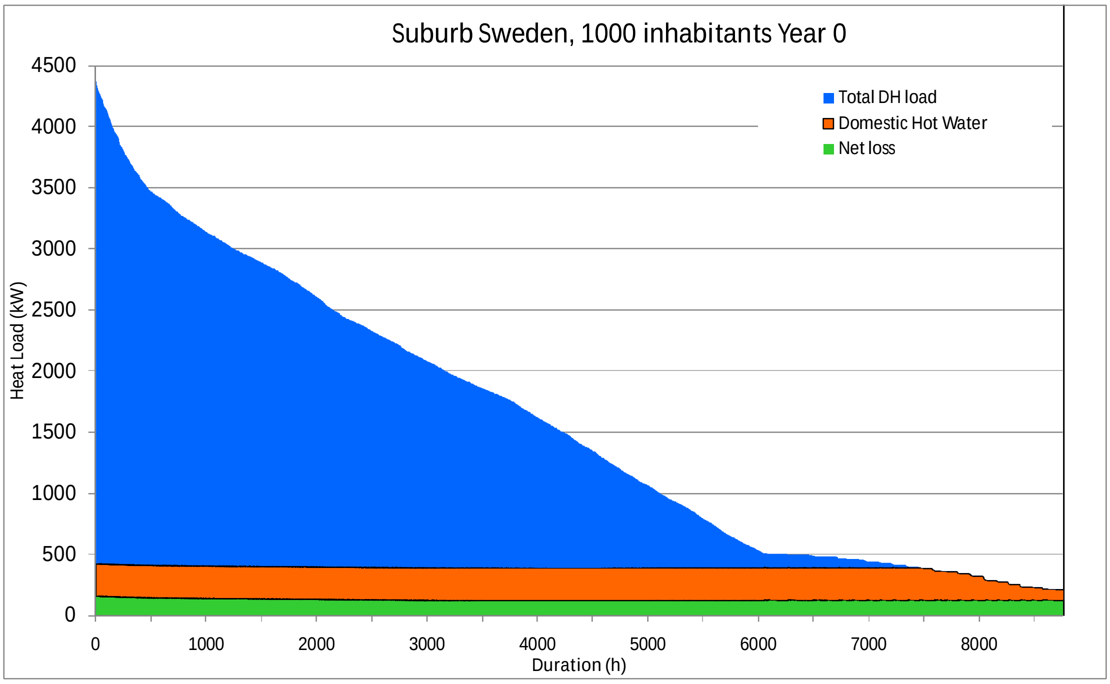

Figure 28. DH load for Swedish suburban area, year 0. DH load (incl losses): 13.8 GWh, Heat loss: 1.1 GWh (8.1%) DHW 16% of total load (2.19 GWh).

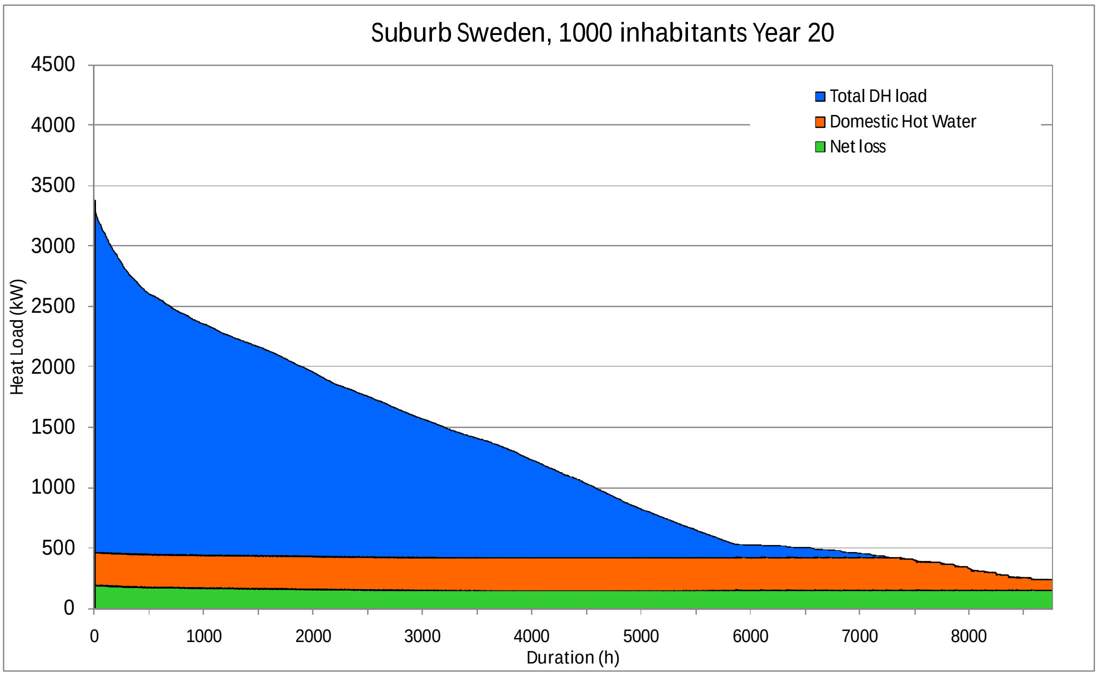

Figure 29. DH load for Swedish suburban area, year 20. DH load (incl. Losses): 10.8 GWh, Heat losses: 1.4 GWh (12.8%). DHW 21% of total load (2.31 GWh).

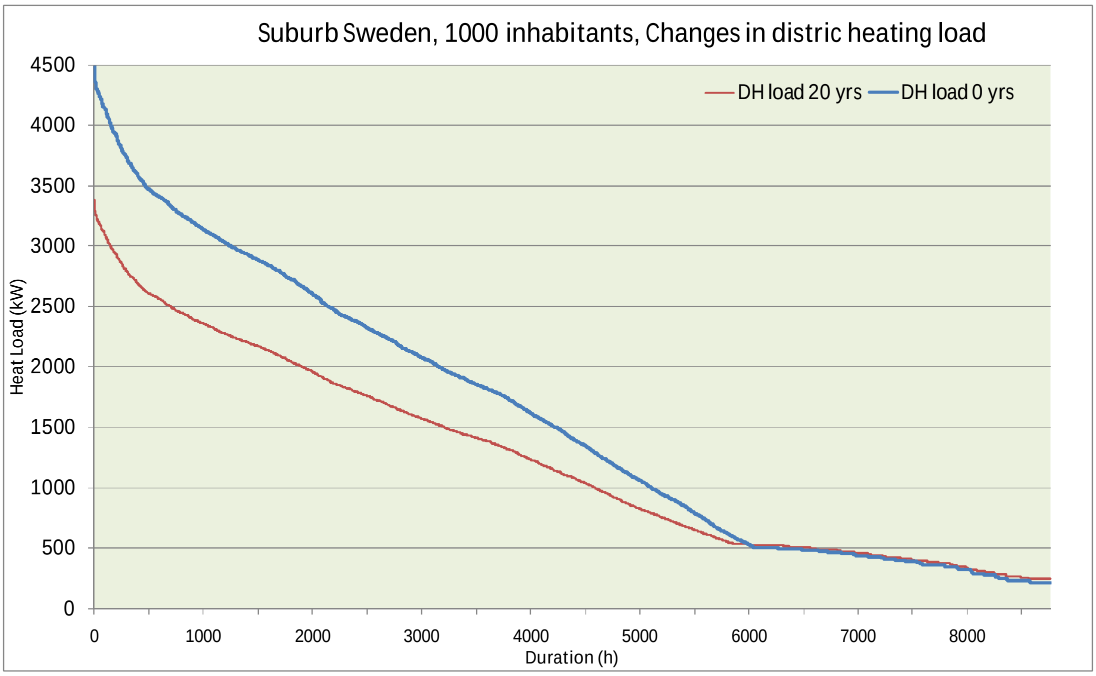

Figure 30. DH load for Swedish suburban area, year 0 and year 20, respectively. Reduction of DH load (excl losses); 26% (incl losses: 22%) Maximum heat load year 0: 4.5MW and year 20; 3.4 MW.

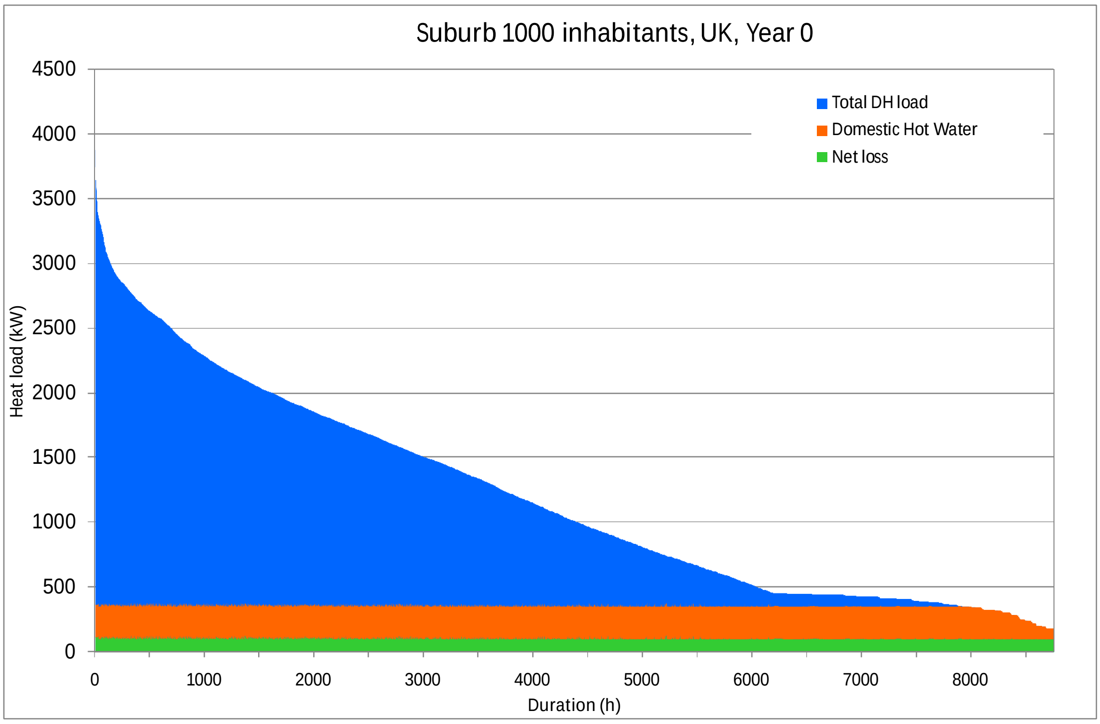

Figure 31. DH load for UK suburban area, year 0. DH load (incl losses): 10.3 GWh, Heat loss: 0.8 GWh (7.5%) DHW 20% of total load (2.06 GWh).

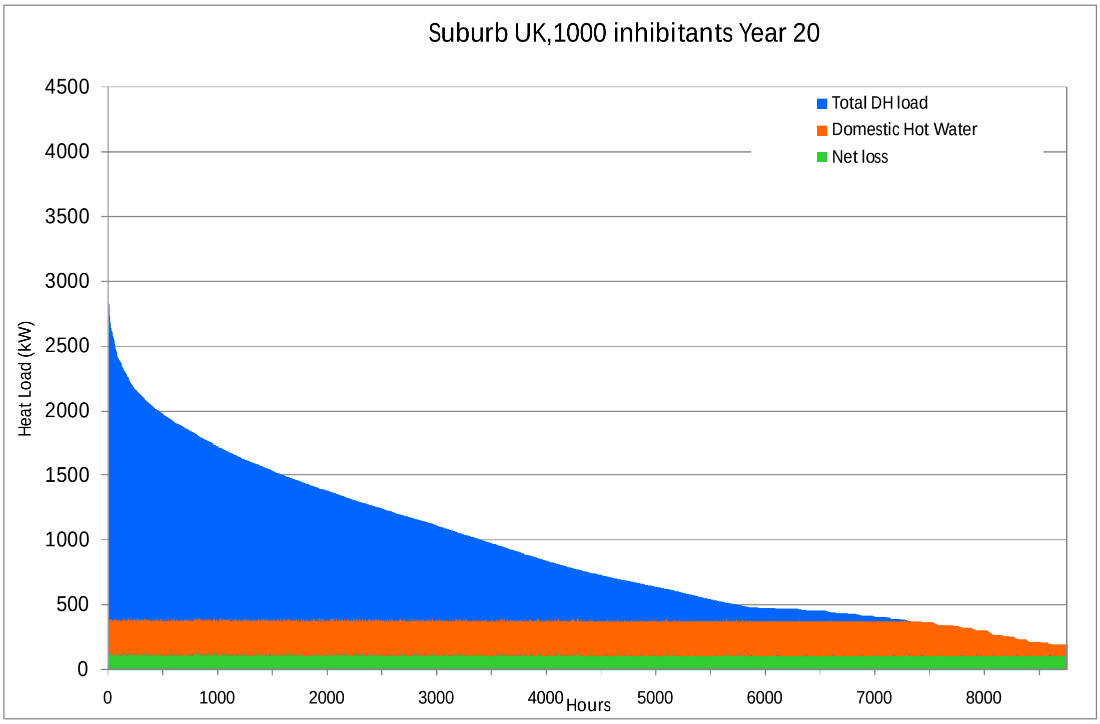

Figure 32. DH load for UK suburban area, year 20. DH load (excl. Losses): 8.0 GWh, Heat losses: 0.85 GWh (10.7%). DHW 27% of total load (2.18 GWh).

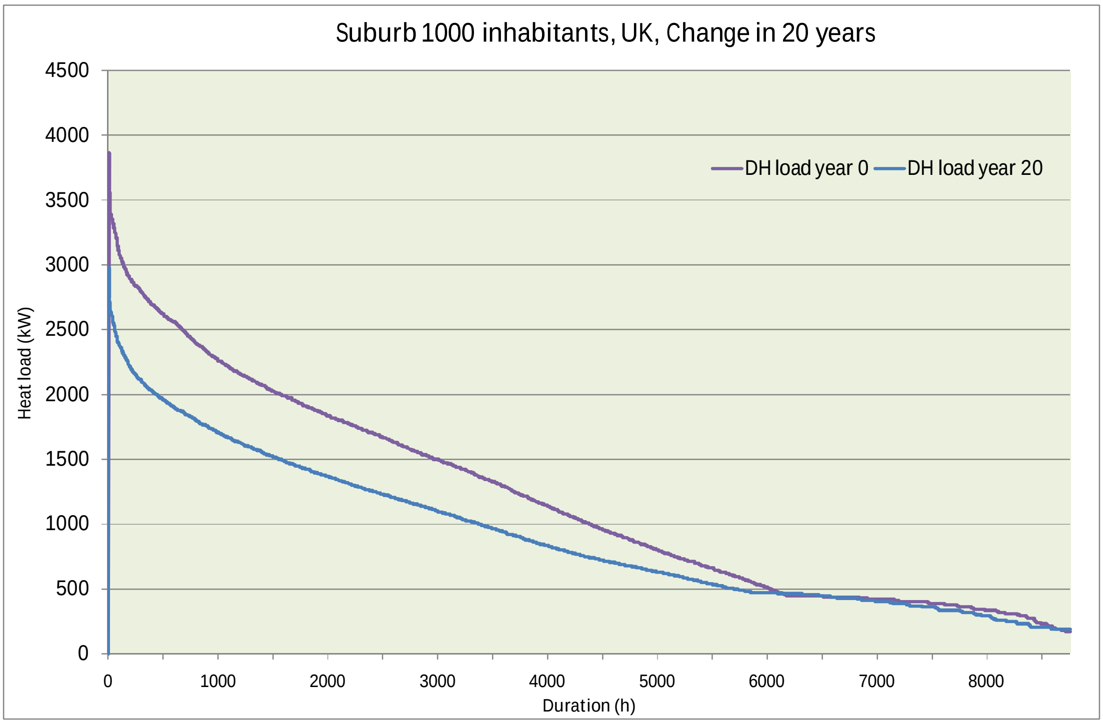

Figure 33. DH load for UK suburban area, year 0 and year 20, respectively. Reduction of DH load (excl losses); 26% (incl losses: 23%)Maximum heat load year 0: 3.7MW and year 20; 3.0 MW.

In both countries, the customer heat demand is lowered by 26% in 20 years. There are environmental, economic and technical consequences of this. The environmental consequences could be a reduction in the amount of fossil fuels used for heat production, and thus a reduction in fossil carbon dioxide to the atmosphere. For DH companies with fossil fuel boilers in peak load production, this will likely be the case. Other DH companies may find themselves with an oversized biofuel CHP plant and a reduced DH load will not be best for the environment.

Lowered heat deliveries will likely lead to lower income from sold heat. DH fares may have to be adjusted to reflect the production and delivery costs for the company. The customers will not accept too much of a raise of heating costs however. A reduction of delivered heat by 26% does not necessarily mean that profits will decrease as much, however. There will be lower costs for fuel, obviously, and there are also other ways to address the decrease in heat load. One method to lower heat losses in the net and, at the same time, increase electricity output from a CHP plant, is to lower the supply temperature to the DH network. A reduction in heat flux opens up the possibility to maintaining the flow at the same levels as before, but instead lowering system temperatures. Some nets may have certain consumers that require a high feed temperature for various reasons. However, there is a lot to gain from lowering the temperature, so it may be worthwhile to find solutions for these individual consumers. Figure 34 shows an example of how the supply temperature before and after adjustments could be. Note that circumstances vary for district heating nets; some nets already have a lower supply temperature level and could lower the temperature even further, while in other nets, the supply temperature cannot be lowered as much as the figure indicate (but might be able to lower the temperature 5-10°C in winter).

The technical consequences for an existing network are not very grave, but if the distribution network was oversized before, it gets even more so in the future. This will make the net more difficult to run; the response time for a change in feed temperature, for instance will be long. There may be a need to adjust supply temperature steering curve, as discussed above. There may also be a need to adjust the level and steering point of the differential pressure in the net. It is also vital to ensure that consumer substations function properly. This work should be done regardless if the district heating or the customer is the owner of the substation. For best result, this is done in cooperation with the customer.

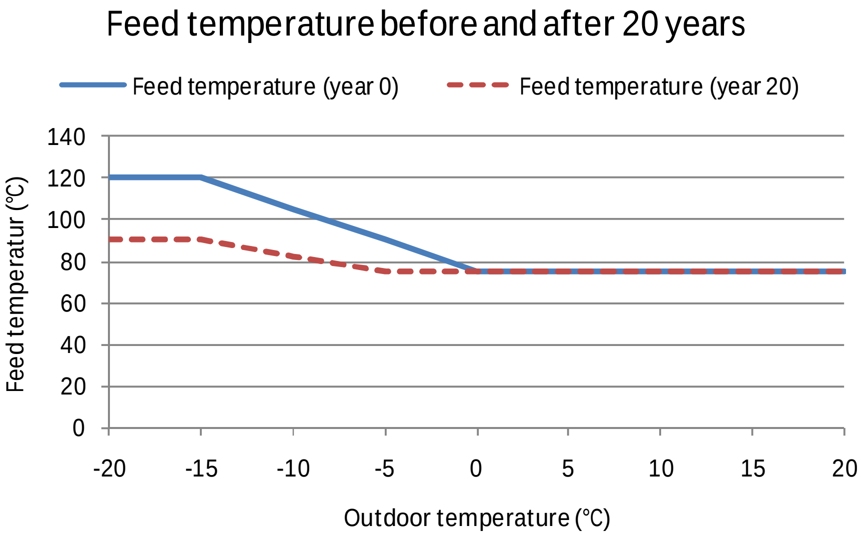

Figure 34. The blue line represents a typical feed temperature steering curve, common in many DH nets. When the heat load is reduced, the feed temperature may be lowered, for example like in this graph. The level of the supply temperature has to be customized for each individual net, however.

2.5.2 Inner City

Duration curves for Swedish inner city, starting year and after 20 years, are presented in Figure 35 and Figure 36. In Figure 37 the heat load duration before and after 20 years are presented in the same graph. The corresponding durations curves for UK are presented in Figure 38, Figure 39 and Figure 40.

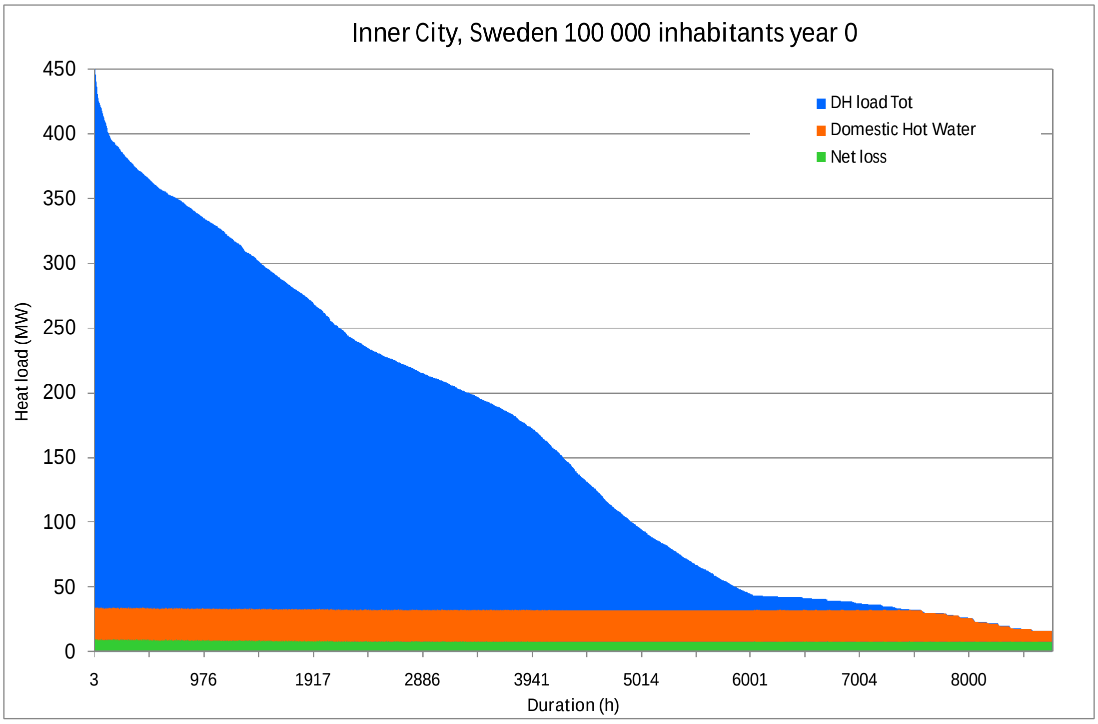

Figure 35. DH load for the Swedish city area, year 0. DH load 1382 GWh, heat loss 72 GWh (5.2%).

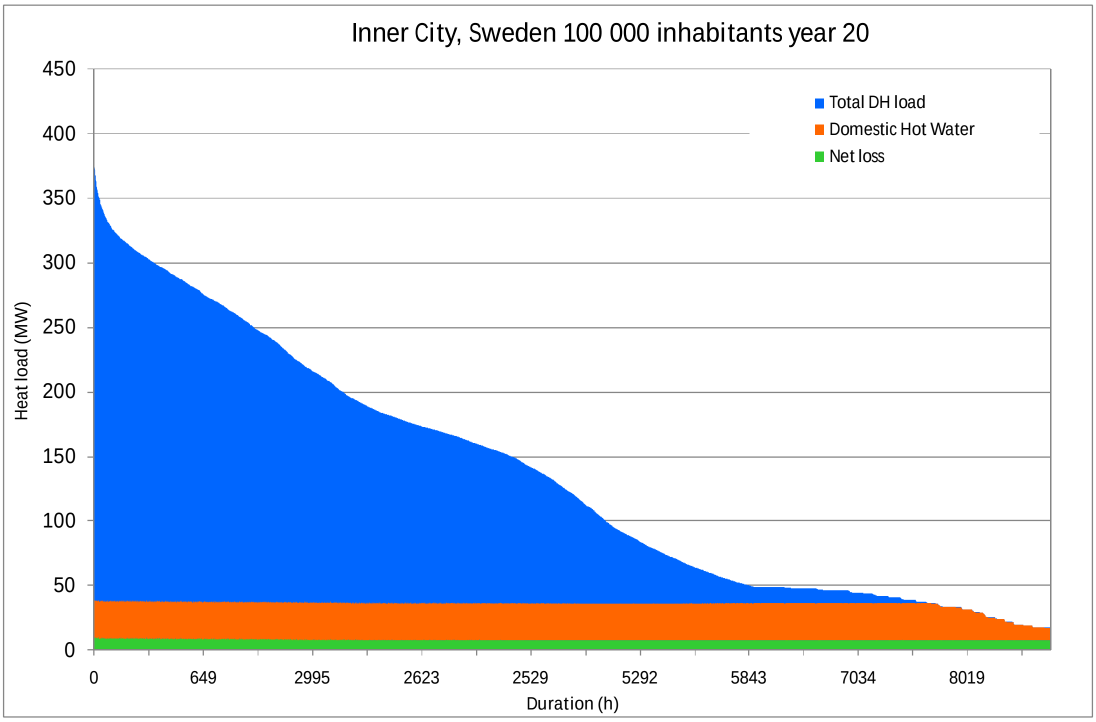

Figure 36. DH load for the Swedish city area, year 20. DH load 1190 GWh, heat loss 73 GWh (6.2%).

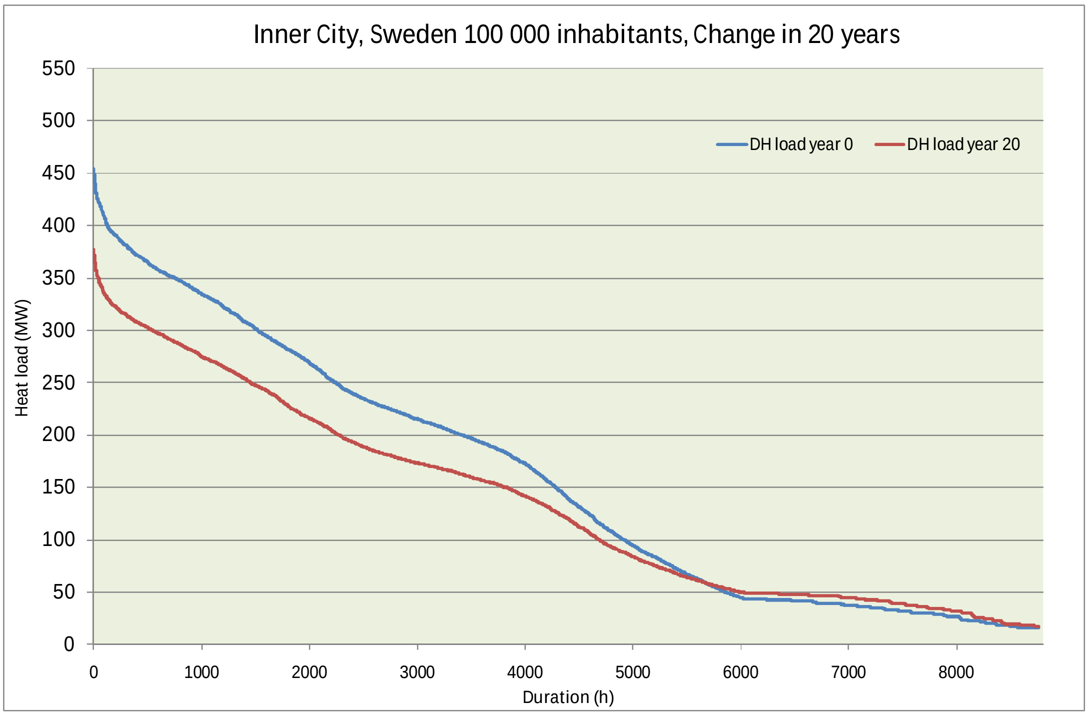

Figure 37. DH load for Swedish inner city area, year 0 and year 20, respectively. Reduction of DH load (excl losses); 16% (incl losses: 14%) Maximum heat load year 0: 454 MW and year 20; 377 MW.

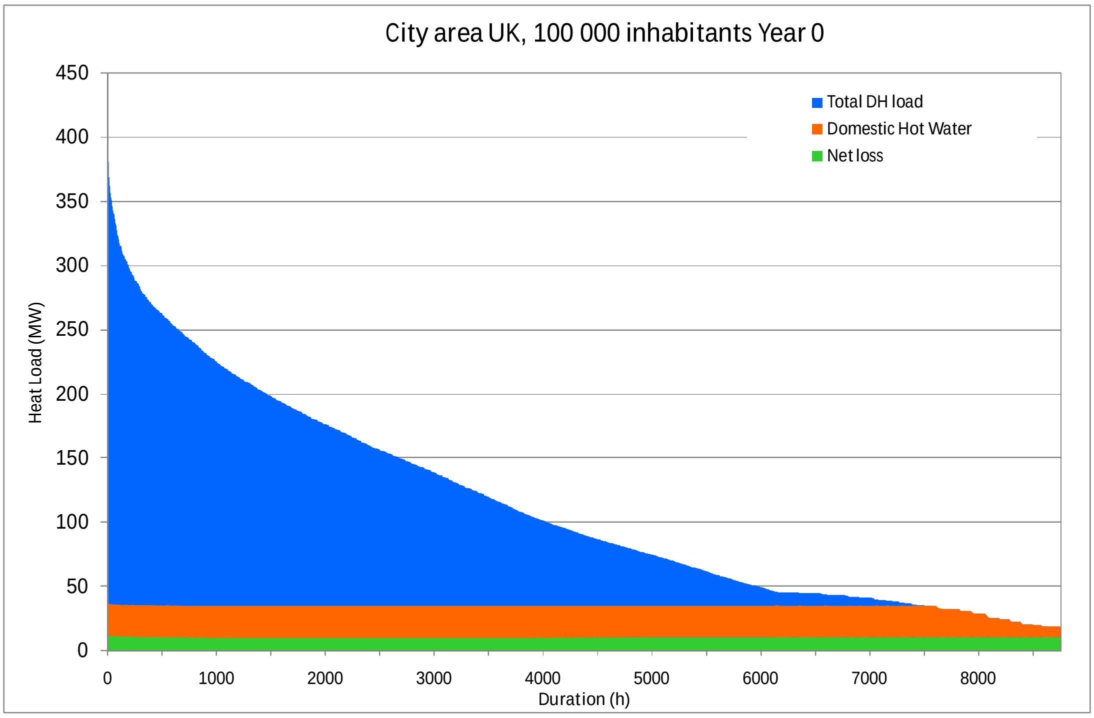

Figure 38. DH load for the UK city area, year 0. DH load 993 GWh, heat loss 92 GWh (9.2%).

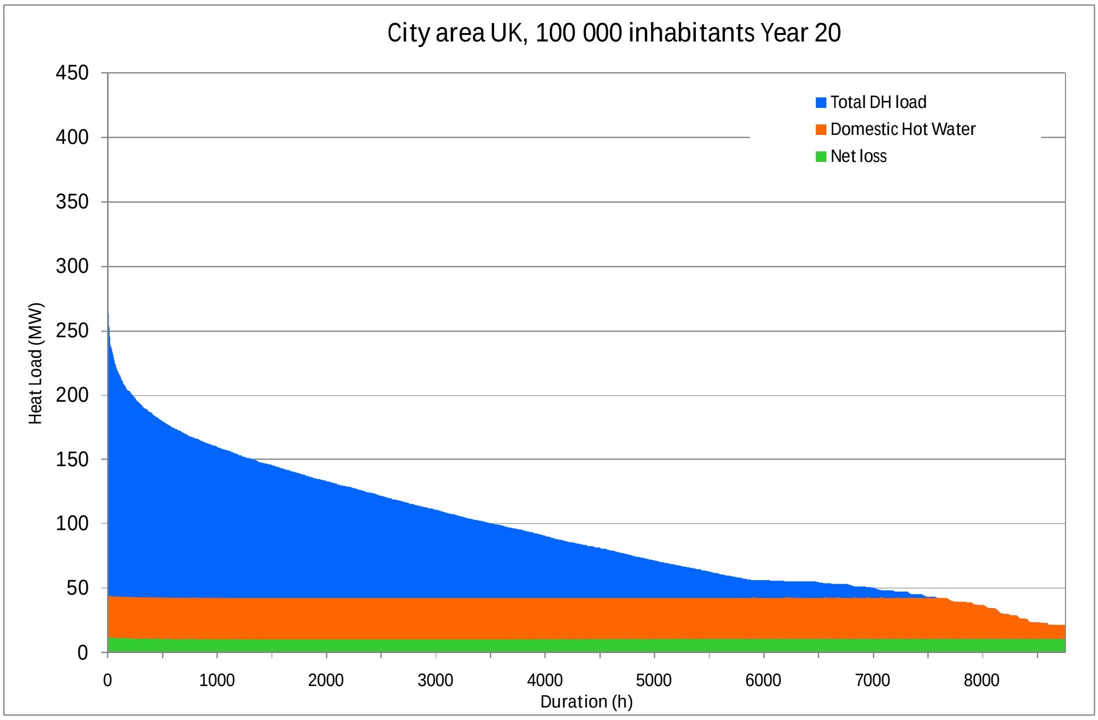

Figure 39. DH load for the UK city area, year 20. DH load 818 GWh, heat loss 94 GWh (11.5%).

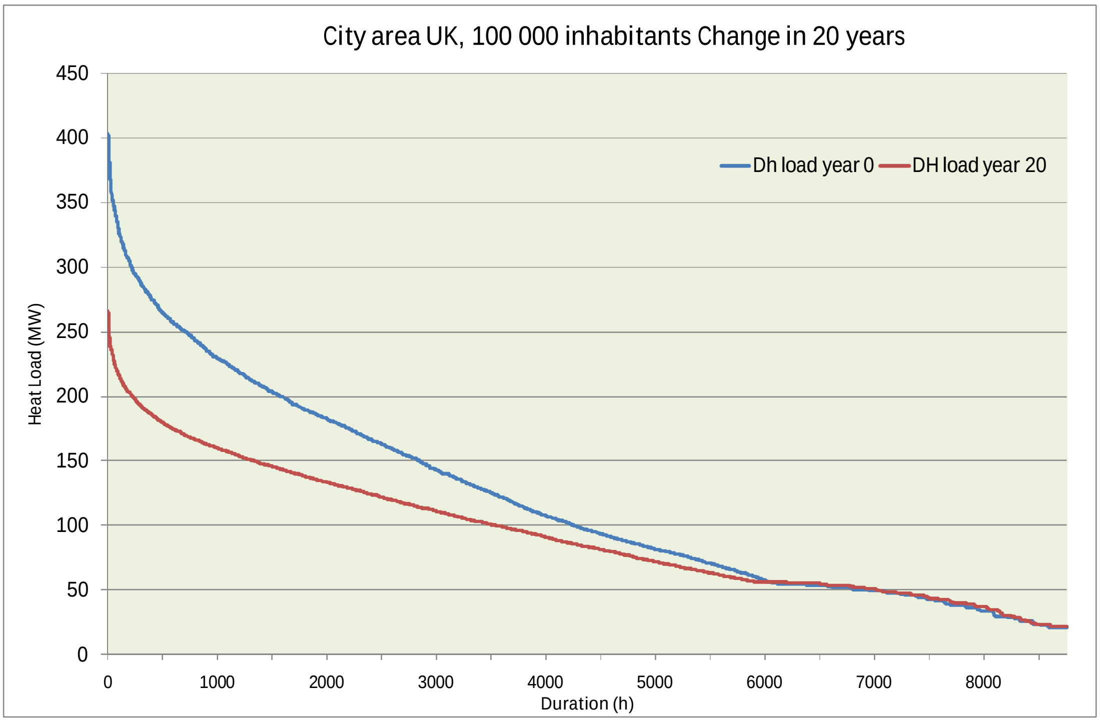

Figure 40. DH load for UK inner city area, year 0 and year 20, respectively. Reduction of DH load (excl losses); 24% (incl losses: 22%) Maximum heat load year 0: 403 MW and year 20; 266 MW.

As with the suburb areas, there is a lowered heat delivery in the city and the duration curve becomes flatter. The same conclusions that were made in 2.4.3 Suburban area, also applies to the city area. In addition, if there is building densification in the city, lowered heat loads to existing buildings will open up capacity for connecting additional loads to the net, without the need to replace piping.

2.5.3 Urban development

As this a new area, there are no “before-graphs”. The load profile for the urban development area in Sweden is presented in Figure 41 and for UK in Figure 42. Compared to the same number of residents in the suburban area, the heat load is significantly lower, but the summer load is almost the same. This means that in the urban development, the peak load is lower compared to the annual heat demand.

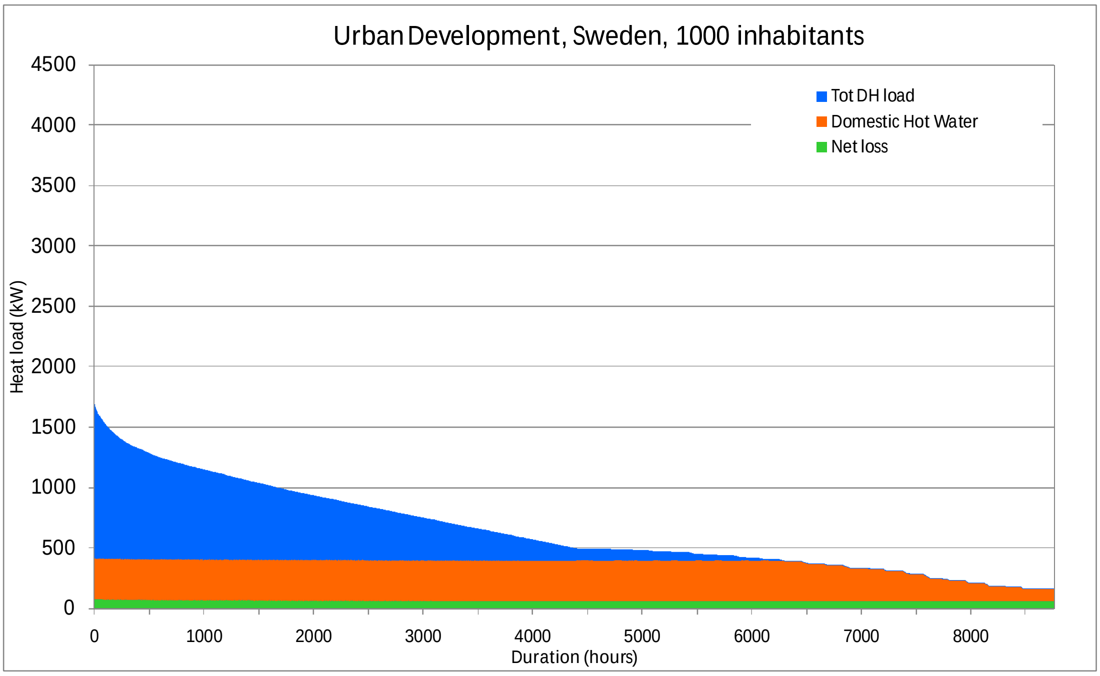

Figure 41. DH load for the Swedish urban development area. DH load 5.6 GWh, heat loss 0.55 GWh (9.9%) DHW load represents 45% of the total DH load.

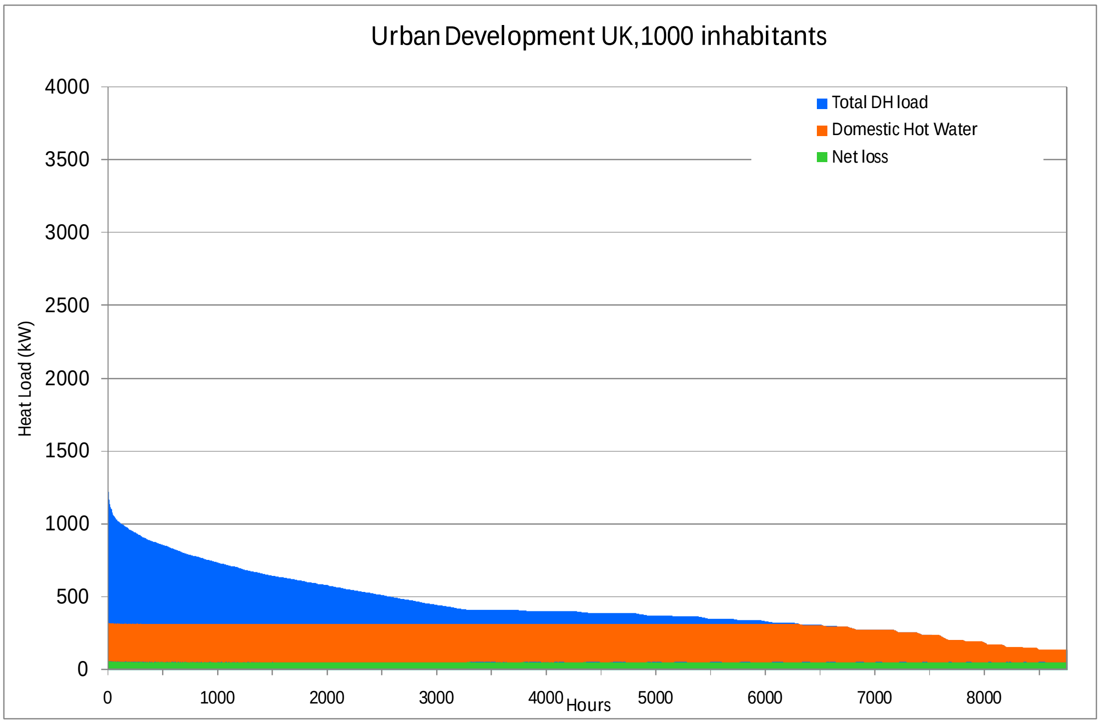

Figure 42. DH load for the UK urban development area. DH load 3.85 GWh, heat loss 0.43 GWh (11.1%). DHW load represents 45% of the total DH load.

It is obvious that the new, urban development have a significantly lower heat demand than the suburb area, or a city area of the corresponding size. This is both a challenge and an opportunity. The challenge is to keep installation and running costs at an acceptable level. This can be obtained by careful planning of all components in the district heating net. Both installation and running costs can be lowered by not over sizing the system. In contact with architects and contractors, there is a high risk of getting overestimated numbers for the buildings' heat demands. Sometimes these heat demand estimations can be a factor 2 or 3 higher than the actual demand. But there have also been cases of the opposite; where heat demand has been underestimated. This has usually been in areas claiming to be Passive House or very low-energy, that has not quite reached their goals. The district heating company should always check the plausibility of information given on heat demand in order to dimension the system as accurate as possible. In general; piping should be as slim as possible. Sometimes distribution pipes needs to be oversized in order to allow future expansion of the DH network, but there are several dimensioning tools on the market that could be used to ensure that distribution pipes aren't larger than necessary. Even if distribution pipes are somewhat over-sized, the service pipes should always be as small as possible. Especially in areas with low dwelling density, where a large share of the networks piping consists of supply pipes. There are also other ways of reducing installation cost, which are discussed in the conclusion part of this report.

The load duration curve for new developments is rather flat, which is beneficial and should be taken use of in the planning and investment phase. The main boiler(s) and/ or CHP can be utilized a large part of the year if an adequate size is chosen. The system temperatures could be kept low, as the internal heating systems in the connected buildings will be of low temperature.

In an existing DH net, this area could be a low temperature area connected with a substation. Since the DHW load is such a large part of the total load, it would be possible to let the circulating domestic hot water run through heat exchangers in the buildings for their internal heating systems and thus reducing installation costs.

2.5.4 Monthly Heat Demands

As indicated in the load duration curves, the monthly demand will differ. In Figure 43 and Figure 44, the monthly demands for heat in the areas with 1000 inhabitants are presented, for Sweden and UK, respectively. Figure 45 and Figure 46 displays the corresponding monthly heat demands for City areas in Sweden and UK.

It's evident that the traditional "heating season" will become less energy demanding in time. This will, in turn, affect the revenues of a district heating company. For a new DH area, there are several measures that can be made in the planning and installation phase to reduce installation cost and future running costs (see discussion in 2.4.5 Urban development area).

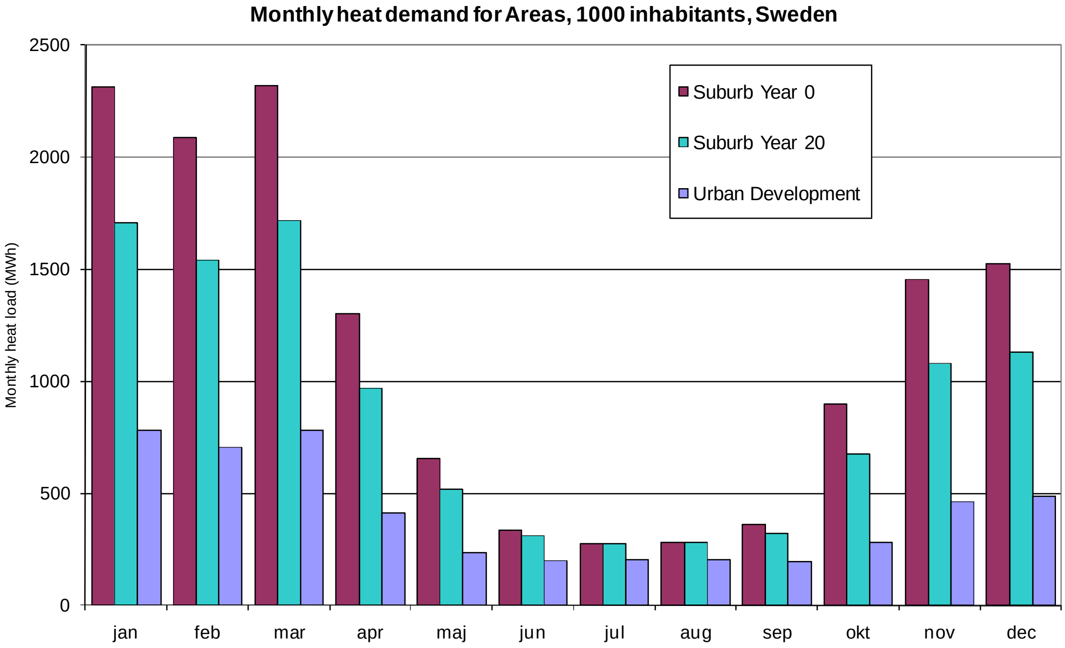

Figure 43. Monthly heat load for different district heating areas (Sweden).

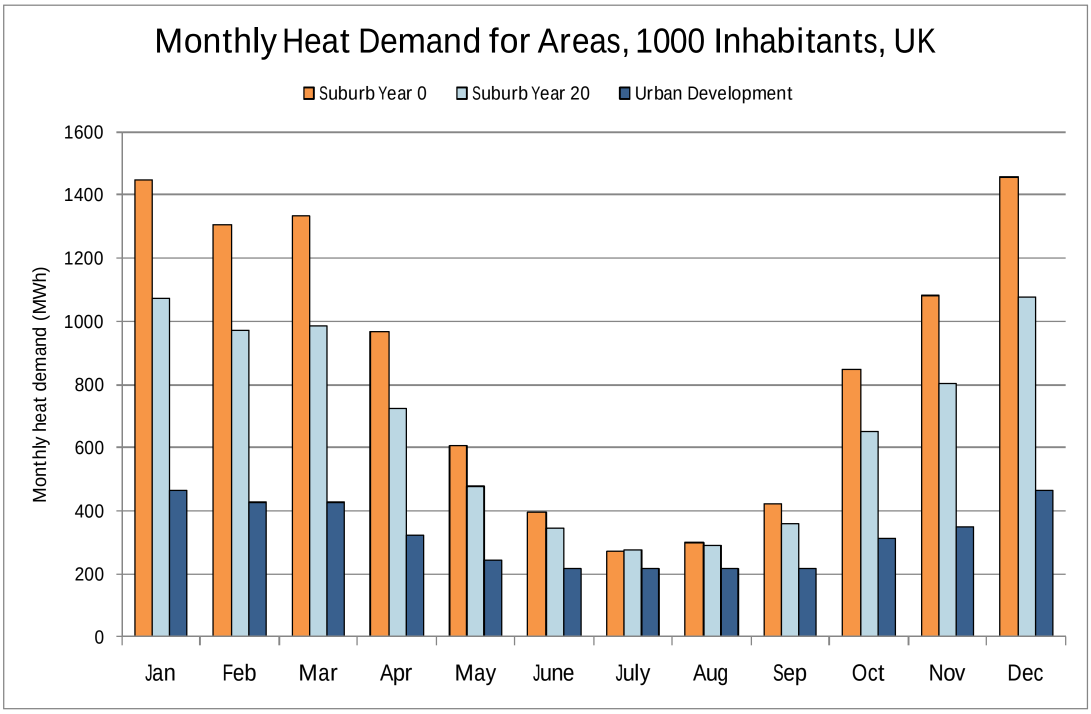

Figure 44. Monthly heat load for different district heating areas (UK).

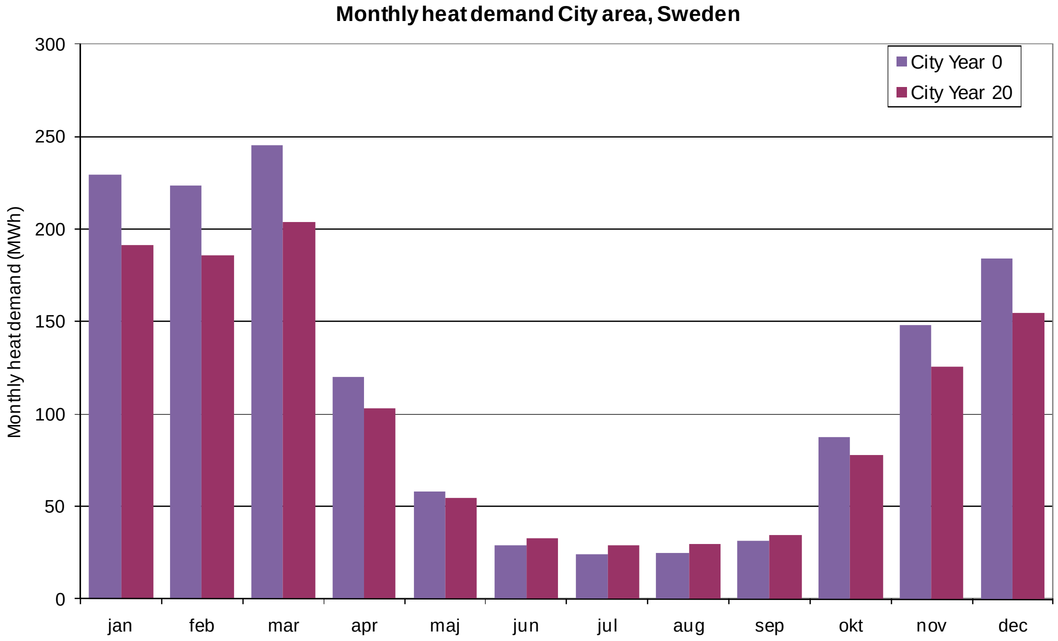

Figure 45. Monthly heat load for City area, 100000 inhabitants, now and after 20 years (Sweden).

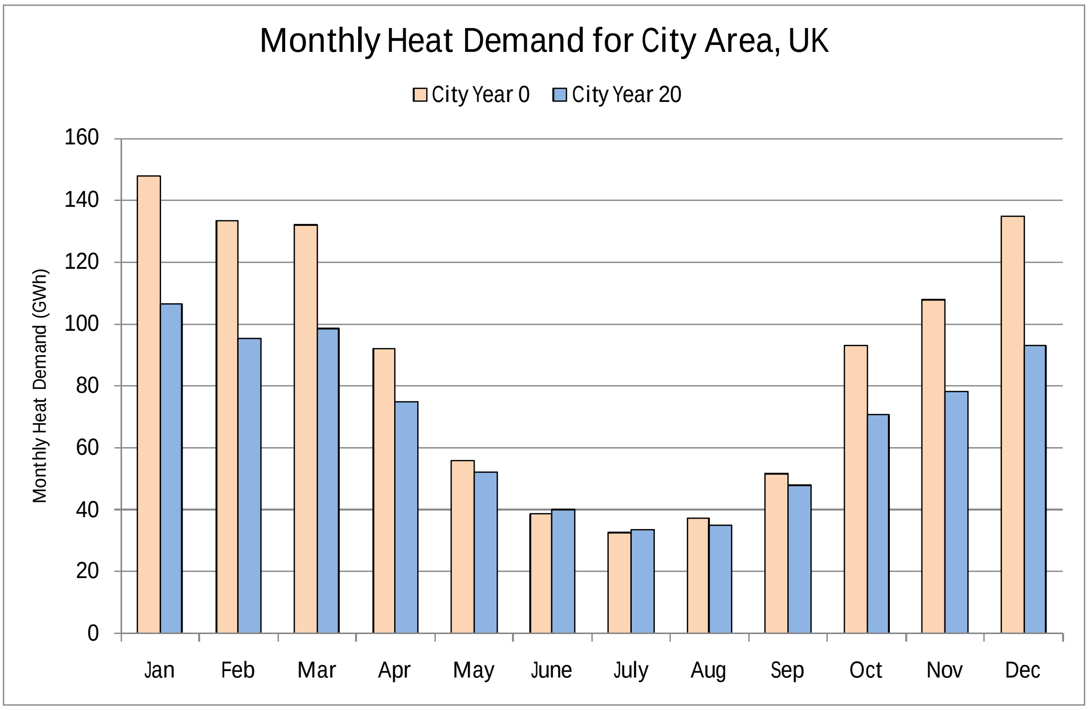

Figure 46 Monthly heat load for City area, 100000 inhabitants, now and after 20 years (UK).

2.5.5 Duration curves for a whole district heating net

By combining the duration curves for the different areas in a district heating system, a duration curve for a whole net is obtained. The district heating net, which duration curve is presented in Figure 47, is built up of a large city area,; 100 000 inhabitants and suburbs with a total of 20 000 inhabitants. In year 20 new developments with a total of about 7000 inhabitants have been connected to the net. The total DH load year 0 is 1682 GWh and is reduced to 1479 GWH, a reduction of 22%. By connecting new developments, more piping is added to the network, thus increasing the heat loss somewhat. In 20 years the relative heat losses are increased; from 7.5% to 9.5%.

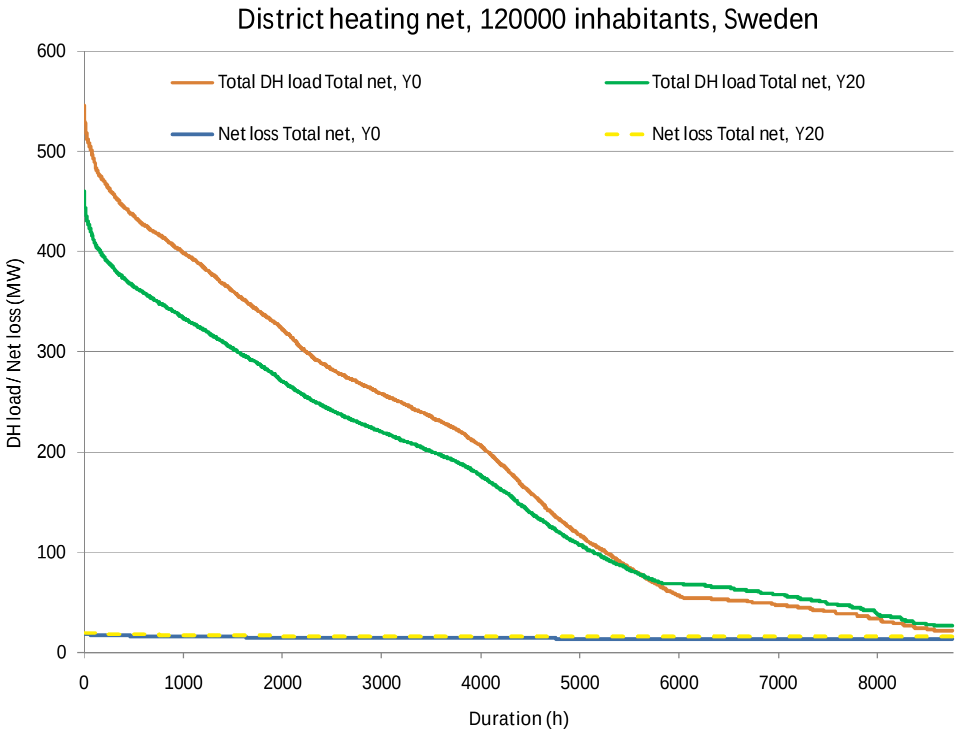

Figure 47. DH load for an area with about 120000 inhabitants year 0.

2.6 International relevance

Most of the statistics used is from Sweden or the UK. Figure 49 and Figure 48 gives an idea of how Swedish and UK heating loads compare to other European countries. In order to calculate load profiles there needs to be an input of climate data for the geographic area that is studied. The results from calculations based on conditions in the British Isles and Scandinavia could be extrapolated for other European countries using *the new European heating index* (Figure 50).

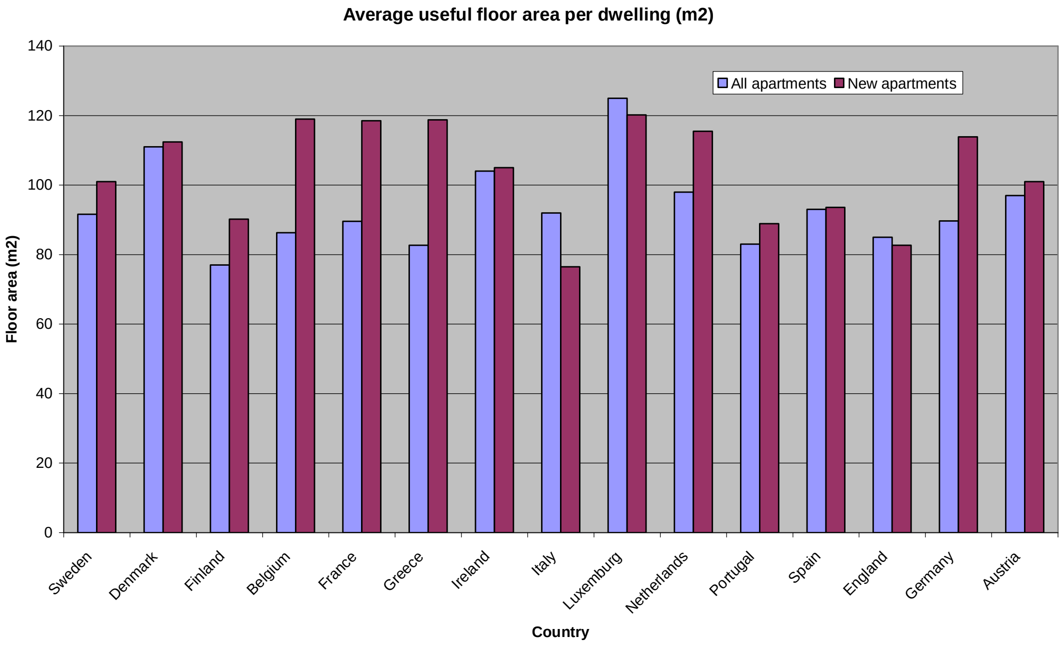

Figure 48. Average useful floor area per dwelling in Europe (source: EU: Housing statistics in the European Union 2005/2006).

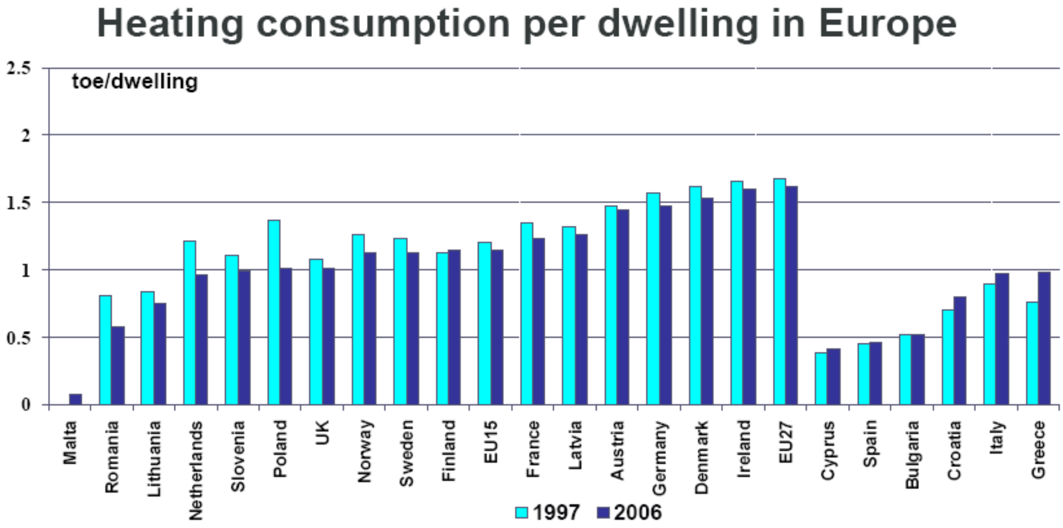

Figure 49. Heating consumption per dwelling in Europe for 1997 and 2006, respectively (source: MURE[14]).

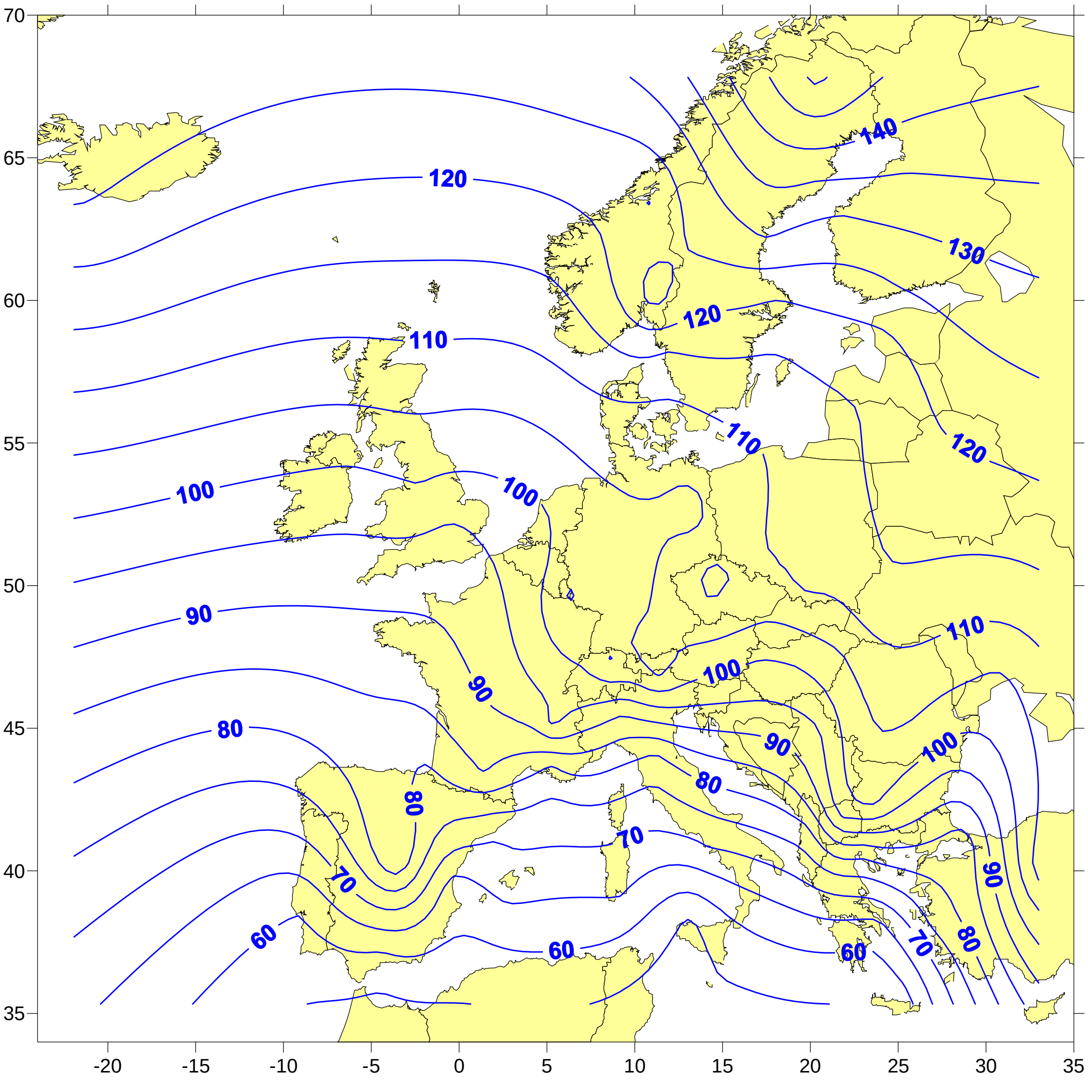

*Figure **50**. The new European heating index (EHI) in a contour map computed from information for 80 urban locations in Europe. Source: Ecoheatcool Work Package 1. The space heating demand should be proportional to this index. Note that the map is not representative for all locations in each country, since the existing data grid consists of only 80 locations.*

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[14] Mesures d'Utilisation Rationnelle de l'Énergie

3 Introduction to designing district heating systems

Heat can be supplied to district heating system from CHP-plant, boiler plant, industrial source, from ground or sewage with heat pump or from solar panel. CHP plant is mainly built on a site. Boiler plants are delivered in complete operational units including all necessary components and functions. Boiler plants are gas, oil and biomass fired. Recycled energy resources (RES) will be more common resource for DH in the future. Industrial source is waste heat water or steam. Water treatment and high level control of water quality ensures high availability of heat supply plants as well as long service life for pipelines and auxiliaries.

District heating system is divided in heat production, transfer and delivering as well as consumer subsystems. Subsystems have their own information system: measurements, data collection, alarm, control and regulation. Advanced total control and information system will be needed for effective use of the future district heating system and also of all sublevel systems, even two-way contact to clients.

District heating system must be adapted to low energy system in buildings or even heat producer buildings. Then heat trade system (Sipilä.K & all, 2005) might be needed in regional heating system like electricity trade nowadays in EU countries. Because of low energy buildings higher buildings will be needed in town cities and tighter building plan in suburbs.

Low heat density area is defined as a heat density per pipeline meter less than 0.5 MWh/m,a or heat density per area like less than 10 kWh/ha,a. The representative other parameters and heat supplies for low heat density area are defined in Table 8.

Table 8. Characteristic of heat density areas.

Characteristic	Unit	High	Medium	Low	Obs!
Heat density/ pipeline	MWh/m,a	> 1,0	<1,0	<0,5	
Heat density/area	kWh/ha,a	50	30	10	
Annual energy/dwelling	kWh/a	16 000	12 000	5 000	
heating/ hot tap water	kWh/a	10 000/6000	8000/4000	1000/4000	
DH temperature	°C	90	60	60	
		90	90	90	
Hot water					
-with heat ex.	°C	55	55	55	
- with heat storage		60	60	60	
DH Heating	CHP	plant			
	Gas	boiler			
	Pellets	boiler			
	Oil	boiler			
	Heat pump	ground, air			
Individual consumer	gas, pellets, oil boiler				
Maintenance cost/a	2	% of investment			
Prices	EUR/MWh	Electricity, DH, gas, pellets, oil			
	Local average price including taxes				
Discount	%	3	6	10	
Utilization time	y	25	DH		
	y	12,5	2 gas and pellets boilers during 25 y		
	y	8,5	3 heat pumps during 25 y		

3.1 Pipe types

DH-pipeline is closed 2- or 3- pipeline system, which has a regulated water flow by speed controlled pumps. The pipes (trench) can be separated or packaged in the same coat. Three pipes system has two outgoing and one return pipes. In four pipes system space heating and hot tap water services have their own outgoing and return pipes. Industrial produced pipe elements with steel or plastic wall are covered by fixed rigid foam insulation and plastic coat. Example of pipe prices is presented in Figure 51. The price of pipes varies in different countries.

The network is mostly located under the ground, sometimes for special reason in air. The water is convenient medium, because it is cheap, easy to be handled, not corrosive and toxic. Many research attempts have been done to develop substitute or additive to the water.

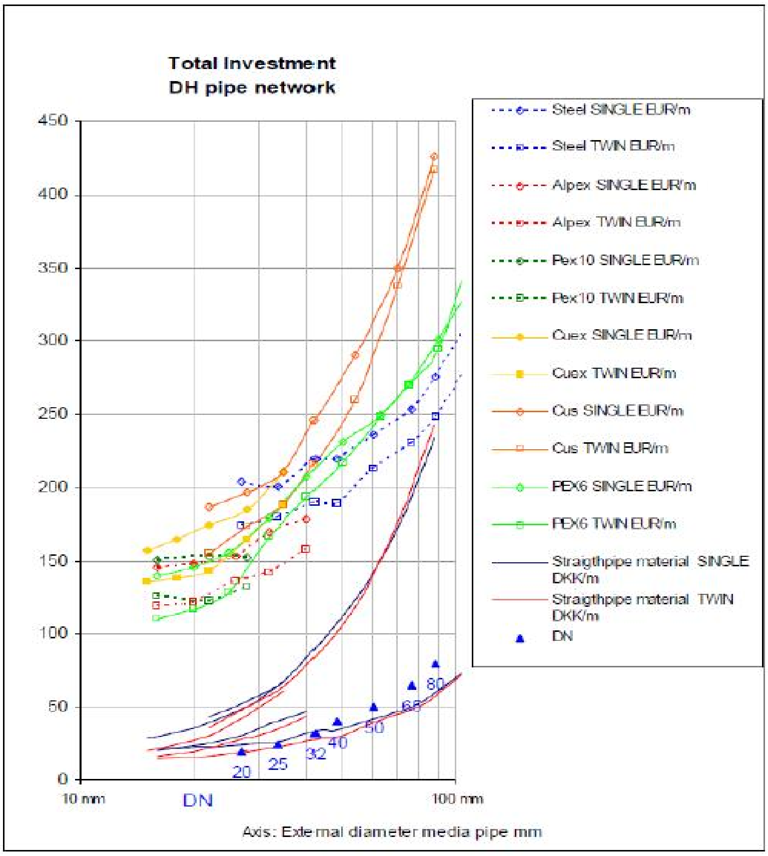


Figure 51. Pipe system cost for steel, Cu- and PEX- pipe in Denmark 2007 (cell : Zinko & all, IEA report, Annex VIII, 2008).

Several pipe type alternatives are calculated and compared in Neidonkallio, Finland (Figure 52) in 2007. In low heat density region steel twin pipe isolation series 2 is the most economical alternative.

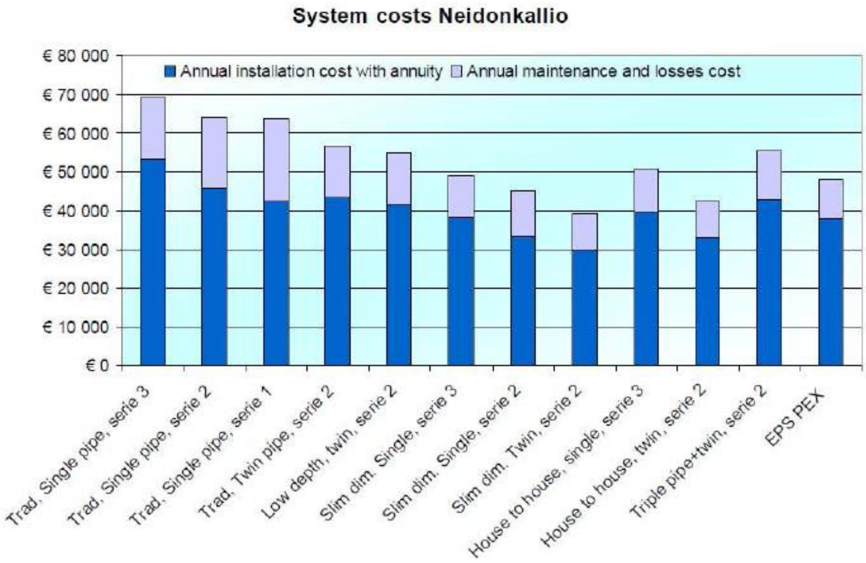


Figure 52. Comparison of total system cost with several pipe types in Neidonkallio, Finland (cell: Zinko & all, IEA report, Annex VIII, 2008).

System design for reduced pipe dimensions are strong drivers for systems supplying especially detached houses. Such systems can be systems with hot water accumulators instead of directly connected heat exchangers, or service pipes with reduced diameter and a booster pump for peak heat demand. Booster pumps can in many applications help to reduce costs.

Service pipes should be as small as possible and no reserve capacity should be calculated for. This is also valid for the distribution pipes. Taken future energy saving measures into account, reserve capacity should only be taken into consideration, if it is obvious that new loads will be connected.

3.2 Temperature level, heat losses and pumping

Nowadays maximum temperature can be chosen 80 – 120 °C and the pressure level 1.0 – 1.6 MPa (heat loss in Fig. 45) and even 2.5 MPa e.g. in Norway, Russia and some Middle European countries. The 4th generation DH-systems will be planned to 60 – 70 °C temperature level, which has dramatic issues to CHP planning. This makes possible to plan new type of CHP plants with higher power to heat ratio better to correspond to consumption structure of the society's energy demand. Solar energy will make invasion to district heating systems. The representative planning pressure is 1.0 – 1.6 Mpa in pipeline depending of the distance of DH-pipeline system.

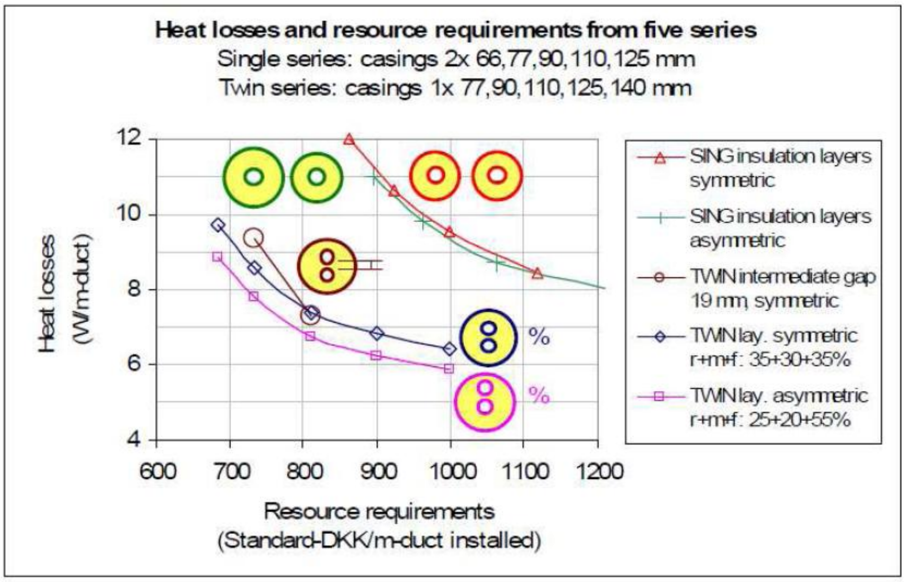


Figure 53. Heat losses for two single or twin pipe (cell. IEA report, Annex VII).

The necessary water flow in district heating network is achieved by pressure difference generated by speed controlled pumps installed at the heating plant (Figure 54). In addition booster pump stations (Figure 55) installed along the network can be used in long pipeline systems. The profitably of installing booster pump stations depends on the network configuration and on the distribution of consumption. Sometimes it may be profitable to install a pump into a separate small delivery pipeline branch, if by this measure the need for overall network pressure difference can be diminished. The booster pump stations save pumping energy and decrease maximum pressure levels and pressure differences in other parts of the network. Known critical points in the DH-system are used to regulate the pressure and to keep pressure difference at those critical points above the accepted level. Speed controlled pumps are used for pressure regulation. Pressure, temperature and water speed of the pipeline system can be simulated with special models (e.g. Bohm & all, 2002, IEA rapport, Annex VI).

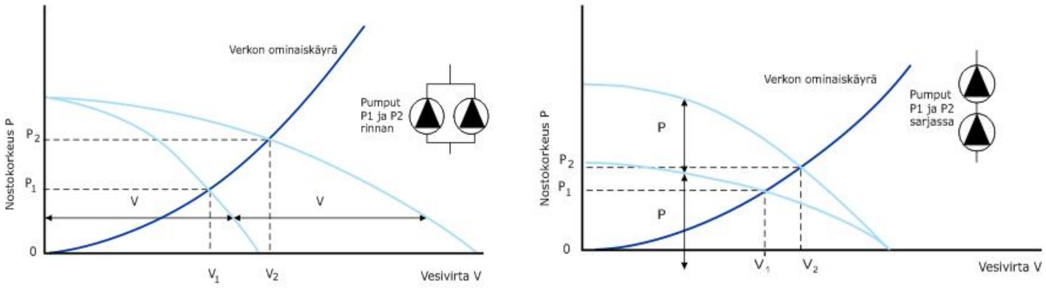
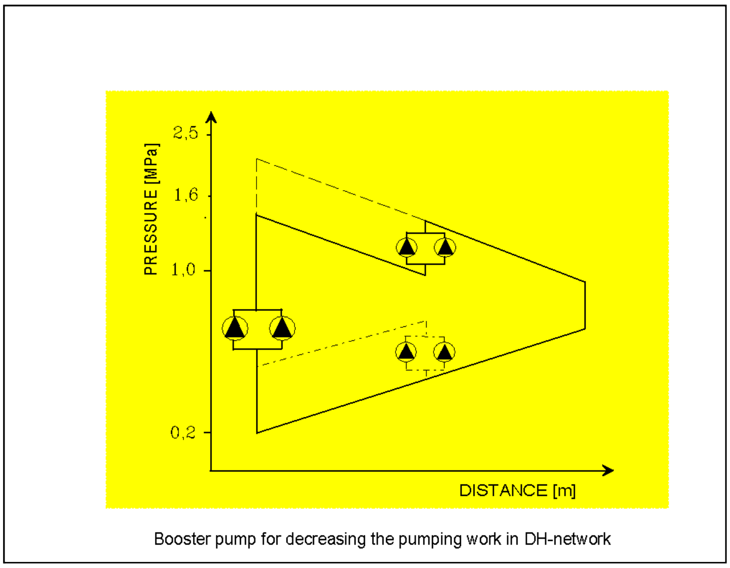


Figure 54. Water pumps parallel and series connection installation (District heating handbook/Finnish Energy Industry/DHC).

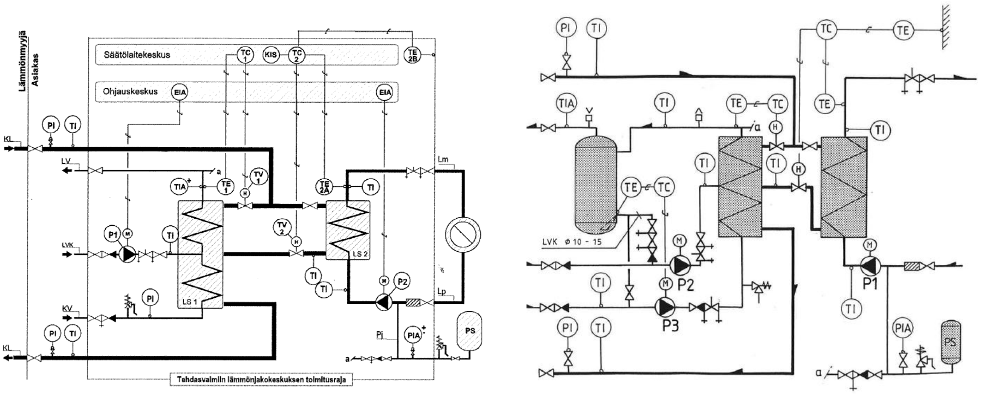


Booster pump for decreasing the pumping work in DH-network

Figure 55. Booster pump in long distance DH-pipeline for lowering the pumping work and construction pressure of the DH-network (cell: Modis DH-system).

3.3 Consumer connection

Mostly big consumers are connected indirect (Figure 56) by a heat exchanger to the district heating system. The domestic hot water system is also recommended to be connected indirect to the DH-system, because then chemical treatment (water Ph-level regulator, colour for leakage indicator, etc.) can be used to insure good transfer function in district heating pipeline system. The main requirements for the substation are easy and common use, reliable, efficient and economical function while guaranteeing needed thermal effect and temperature for consumers. Consumer connection is possible to be boosted by extra pump, if pressure difference before the consumer is too low.



a)

b)

Figure 56. Principal of indirect two stages connection of the consumers (big houses). a) no hot water tank, b) with hot water tank (cell: Report K1/Finnish Energy Industry/DHC).

Figure 56 shows the schematics for a so-called two stage coupling substation. The primary side is divided into two parallel water flows in the first stage, one for the space heating side and the other for the domestic hot water side. In the first stage the primary flow is cooled separately and united before a preheater of the domestic water in the second stage before returning to the district heating return pipe line. The purpose is to reach better temperature drop before feeding the water back to the return pipeline. Practically the hot water heat exchanger is into the second stage of the heat exchanger. There are several prefabricated packages on the market ready for installation and ready to connect to electricity and plumbing.

A parallel indirect connection (one stage) substation is presented in Figure 57. The substation has one heat exchanger for both domestic hot water and space heating. This is a cost efficient solution, which is easy to operate and is recommended nowadays, not only for small houses, but for any installation, except for larger residential buildings (>80-100 apartments). This connection type can be recommended also all house types in low heat density areas, where can be used also low delivering temperature (< 70 °C). The secondary side (consumer side) must be curried out to assure high enough temperature drop in all circumstances (min. 30 °C).

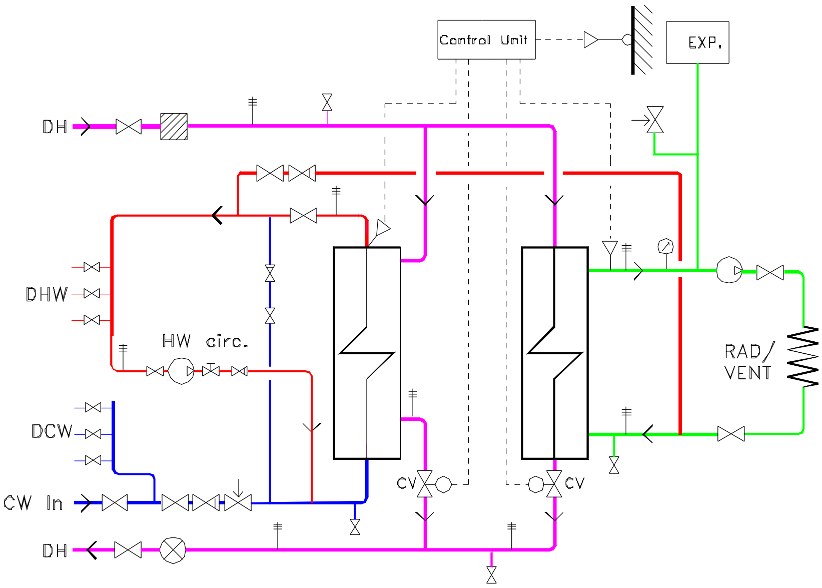


Figure 57. Parallel (one stage) indirect connection (cell: Svensk Fjärrvärme, 2009).

A hot water tank connection of consumer in DH primary side is presented in Figure 58. Hot water tank is in supply side at consumer installation. This kind of substation makes possible to cut peak loads caused by DHW variations. The volume of the tank is some hundred litres based on a house type (one family to multi family house).

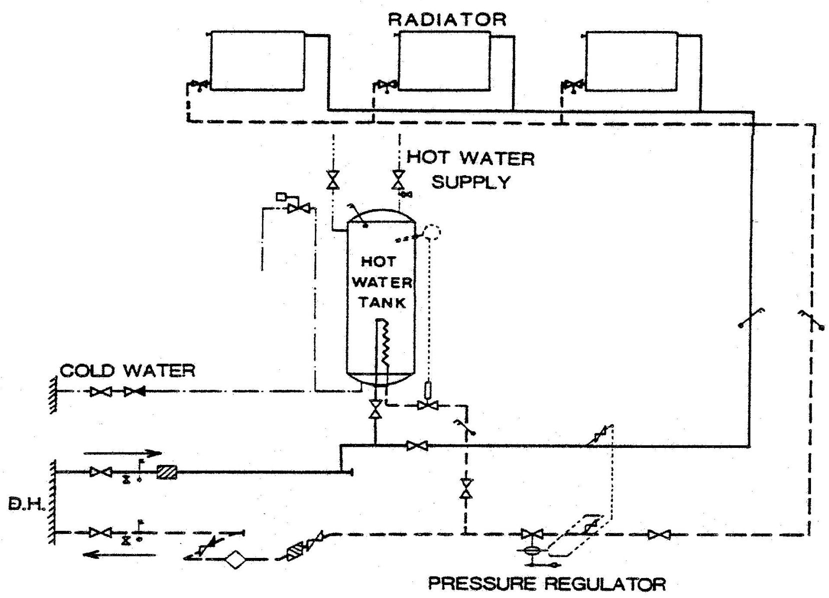


Figure 58. Principal of hot water tank connection for the consumer in DH primary side. (cell: Bøhm, B, 1988).

Building groups can be connected to DH-network with a heat exchanger as shown in Figure 59. Individual houses have their own heat exchanger for domestic hot water heating. The subsystem has also one expansion system. In Denmark, many houses are connected directly to the DH net, in a manner similar to the connection to this subsystem. This is possible when temperature and pressure is low enough (max. 6 bar).

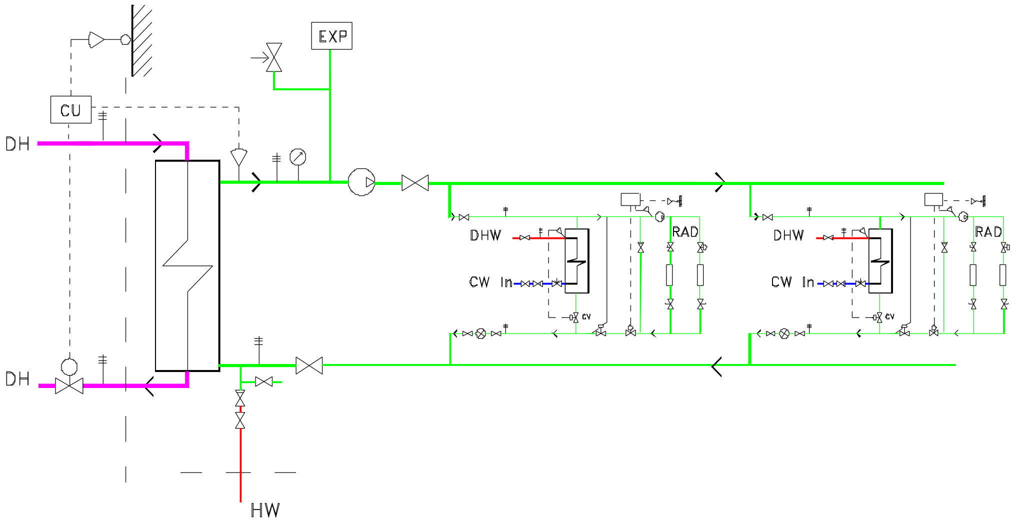


Figure 59. Small houses connected with a group heat exchanger to DH system (cell: Svensk Fjärrvärme, 2009).

3.4 Consumer installations after substation

The consumer can use heat taken from DH-system in many ways in addition to domestic hot water and radiator space heating, e.g. floor heating, air heating, drying ventilation air, snow melting, heat source for heat pump, energy source for cooling machine (absorption), heating for washing and dishwasher as well as heating a spa and a bath (sauna). Here are shown some examples.

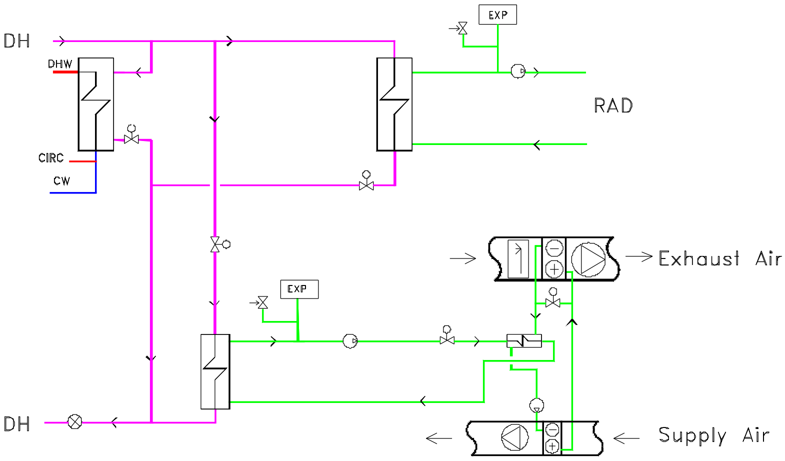


Figure 60. District heating for air conditioning with recuperation (cell: Svensk Fjärrvärme, 2009).

Figure *60* gives an example, how exhaust air heat pump should be installed, if combined to the ventilation system in a building.

If low temperature system is used, floor or air heating system should be used in the house and domestic hot water temperature can be boosted by heat pump. The Figure 61 shows an example how the heat pump could be connected to heating system in the consumer side.

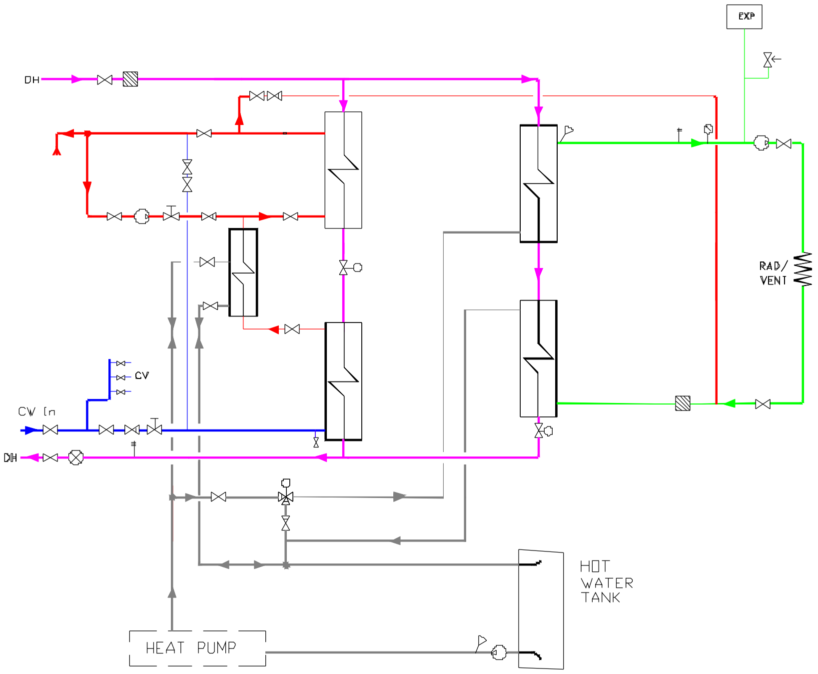


Figure 61. District heating connected to house hearing systems with heat pump (cell: Svensk Fjärrvärme, 2009).

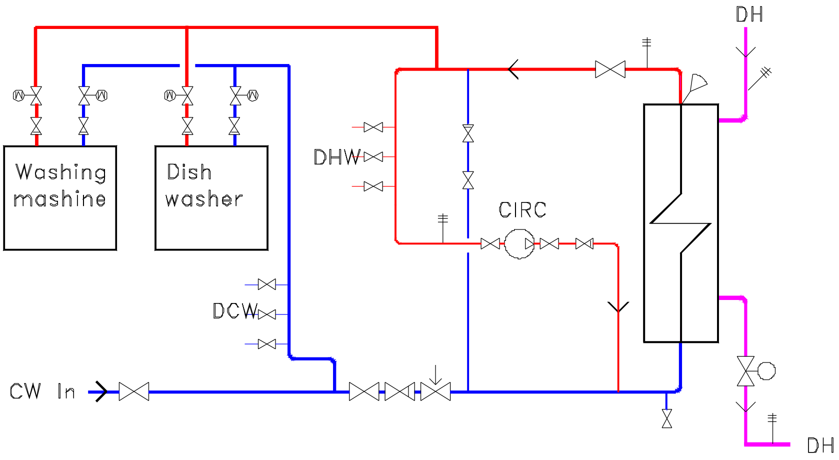


Figure 62. District heating for washing and dishwasher machines (cell: Svensk Fjärrvärme, 2009).

District heating can be used also for heating of washing machine and dishwashers as shown in the Figure 62. Machines for those purposes are not yet on the market, but some prototypes have been made and are installed in a house in Gothenburg. Also a spa is heated by district heating in the same experimental building. The sauna could be also preheated by DH acting like a radiator in that room and boosted by electricity when used.

4 The borderline between district heating and individual systems

This chapter concentrates on investigating the borderline between where district and individual, house specific heating systems become most appropriate. This is done by studying systems of low heat density on both sides of this borderline while making financial evaluations of different alternatives. Network simulation models are used to calculate heat losses, required pumping power and also to give an insight into the operation of these borderline systems.

In the first part of the chapter, the basic concepts of heat demand density and dwelling density are discussed. This is followed by a breakdown of the basic problem; is it reasonable to choose district heating or an individual heating system as a heat source for a dwelling. The next subchapter describes the differences between new and old district heating systems from a borderline system point of view. After this, a number of examples with simulation results and financial evaluations are presented. The chapter ends with a conclusion containing the main points and results.

4.1 Basic concepts

The concepts essential in describing the borderline areas are explained below. These concepts are heat density and dwelling density.

4.1.1 Heat density

Heat density refers to a number of characteristics all describing heat or heat demand per unit of area or per unit of length, usually trench length, in a district heating system or simply in an area. The most common is linear heat density which is defined as consumption per trench length. Linear heat demand density is also used and is defined as peak load per trench length. Another alternative is to state heat demand or heat consumption per unit of area, e.g. plot area or the total acreage of an area.

Heat density is a key parameter in evaluating the applicability and viability of district heating; the higher the heat density, in theory, the lower the capital cost per unit of heat energy supplied and the lower the distribution losses, again per unit of heat.

Government policies and directives, such as the European Energy Performance of Buildings Directive, invariably require increases in the standards of energy efficiency for buildings. This means that the heat demand of future buildings will be significantly reduced, with corresponding reductions in related heat density.

4.1.2 Dwelling density

Dwelling density is defined as the number of dwellings per unit of area; later in this report, dwellings per hectare. It has a relationship to linear heat density but as the specific heat consumption of dwellings differs significantly and energy efficiency keeps improving, the linear heat density can vary somewhat for any given dwelling density. When dwellings in an area with district heating are renovated to be more energy efficient, the linear heat density drops while the dwelling density remains the same. The concept of dwelling density is, however, a useful concept to describe an area on a more general level, even if additional calculations are needed to evaluate the district heating potential.

4.2 District heating vs. individual heating

Installing a DH scheme invariably involves a major capital investment but can provide low annual running costs. The capital cost per dwelling depends on a range of factors but particularly on how close together the dwellings are. For example, whereas the pipe length per dwelling is least for flats, for individual houses it may be substantially increased.

In contrast, individual heating solutions often have relatively low capital costs, but higher running costs. Additionally, they would typically have to be replaced at least once during the equivalent lifetime of a district heating network.

The decision on whether to choose district heating or individual solutions will often depend on which approach has the lowest whole life cost. Whole life costing is the evaluation of options taking into account all capital costs, running costs and replacement costs, discounted back to current values. The final choice of system may ultimately also take into account other indirect benefits e.g. environmental effects.

4.3 New and old district heating areas

The most significant difference between new and old district heating systems is obvious, the size. Old and developed systems tend to be extensive covering most dwellings in the area while new systems are often small networks, either separated local heating systems or fledgling district heating systems with growth potential. A third option is a local system to be absorbed into a larger system in the future. The district heating systems in Finland, Sweden and Denmark are mainly fairly developed although small scale systems also exist, but in United Kingdom the smaller systems are more common.

The extension of large scale systems often takes place in areas with lower heat density and thus areas that are less attractive financially. In this case, finding the borderline where district heating is feasible is strongly related to the distance from the main system. In these systems, the production costs are usually lower due to larger combined heat and power plants supplying the heat.

Smaller separated areas need their own dedicated production but have no need for long connection pipes to the rest of the system. Usually these systems consist of a collection of dwellings close to each other surrounded with areas of lower or non-existent heat density. If a larger district heating system is located nearby, the area might later be connected to a larger network if the surrounding areas are built up.

4.4 Examples of borderline between DH and individual house heating

A few examples of borderline areas where the economic feasibility of an efficient district heating network is challenged by individual house heating systems are presented in the following pages. The aim is to give an impression of this borderline in different low heat density developments. In the Finnish example of a detached house area in Marja-Vantaa in Southern Finland, a district heating system with and without a connection to a larger main district heating network is compared to different individual house heating systems. The UK case studies present three housing developments of different dwelling densities for which three energy efficiency scenarios, standard, low energy and passive, are considered. Characteristics, such as relative heat losses, of each case are presented and the evaluation of the alternatives is done by comparing net present costs and values.

4.4.1 A detached house area in Southern Finland

Marja-Vantaa is a new development in the Helsinki metropolitan area to be built gradually until 2030. The plans include over 3 000 000 m^2 of floor area in residential, commercial and public buildings. While the central part of the area consists strictly of multi-storey buildings well suited for district heating, there are some older detached house areas just outside the central area with possible district heating potential. One of these areas was selected for closer examination. The potential of the area is, however, quite limited and the possible role and operation of this low heat density area in the overall district heating system is discussed below.

The investigation of the selected district heating setup was conducted by year long simulation of the district heating network using separately modelled hourly heating and domestic hot water consumptions for the buildings. This approach not only gave accurate data on heat losses on annual level and its variation during the year, but also pointed out operational challenges on a practical level by revealing the difficulties of maintaining the temperature level in the detached houses part of the network in summertime when the district heating load consists only of domestic hot water based consumption.

The attributes describing the area investigated are listed below in Table 9.

The initial values used in simulation for the detached house area are presented below. Figure 63 illustrates the total heat demand of the area, Figure 64 the share of domestic hot water of total demand and Figure 65 the monthly consumption divided into heating and domestic hot water.

Table 9. Characteristics of the studied detached house area in Marja-Vantaa.

Attribute	Value
Estimated area	6.27 ha
Number of dwellings	56 dwellings
Dwelling density	8.9 dwellings/ha
Average pipe length per dwelling (250 m connection pipe)	42.6 m/dwelling
Heat density (plot area)	22.3 kWh/m^2
Linear heat density (pipe)	0.59 MWh/m
Maximum demand per pipe length	0.28 kW/m

The total consumption in a year is 1 400 MWh, domestic hot water based demand being 280 MWh (20 % of total consumption).

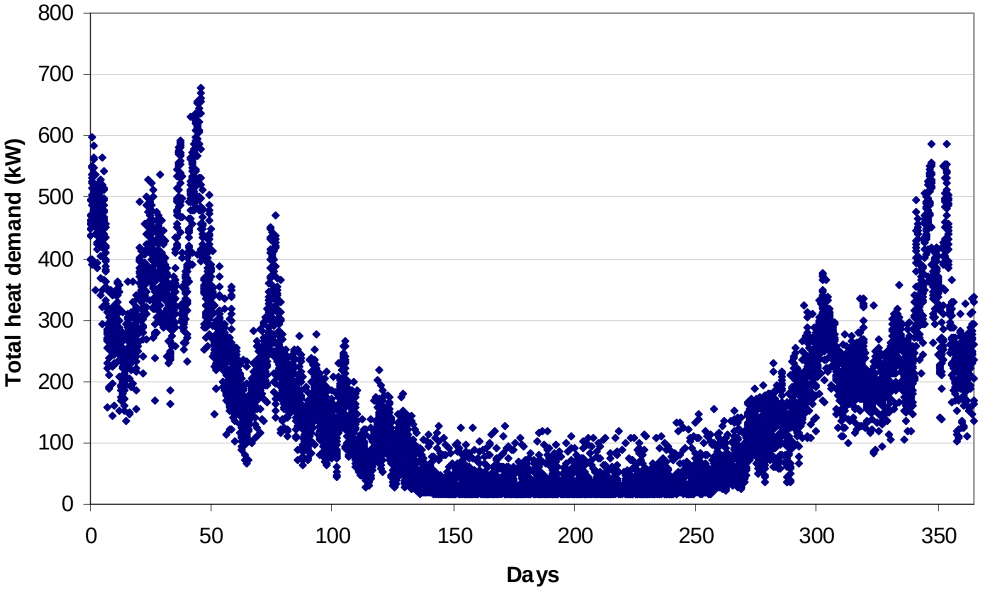


Figure 63. Total heat demand of the detached house area.

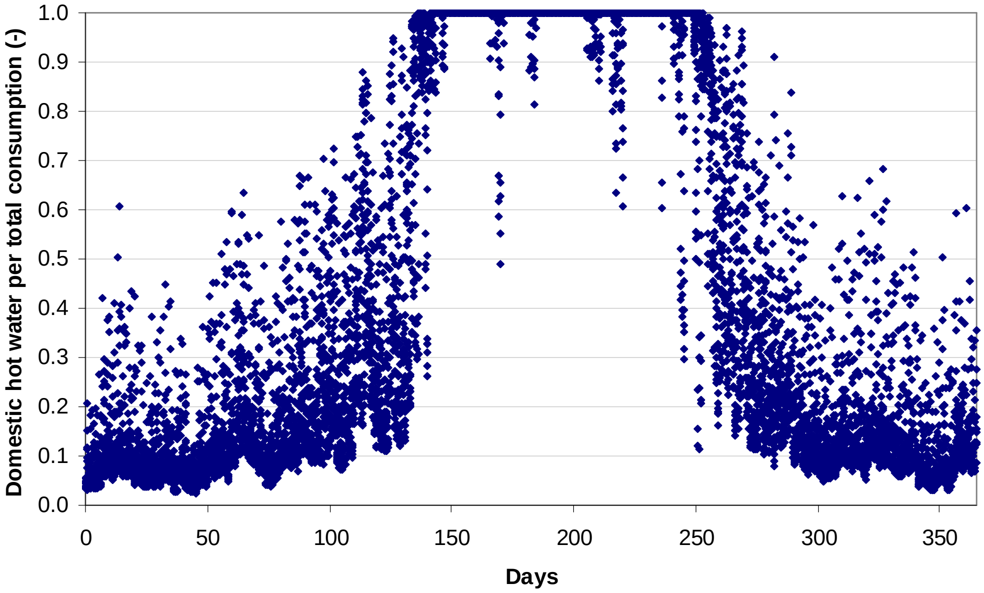


Figure 64. The share of domestic hot water of total consumption.

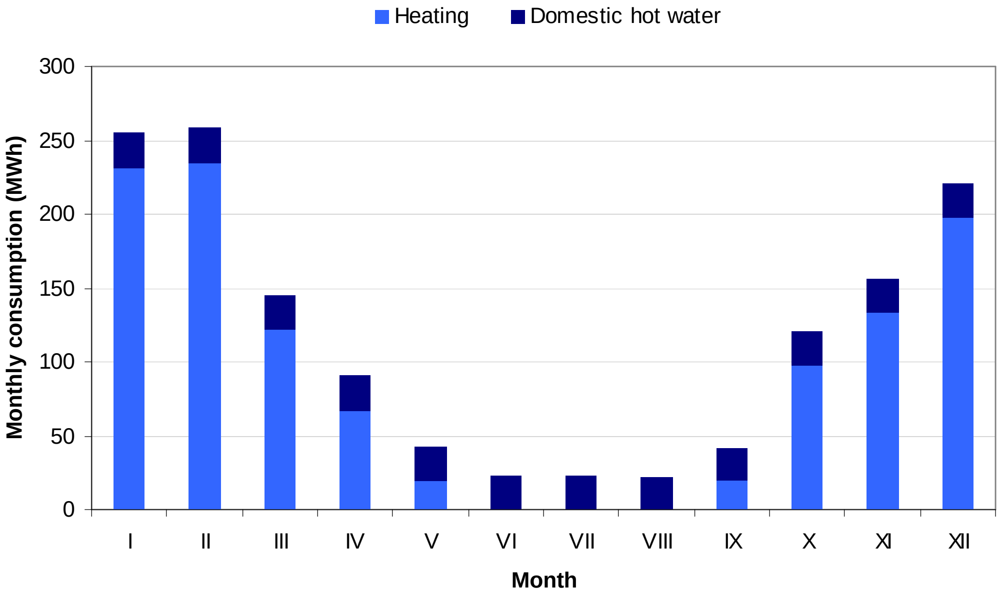


Figure 65. Monthly heat consumption divided into heating and domestic hot water.

The results of the simulation of the detached house area in Marja-Vantaa can be seen in the figures below. The heat losses for the detached house area are 183 MWh, which translates to heat losses per production ratio of 0.12. The monthly ratios are presented in Figure 66.

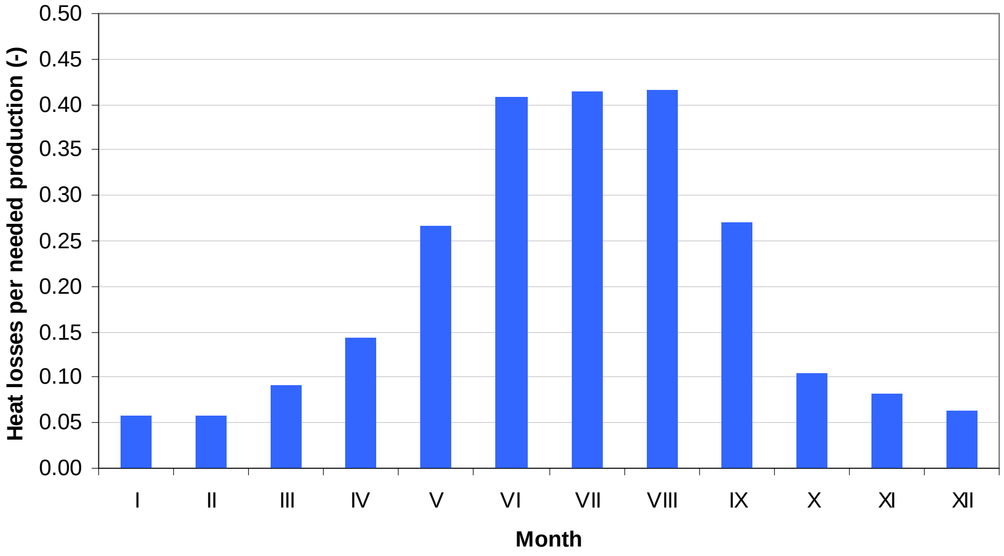


Figure 66. Relative heat losses, i.e. the ratio of heat losses to the sum of heat losses and heat demand.

The investment costs of district heating pipes divided into material, construction and piping work costs (Energy Industry 2010) for twin pipes with series IV insulation are shown in Figure 67. Using these prices and information on the pipe size distribution of the detached house area (Figure 68) the total network investment cost of about 239 000 € can be calculated. In this number, the connecting pipeline between the area and the main district heating network is not taken into account. The investment cost for the connecting pipeline (DN 65) is approximately 34 000 €, 137 000 € or 342 000 € as the distance from the main network grows from 250 m through 1 000 m to 2 500 m.

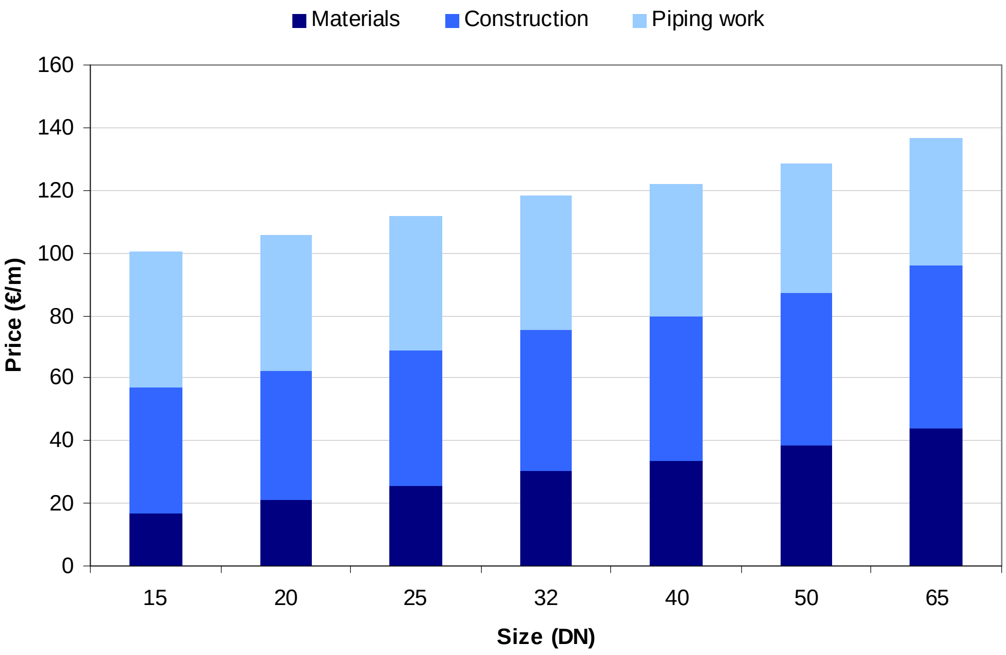


Figure 67. Investment costs of district heating pipes divided into material, construction and piping work costs.

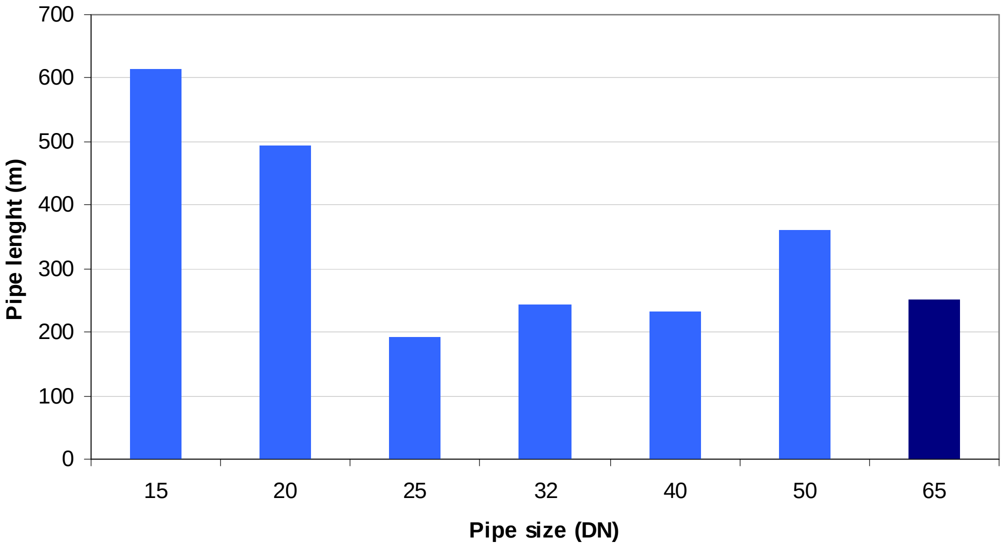


Figure 68. The pipe size distribution in the detached house area, the connection pipe in dark blue.

For calculating the revenues to the district heating company, the district heating pricing by Vantaa Energia energy company was used. The pricing for customers in the detached house area is presented in Table 10 below.

Table 10. District heating prices for the detached area.

Description	**Price**
Connection fee	3 950 €
Basic yearly fee	441.6 €/a
Energy fee	38.31 €/MWh

The costs for the district heating system were calculated as follows. Network investment is done in year 0 and the revenues and running costs are discounted for every year until 25th year and summed. Running costs include production costs (25 €/MWh for district heating, 30 €/MWh for local production), heat losses, pumping and maintenance (2 % of the investment). Investment in production facilities is assumed to be 288 €/kW for large CHP production and 428 €/kW for a local boiler. Other investment costs come from the area network and the possible connection pipeline to the main district heating network. These assumptions lead to results presented in Figure 69 and

Figure 70. In these figures, the distance of the detached house area is varied and compared to an alternative with a local boiler.

The heat losses increased as the length of the connection pipe grows, but this does not show in the results, e.g. Figure 69, where all the lines representing net present values are almost parallel. It can be seen from the figures that the crossover between a reasonable stand-alone local network and a feasible extension of an existing district heating system takes place approximately when the distance grows over 1 km.

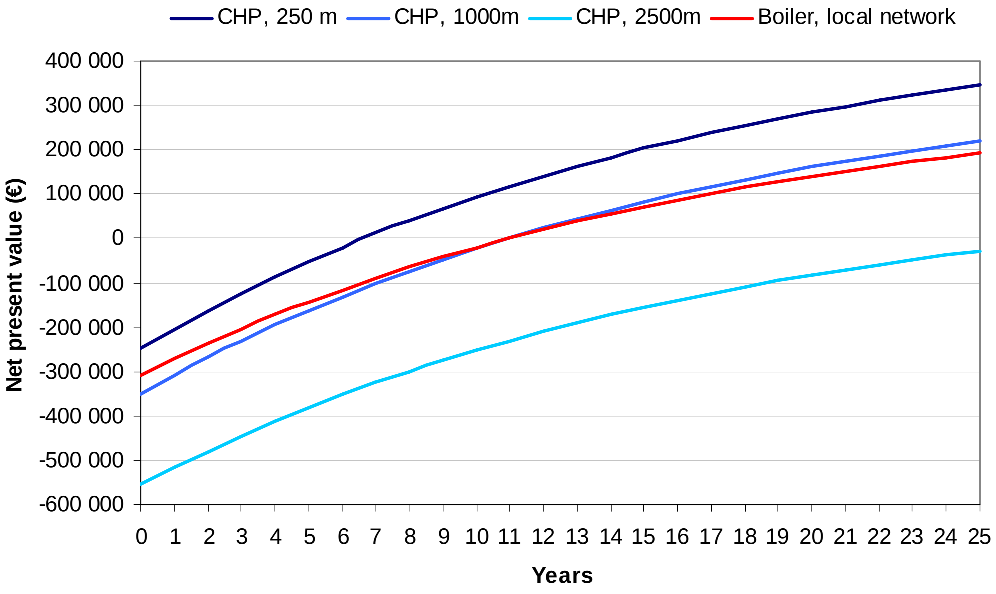


Figure 69. Net present value for the four alternatives.

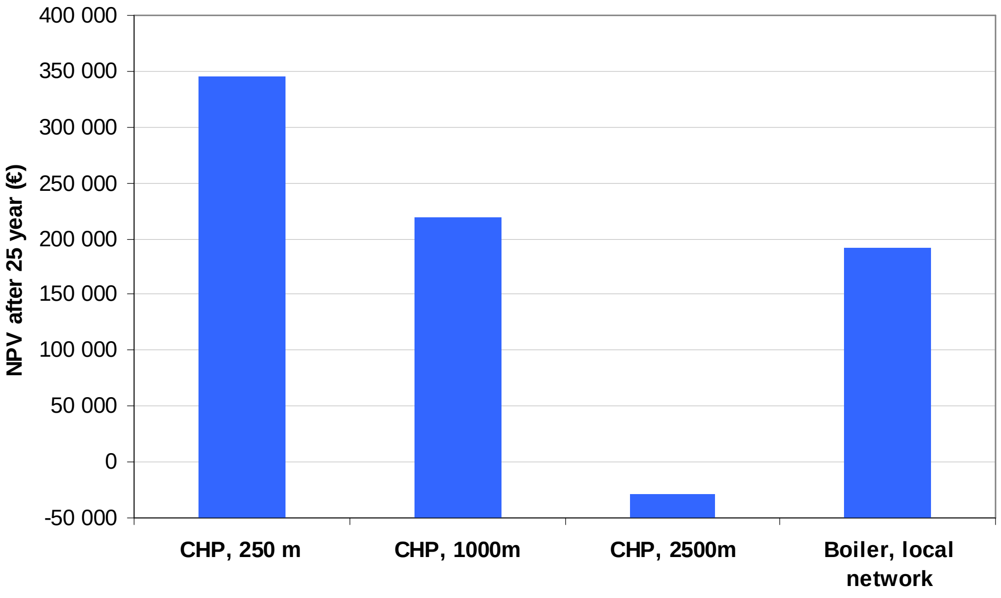


Figure 70. Net present value at 25 years for the four alternatives.

The calculations above were done from the producer point of view, but a different perspective is required to compare the overall profitability of individual and centralised heating solutions from the consumer point of view. The following Figure 71 and Figure 72 present the net present cost of electricity, oil and pellet based heating compared to the centralised heating alternatives presented above. The district heating related alternatives, boiler with a local network and plain district heating are quite different. For the local network, investment for the distribution system and the boiler is included with appropriate radiators, heat exchangers and piping, but for plain district heating, the investment cost include aforementioned consumer side equipment and the district heating connection fee.

It can be seen that the lowest net present cost is achieved with ground heat pump followed closely by district heating either by dedicated production with a local network or as an extension to a larger district heating network. The highest net present costs by a margin are in oil heating, which has the yearly running costs comparable to electric heating. What are interesting in Figure 71 are the crossover points, e.g. electrical heating remains the most affordable solution until 7th year and the period between year 14 and 16 when the ground heat pump becomes more cost effective than the district heating based solutions.

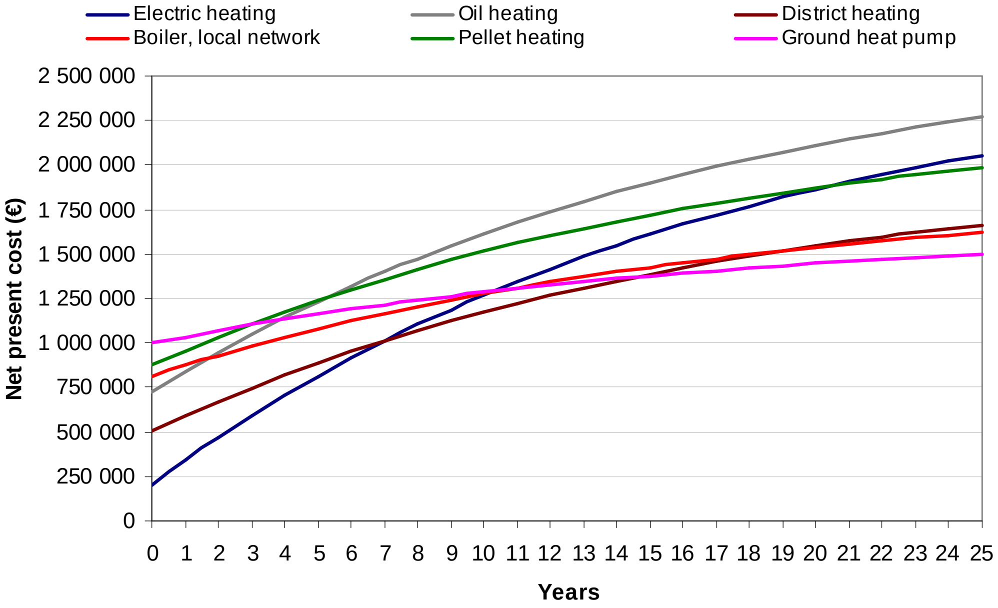


Figure 71. Net present costs for four centralised and three individual heating alternatives.

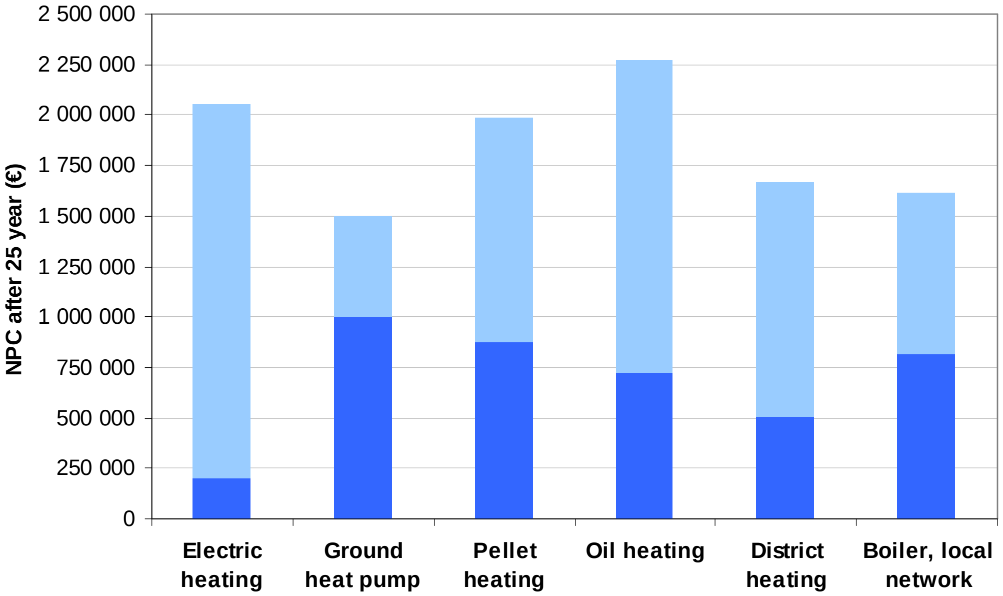


Figure 72. Net present costs at 25 years for the alternatives, separated into running cost (light blue) and investment.

Calculations behind the above figures require information on the investment sizes for house specific heating systems as well as energy prices. These are listed below in Table 11. The investment for radiators and piping is included in pellet, oil and district heating. All the prices, except district heating, are from a Finnish expert company providing information concerning energy efficiency etc. for public administration, businesses, communities and consumers (Motiva 2010).

Maintenance costs for other heating solution than district heating are 0.2 %, 3 % and 4 % for electrical, both for oil and ground heat pump, and for pellet heating, respectively. A constant value for coefficient of performance, 4, is used for the ground heat pump. House specific boiler efficiency is 0.8 both for the oil and pellet boilers.

As the choice of assumptions greatly influences the results, the interpretation of the results remains to be difficult. The assumptions used here are, however, quite reasonable even if not fully applicable to different countries and regions.

Table 11. Investments for individual heating systems and energy prices for electricity oil and pellets. (Motiva 2010)

Description	**Value**	**Unit**
Electric heating	3 647	€/house
Pellet heating	15 592	€/house
Oil heating	12 912	€/house
Ground heat pump	17 820	€/house
Radiators and piping	5 070	€/house
District heating connection	3 950	€/house
District heating yearly basic fee	441.6	€/house/a
Electricity price	103.0	€/MWh
District heating energy price	38.3	€/MWh
Oil price	56.7	€/MWh
Pellet price	47.8	€/MWh

One aspect not taken into account in the results is the residual value of the alternatives. This can be difficult to evaluate and varies most definitely between the chosen heating solutions.

4.4.2 Consideration of new district heating networks for three housing developments in the United Kingdom

Three case studies representative of UK new build housing developments have been considered. These represent developments of different dwelling densities, from 15 to 60 dwellings per hectare.

Development 1 is representative of a detached housing development with a dwelling density of 15 dw/ha (see Figure 73). Development 2 is representative of a development that includes detached and semidetached houses and some maisonettes with a dwelling density of 30 dw/ha (see Figure 74). Development 3 is representative of a series of blocks of flats with a dwelling density of 60 dw/ha.

Figure 73. Development 1.

Figure 74. Development 2.

Table 12 below characterises the heat demand density and the modelled heat networks (see further details below) for each of the 3 developments considered and for 3 different scenarios of energy efficiency:

- New dwelling: this is representative of current building regulations
- Low energy dwelling: representative of 30 % decrease in heating consumption relative to new built
- Passive House standard: equivalent to 15 kWh/m^2 per annum for space heating plus domestic hot water

Table 12. Characterisation of district heating network for the 3 housing developments investigated.

	Development 1	**Development 2**	**Development 3**
Estimated area (ha)	2.7	3	6.8
Number of dwellings	42	96	420
Density (dw/ha)	15.45	31.53	61.4
Pipe average length per dwelling	20.09	12.46	1.54
New dwelling			
Area heat density kWh/m^2 land	13.76	23.07	31.16
Linear heat density MWh/m trench	0.44	0.59	3.3
Low energy dwelling (circa 2013)			
Area heat density kWh/m^2 land	9.74	16.37	22.81
Linear heat density MWh/m trench	0.31	0.42	2.41
Equivalent to Passive House Standard			
Area heat density kWh/m^2 land	7.36	13.23	19.16
Linear heat density MWh/m trench	0.24	0.34	2.03

For each of the three developments, new district heating networks were designed using modelling software. A summary of the main assumptions used in designing the networks is shown in Table 13 below. Although not commonly used in the UK, twin pipes were assumed to be used due to their lower heat losses than single pipes. Additionally lower flow/return temperatures than traditionally adopted in the UK have been assumed. These steps go some way beyond usual practice in the UK, although there may be additional ways of further optimising the system design.

Table 13. Network modelling inputs.

Design load per dwelling	25 kW, distribution pipes sized for 50% of this
Pipes	Steel twin pipes
Service pipes	DN15
Design supply temp	70 °C
Design return temp	40 °C
Design ground temp	10 °C
Design sizing criteria	2 m/s

By way of example, Figure 75 below shows the network layout for development 1. Network layouts were also devised in relation to developments 2 and 3.

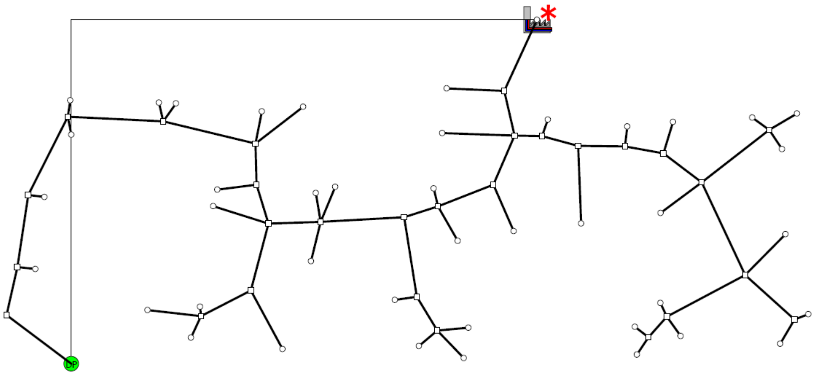


Figure 75. Network layout for Development 1.

Figure 76 below shows the modelled relative heat distribution losses calculated for the three residential developments investigated in this work and for different levels of energy efficiency standards.

As expected, the following can be concluded:

- the percentage heat losses increase the lower the dwelling density
- for a development with the same dwelling density, the percentage heat losses increase the more energy efficient the dwellings are, i.e. the district heating distribution losses increase the lower the heat density is
- above a certain linear heat density, the heat distribution losses are less sensitive to changes in the linear heat density

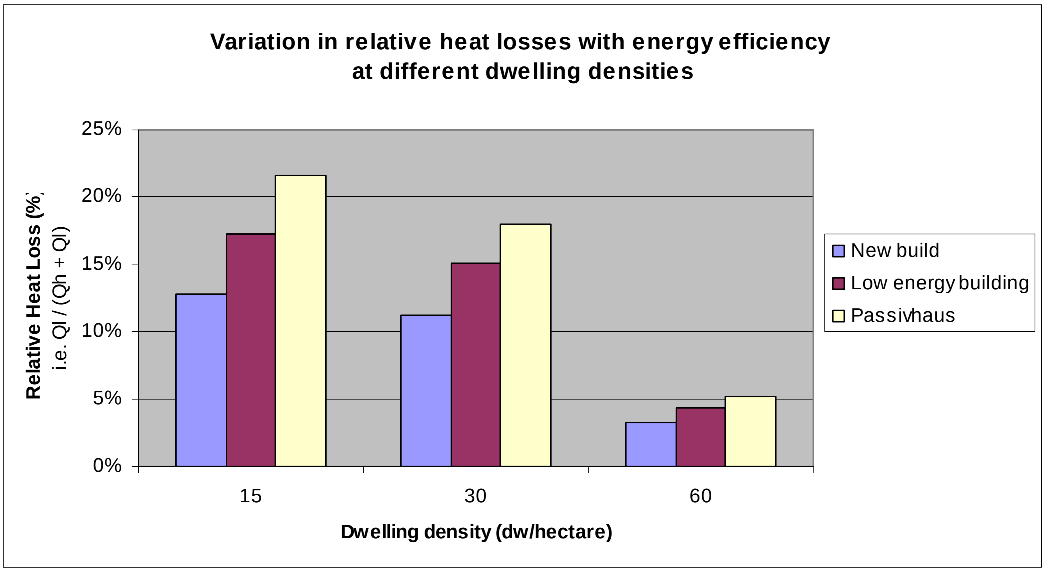


Figure 76. Variation of relative heat losses with energy efficiency at different dwelling densities

Figure 77 shows the relative heat losses as a function of linear heat density. While the relative heat loss will, in practice, vary due to many individual factors, e.g. level of pipe work insulation, it can be seen that there is a clear relationship between the relative heat losses and linear heat density. As the linear heat density drops below circa 0.5 MWh/m, in these examples, the relative heat losses start to rise at a much greater rate.

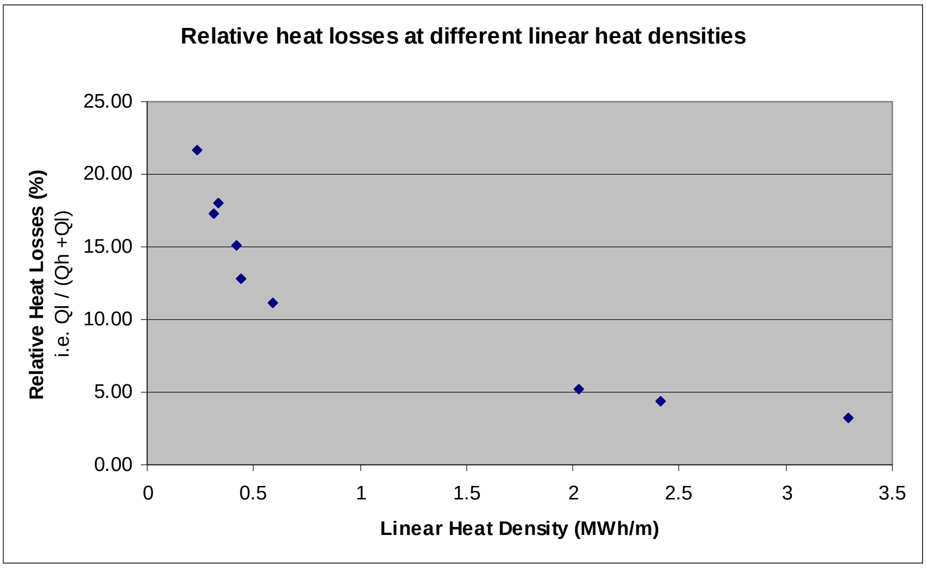


Figure 77. Heat distribution losses relative to linear heat density [for twin pipe system].

In relation to the three developments, net present cost (NPC) calculations have been undertaken for both district heating and individual heating solutions. In each case, the capital cost, fuel and maintenance costs over the life time of the equipment have been taken into account and discounted back to present day prices. For both the district heating and the individual heating system, 100 % of the space heating and domestic hot water requirements were assumed to be met.

The individual heating solution was assumed to be air source heat pumps (ASHP) with a seasonal coefficient of performance of 2.5. For each of the development's examined, the ASHP was assumed to have the same capital cost per dwelling, as shown in Table 16 below; this excludes internal dwelling heating systems e.g. radiators and pipes. The price for electricity used by the ASHP was assumed to be 14.2 cents/kWh.

The capital costs of the district heating have been derived by applying typical installed costs for different pipe diameters, supplied by a leading UK pipe supplier, to the particular designs for each of the developments examined. The capital costs shown in Table 14 below include the energy centre, plant installed in the energy centre, the heat network and the hydraulic interface units (HIU). As for the individual systems, the costs exclude the internal dwelling heating systems e.g. radiators. The fuel cost for the biomass boilers assumed to serve the district heating was 2.7 cents/kWh.

Table 14. Investment Costs for District Heating and Individual Systems (both exclude dwelling internals e.g. pipes downstream of the Hydraulic Interface Unit)

	Installed Cost per Dwelling
District Heating for Development 1	17 452 €
District Heating for Development 2	12 833 €
District Heating for Development 3	6 479 €
Air Source Heat Pump	4 248 €

The Figures 78, 79 and 80 below show the NPC of the heat delivered for the three developments investigated. The following is concluded:

- at low dwelling (heat) density the cost of individual solutions can be less than district heating
- for current new build developments once you move to higher dwelling densities (e.g. blocks of flats), DH can provide a more economic approach relative to individual solutions

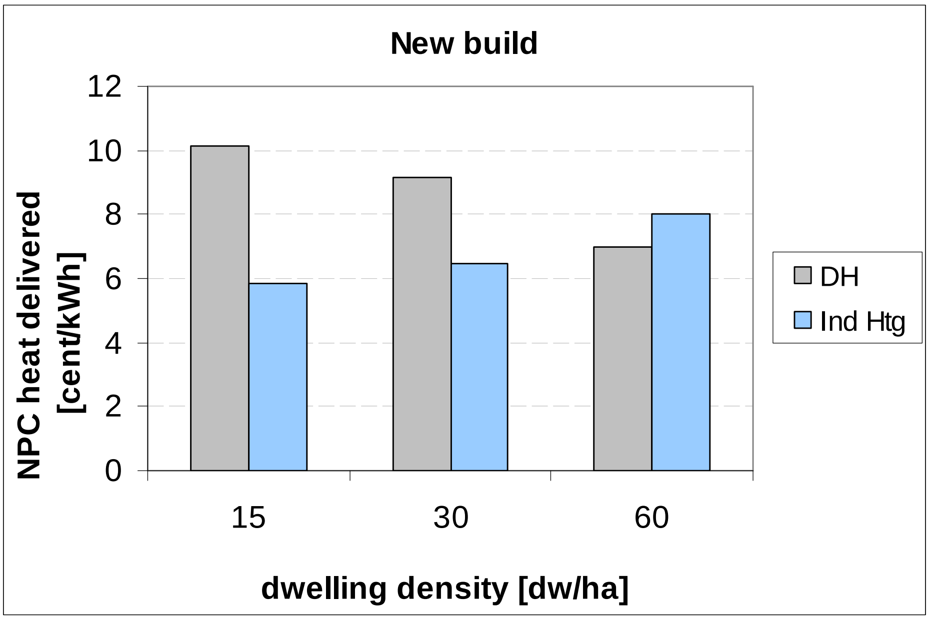


Figure 78. NPC of delivered heat from DH and individual systems for developments of different dwelling density.

As shown in the Figure below, the NPC of the heat delivered by DH relative to individual solutions has also been investigated in the context of very low energy buildings. It can be seen how the more efficient the buildings are, the higher is the NPC of the heat delivered.

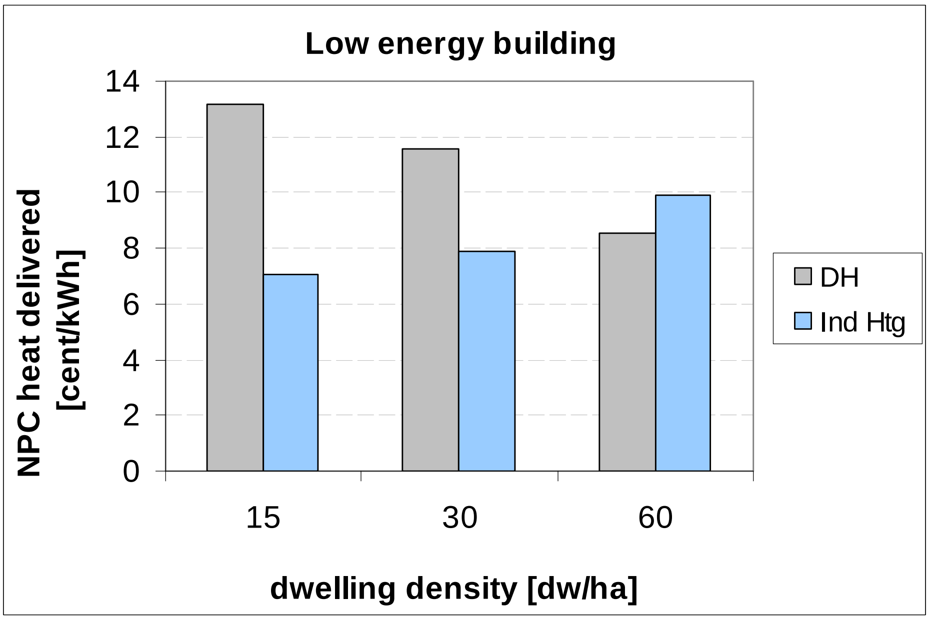


Figure 79. Cost of heat delivered.

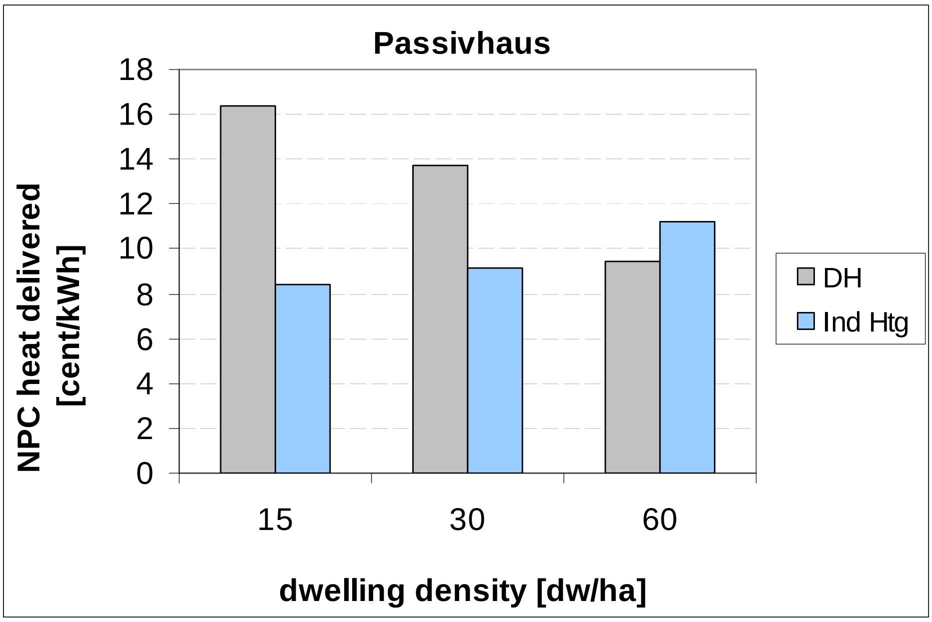


Figure 80. Cost of heat delivered.

The Figures 81, 82 and 83 below show a detailed breakdown of the NPC of the heat delivered for the three developments of different dwelling density over 25 years. It can be seen that:

- the capital cost per dwelling for the DH scenario are higher for all dwelling densities
- the running costs for the DH scenario are lower for all the developments looked at
- it is only for the higher density development (above 60 dw/h) that the running cost for the DH scenario are low enough to compensate for the higher capital cost so that at the end of the 25 years the cost of the heat delivered with the DH scenario is lower relative to the individual heating solutions

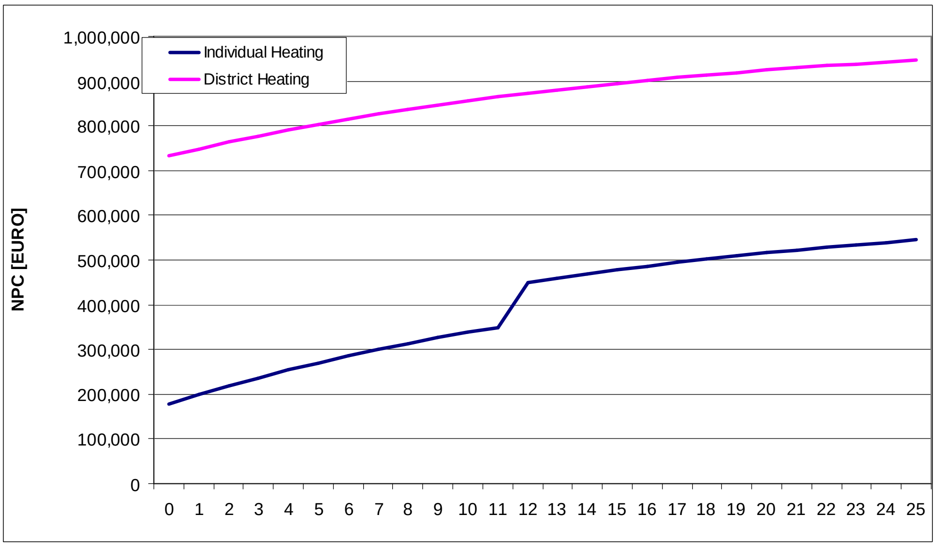


Figure 81. 15 dw/ha new build.

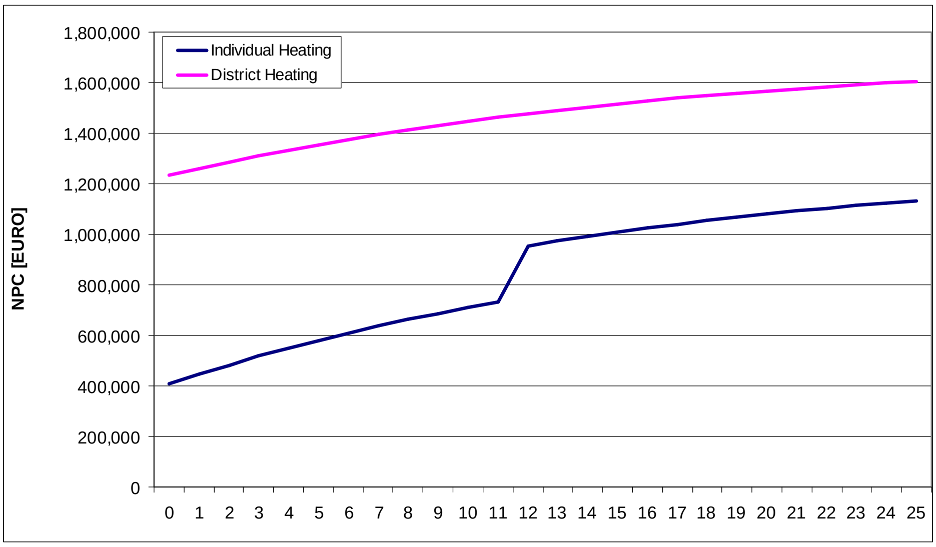


Figure 82. 30 dw/ha new build.

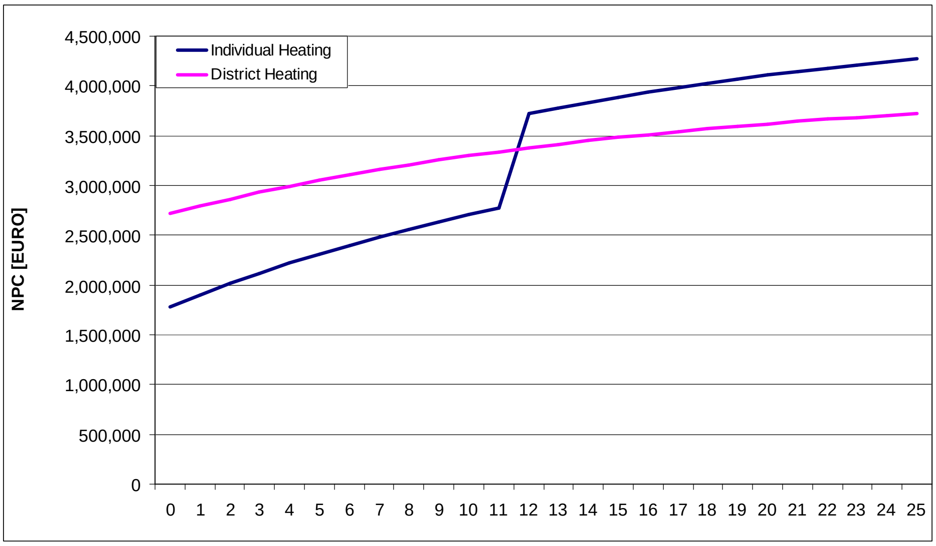


Figure 83. 60 dw/ha new build.

Figure 84 and Figure 85 below show a relationship between the linear heat density and the NPC of heat delivered. It can be seen how for the lower linear heat densities the NPC of the heat delivered with DH is higher than the individual solutions – this is due to the higher capital costs associated with the DH system and higher running costs (higher heat losses). For higher linear heat densities, DH is the most economic approach – although it has higher capital costs it has lower running cost.

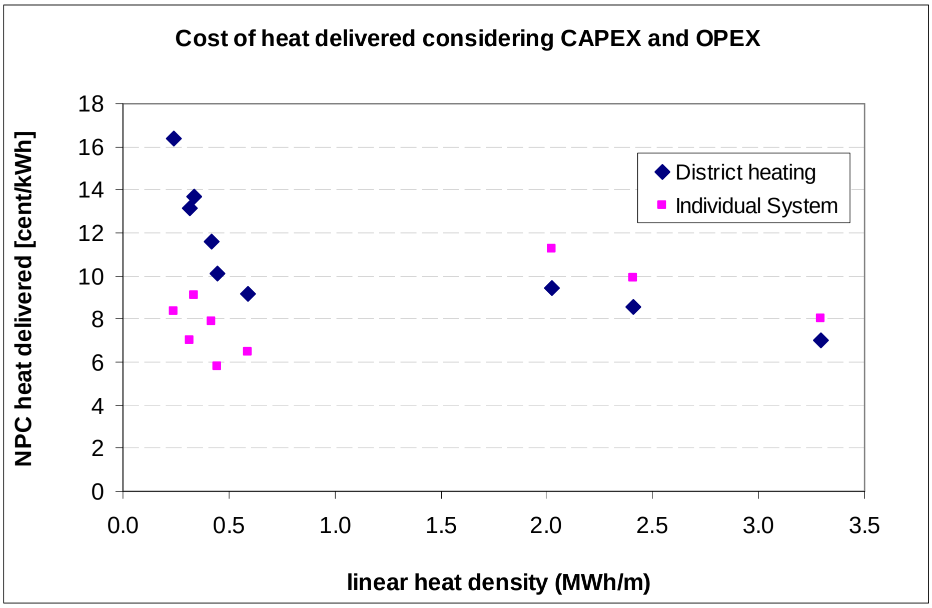


Figure 84. Relation between cost of heat delivered and linear heat density. Both CAPEX and OPEX considered.

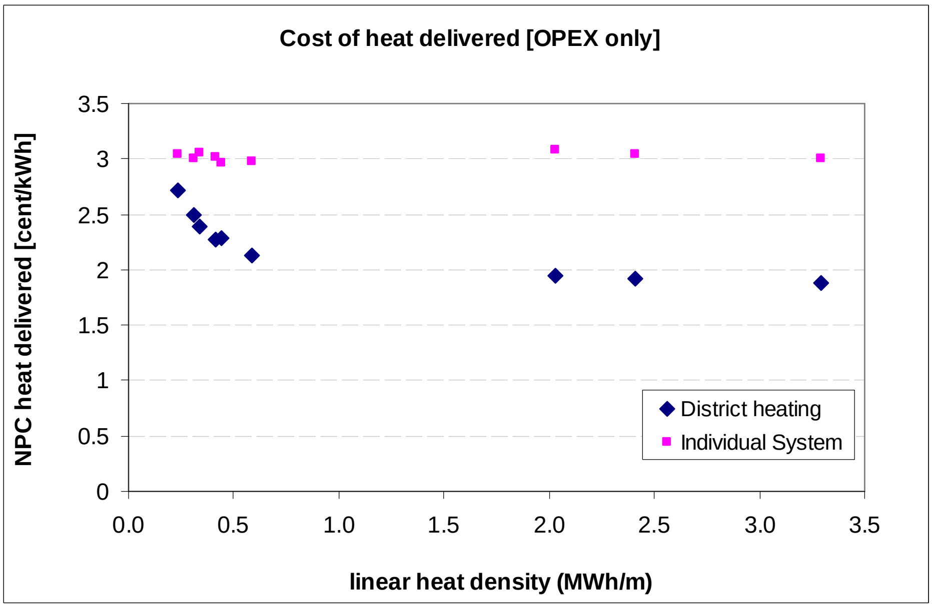


Figure 85. Relation between cost of heat delivered and linear heat density, only OPEX considered.

4.5 Discussion of the impact of Carbon Reduction Targets on the Borderline

District heating offers a fuel flexible mechanism for facilitating the use of a range of different technologies. As such it provides a vehicle for adopting low and zero carbon fuels such as biomass. This can provide low carbon heat supplies, helping to meet carbon reduction targets set by governments, particularly where the use of top-up fossil fuels are minimised.

4.5.1 Plant emissions and GHG-savings

The emissions from a plant are dependant on the fuel going into the plant as well as how the plant is run with the efficiency limits set by chosen technology. Life cycle analyses have shown that gathering, chipping and transportation of biomass corresponds to only 3-5 percent of the fuels energy content. In Western Europe the assist energy for natural gas is about 5 percent. However, the costs associated with processing and transporting the biomass can be significant.

Table 15 lists the CO_2 specific emissions by fuels in Finland and electricity in participating countries.

Table 15. CO_{2eq}- emissions for different fuels and produced electricity (Statistics Finland 2009)

Fuel	CO_2 emissions, kg CO_{2eq}/MWh
Wood chips	0
Coal	340
Natural gas	202
Heavy fuel oil	279
Electricity, Finland	240
Electricity, Denmark(*	565
Electricity, UK(*	506
Electricity, Sweden(*	30
Electricity, Norway(*	3
Electricity, USA(*	572
Electricity, Canada(*	218

(2007, cell: Graus, W, Worrel,E.*

A wood fuel will normally not necessitate a system for acid reduction. Any measurable levels of dioxins, mercury or other substances are not anticipated unlike in waste incineration.

Wood-based solid biomass does not normally cause in-furnace problems for heating plants and low efficiency CHP units. However, if the process efficiency is maximized, i.e. steam (>500 °C) and furnace temperatures are raised, the presence of corrosive compounds can cause problems. This problem can be solved by co-firing with fossil fuels or, if the use of fossil fuels is out of the question, by additives that react with the main source of corrosion, chlorine, preventing the harmful corrosive reaction between Cl and the super heater tubes.

Table 16 contains specific emissions (g/MWh) of dust, HCl, CO, SO_2, and NO_x for a typical small-scale (12 MW thermal) biomass CHP plant. The emission values are also presented as mg/m^3n, dg, 6% O_2, which stands for mg per normal (i.e. normal pressure and temperature) m^3, dry gas with 6% O_2 content. The fuel used is standard recycled wood, 23% H_2O. Values are based on energy supplied to plant (heat value of fuel).

Table 16. Example of calculated emissions from a typical Bio-energy CHP, 12 MW thermal

Emission	Value	
Substance	*(mg/$m^3_{n,}$ dg 6% O_2)*	*(g/MWh)*
Dust	21,2	65,5
HCl	30,1	110,8
CO	100	130,8
SO_2	93,4	122,1
NO_x	275,0	359,7
Fossil CO_2	0,0	0,0

4.5.2 Heat pump in the system

Where heat pumps are the alternative individual heating system to district heating, the carbon intensity of the heat supplied to the dwelling will depend on the assumed carbon intensity for grid supplied electricity, as well as the coefficient of performance of the heat pump. The carbon intensity of grid supplied electricity can vary widely depending on the fuel mix and efficiency of the power stations in any given country. There is also considerable uncertainty in projecting forward how the mix will develop in the future; this is particularly important as new heating equipment will, over their lifetime, use the future mix of plant, rather than that prevailing on the system at the time of investment. On the one hand, some commentators argue that grids will be decarbonised in the future; for example, through the increased use of technologies such as off-shore wind and nuclear power. On the other hand, others suggest that the widespread use of fossil fuels, such as gas and coal, will continue for a long time to come. It is, therefore, difficult to predict with any certainty the future carbon intensity of heat from the main alternative to district heating in new build developments.

The extent to which district heating is adopted at different densities will ultimately be influenced by the carbon savings it can deliver relative to the alternative methods of providing low carbon heating, as well as the relative cost at which heat can be supplied.

5 Integration of RES heat sources in district heating areas

5.1 A change in attitude

A remarkable change in the attitude towards solar energy and other kind of RES can be noticed. When a questionnaire was carried out in the beginning of the 1980'ties, Bøhm and Mikkelsen (1983), about the readiness to invest in solar heating plants among Danish DH companies, not many were positive to use this technology. Much has happened since then. The European Union has set targets for energy reductions, energy efficiency and for the integration of RES in community systems. These goals have been supported by the policy of national governments. In Denmark, for instance, DH companies have made agreements with the energy authority to save energy at the customer level of about 2 % per year towards 2020. Not only has these agreements made it both attractive and necessary to invest in RES technology for the DH-company but at the same time the attitude towards RES has change in a positive direction.

At present there is a huge interest to establish large solar heating plants and to use geothermal energy. This is true not only for Denmark but for many European countries. And for a long time biomass, primarily straw, has been used by approximately 200 DH companies in Denmark. Also in Sweden and Finland biomass is extensively used for heat and CHP production. In the majority of these DH systems, the RES-system is connected centrally to the (existing) DH plant.

5.2 Fuel taxes and tariffs, economic incentive and risks

However, problems are reported about fiscal issues and less convenient tariff structures which hinder the effective use of RES. Furthermore the economic interest rate used in economic calculations has a big influence on the economic profitability because a high interest rate can be less favourable for RES systems. This is due to the high investments compared to annual running costs for these plants. Problems may exist in all EU member states and the problems probably differ from country to country. Furthermore the subsidies and fuel duties change from time to time which makes it difficult to invest in a long term perspective.

Geothermal energy systems involve large investments and technical risks of not finding enough warm water (or as in a case in Iceland where volcanic activity destroyed the drilling). In Denmark the concession to drill for geothermal energy belonged to a state owned company so that the DH-companies could not drill themselves. The state owned company has recently given up the concession because economy was not good enough, leaving behind DH companies with big problem and a bill to pay for the drillings. Considering the risk and the large investment in geothermal systems some kind of risk handling and economic "safety net" from the government would be fair.

To give another example, electricity produced by wind mills can be used by DH companies in Denmark when there is "too much" electricity in the electricity system. If the electricity is used at this time to heat up energy storage, the DH-company will receive a subsidy in the form of a cheap electricity price. However, if the electricity instead is used by a heat pump, the electricity is more expensive. At present one large RES project in Denmark using solar collectors combined with a heat pump has been postponed because of too high electricity price for the heat pump. In short, there is a need to harmonise national fuel taxes and subsidies to achieve efficient DH systems based on RES.

A final example concerns individual heat pumps and peak loads. With the growing interest for using smaller heat pumps in single and multi-family houses, it is of economic interest to design the heat pump for a maximum power less than the design load of the building. In order to cope with the maximum load, DH can be used to supply the residual heat power. In Sweden, it has been discussed which price the DH company should charge for such a heat deliverance and it appears to be an area for a future new tariff structure of the DH company.

5.3 Status for RES integration

In a recent study supported by Intelligent Energy Europe a survey was made of the present use of RES in Europe and of the potential for integration of RES in DH systems, EcoHeatCool (2006). In the following some of the results will be presented here.

Figure 86 shows renewable and recycled shares in heat generated for DH systems in 2003.

The renewable share in heat generated was 14% during 2003. The renewable share is defined here as the sum of the shares for geothermal heat, solar heat, combustible renewable, and all waste. For details, cf. EcoHeatCool (2006).

For Denmark the production fuel mix from 1980 to 2008 is shown in Figure 87. For Finland and Sweden the production mix is shown in Figure 88 and Figure 89. It is quite evident that major changes have happen towards a bigger share of RES in the DH sector. However, as evaluated in the EcoHeatCool (2006) report, the potential of RES to be used by the DH sector is many times higher, Figure 90. Here five strategic heat source options (CHP, waste incineration, surplus heat, geothermal heat, and combustibles) are summarised and compared to the present DH production.

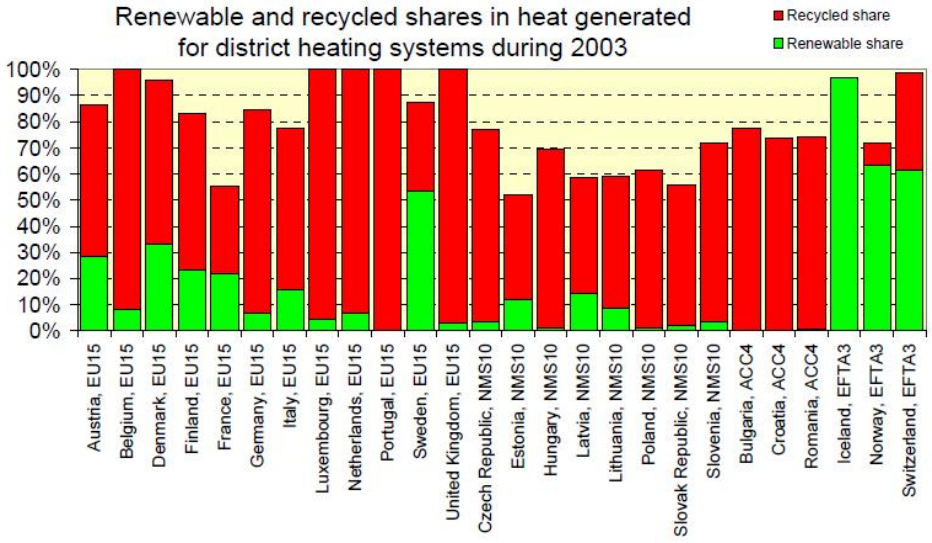


Figure 86. Share of renewables and recycling 2003, EcoHeatCool (2006). Recycled heat is defined as the sum of heat from fossil and nuclear CHP together with surplus heat recovered from industrial processes and with heat pumps.

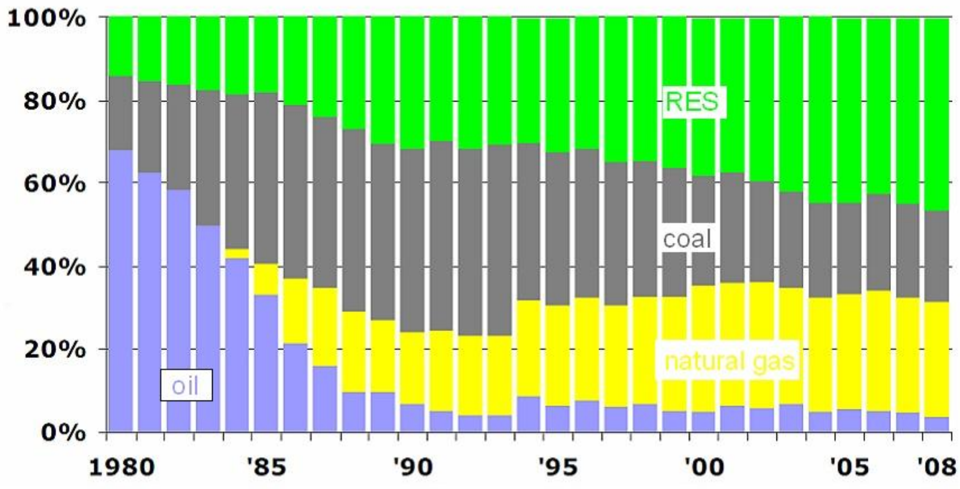


Figure 87. DH Fuel mix for DH production in Denmark 1980-2008, Danish Energy Authority (2010).

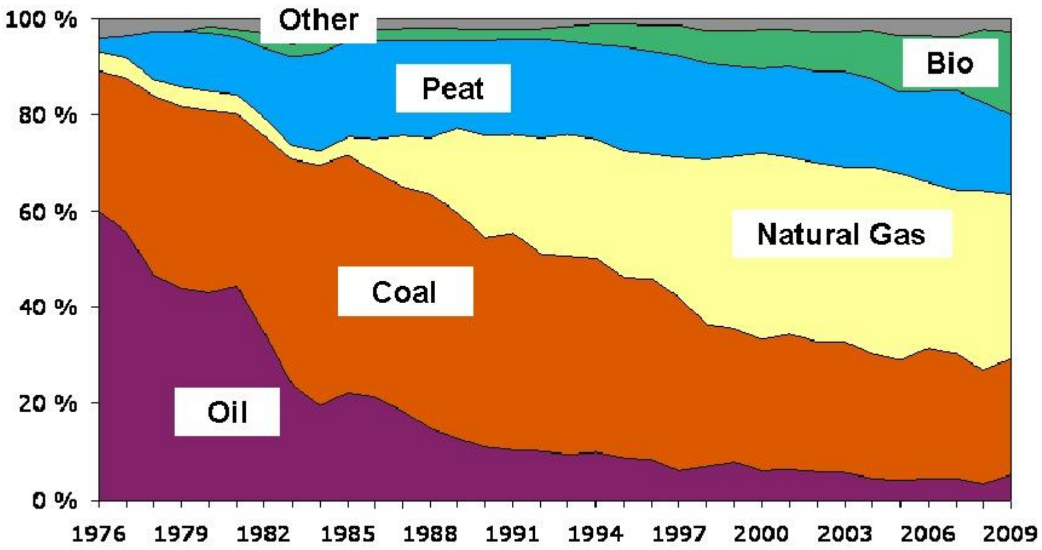


Figure 88. DH Fuel mix for DH production in Finland 1976-2009,(cell: Finnish Energy Industry/DH, 2010).

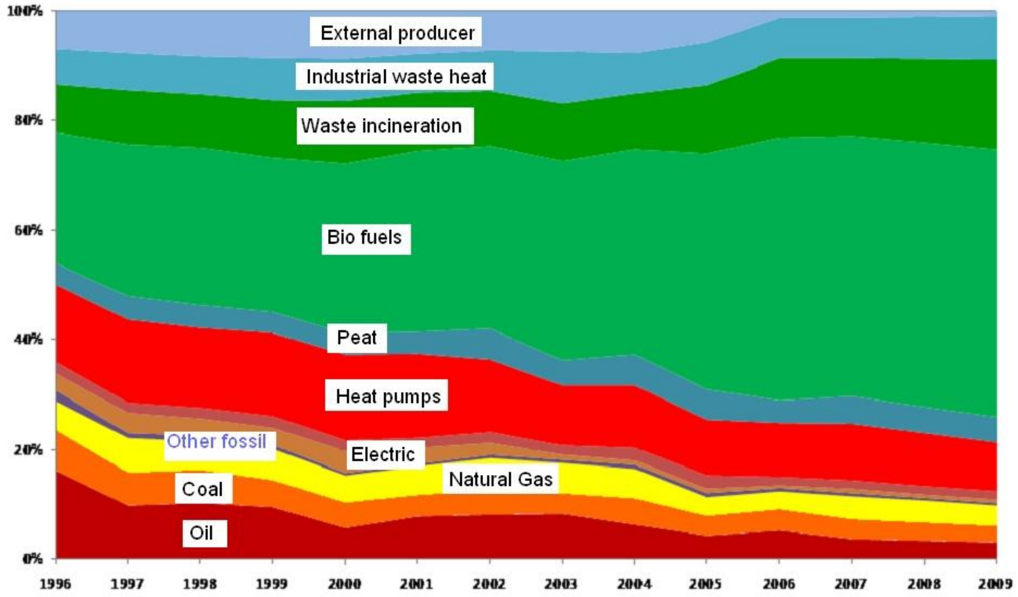


Figure 89. DH Fuel mix for DH production in Sweden 1996-2009. (Svensk Fjärrvärme 2010/UO)

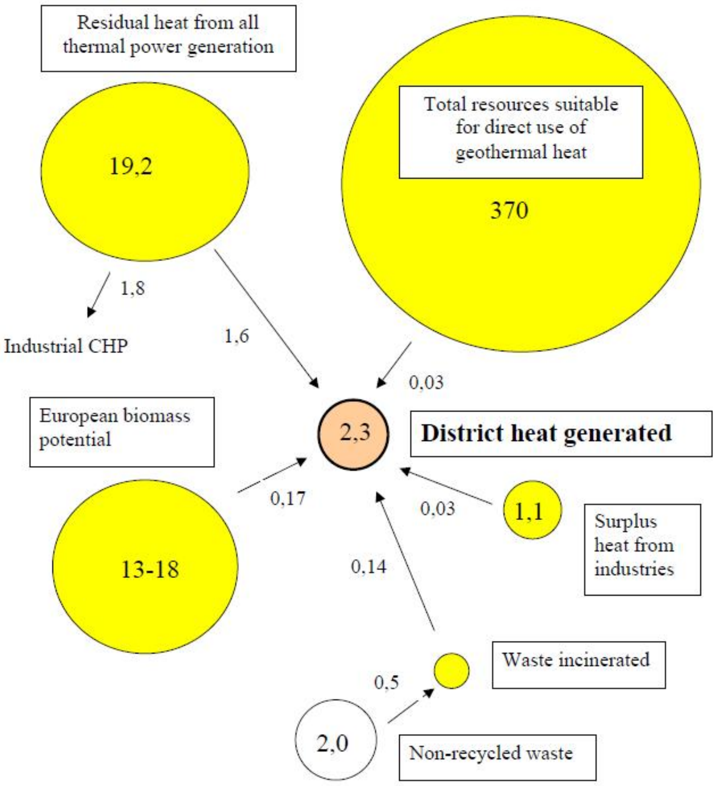


Figure 90. The potential of RES for the DH sector, EcoHeatCool (2006). Heat flows in EJ (1 EJ = 278 TWh) during 2003 for the target area of 32European countries. The five strategic heat source options (CHP, waste incineration, surplus heat from industries, geothermal heat and combustibles) are summarised and compared to the DH generated in 2003.

5.3.1 Solar heating

There is a growing interest to use solar collectors in DH systems, even in areas supplied by CHP. Less than 3 % of the solar thermal market in Europe is used in district heating systems, but these systems make the most of large-scale solar heating plants, /ESTTP (2009)/.

The first plants establish in the 1980'ies often had an advanced seasonal storage, like the plants at Studsvik and Lyckebo in Sweden. Figure 91 shows the Lyckebo plant supplying heat to 500 detached houses.

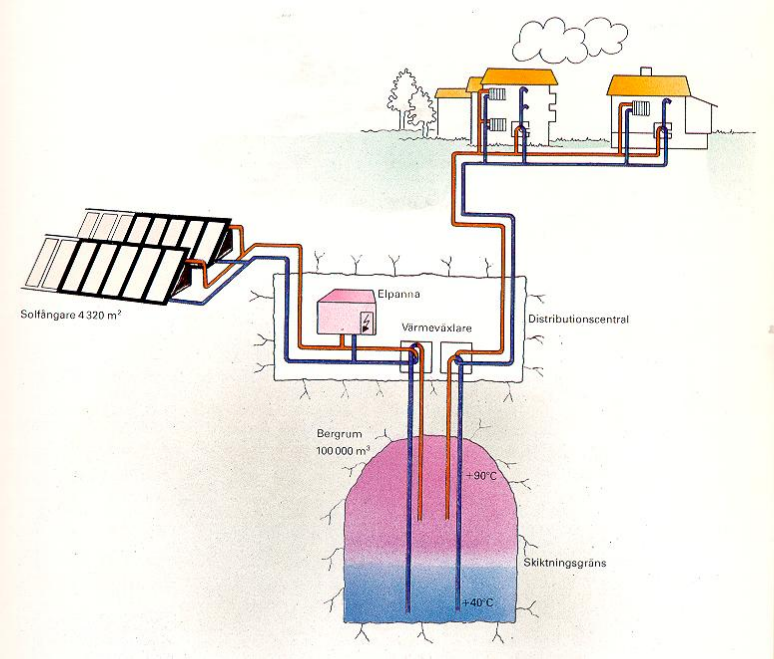


Figure 91. System scheme of the Lyckebo Solar Heating Plant, Sweden. Zinko (2009).

During the last 10-15 years the majority of plants have had ground mounted collector fields and a pressure less water tank for diurnal storage. Marstal is at present the largest system with 18 300 m^2 collector area, although a plant with 35 000 m^2 collector area is in preparation.

From an economic point of view it is attractive to establish the solar collector field on the ground, as shown in Figure 92, however, in some countries the high price for purchase of land can make it more attractive to place the collectors on the roofs of the buildings, cf. Section 5.5.2.

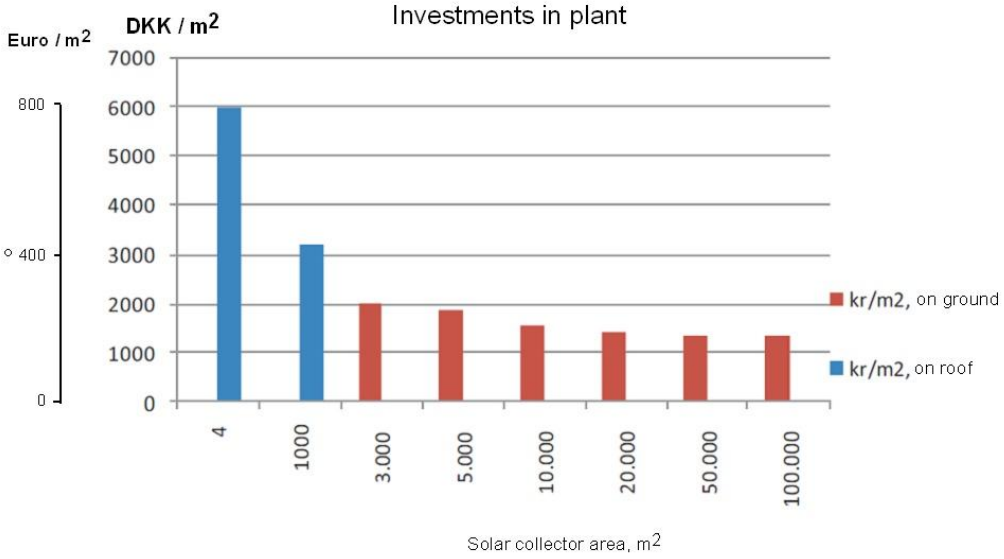


Figure 92. Investments in solar-DH plant, either on the roof of the buildings or on the ground, Ramboll (2010c).

Table 17 shows large Danish ground mounted solar DH plants. In autumn 2010 more than 115 000 m^2 solar collectors have been installed in Denmark. Large roof mounted solar plants are shown in table 18.

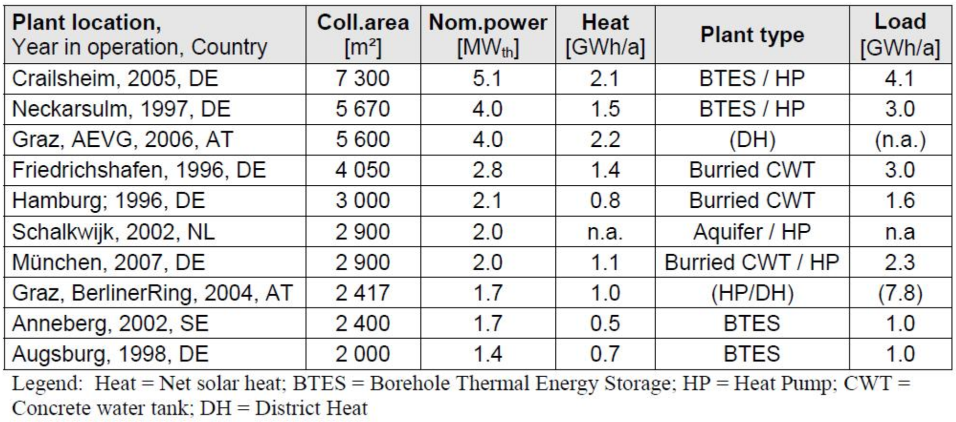
Information about existing solar heating plants can be obtained from the European Large-Scale Solar Heating Network ESTTP and the Solar District Heating take-off project, cf. the list of References.

Figure 93. Brædstrup DH plant with 8,000 m2 solar collectors. Photo Brædstrup Fjernvarme.

Table 17. Danish Solar District Heating plants. Partly based on information by PA. Sørensen, Planenergi (2009).

Danish Solar DH plants	**Built**	**Collector area, m^2**
Saltum	1988	1 005
Ry	1990	3 000
Marsta lI	1996	8 000
Ærøskøbing I	1998-2000	4 900
Rise, Ærø	2001	3 750
Nordby, Samsø	2001	2 500
Marstal II	2003	10 300 (18 300 in total)
Ulsted	2006	5 000
Brædstrup I	2007	8 000
Strandby	2008	8 000
Hillerød	2008	3 019
Sønderborg	2008	5 866
Tørring	2009	7 300
Gram	2009	10 073
Broager	2009	10 000
Ringkøbing	2010	15 000
Jægerspris	2010	10 000
Status autumn	**2010**	**115 700**
Ærøskøbing II	2010	2 000 (6 900 in total)
Brædstrup II	2010 (under const.)	8 000 (16 000 in total)
Dronninglund	2010	35 000
Marstal III	2014	15 000
Others in preparation	2010-2014	60 000

Table 18. Large roof mounted solar heating plants, Dalenbäck (2010).



Plant location, Year in operation, Country	**Coll.area** [m²]	**Nom.power** [MW$_{th}$]	**Heat** [GWh/a]	**Plant type**	**Load** [GWh/a]
Crailsheim, 2005, DE	7 300	5.1	2.1	BTES / HP	4.1
Neckarsulm, 1997, DE	5 670	4.0	1.5	BTES / HP	3.0
Graz, AEVG, 2006, AT	5 600	4.0	2.2	(DH)	(n.a.)
Friedrichshafen, 1996, DE	4 050	2.8	1.4	Burried CWT	3.0
Hamburg; 1996, DE	3 000	2.1	0.8	Burried CWT	1.6
Schalkwijk, 2002, NL	2 900	2.0	n.a.	Aquifer / HP	n.a
München, 2007, DE	2 900	2.0	1.1	Burried CWT / HP	2.3
Graz, BerlinerRing, 2004, AT	2 417	1.7	1.0	(HP/DH)	(7.8)
Anneberg, 2002, SE	2 400	1.7	0.5	BTES	1.0
Augsburg, 1998, DE	2 000	1.4	0.7	BTES	1.0

Legend: Heat = Net solar heat; BTES = Borehole Thermal Energy Storage; HP = Heat Pump; CWT = Concrete water tank; DH = District Heat

Although most solar heating plants have built in Denmark in recent years, the solar potential in North Europe is not very different as shown in Figure 94. The annual number of sunshine hours is approximately 1 800 hours in Denmark and 1 500 hours in Finland.

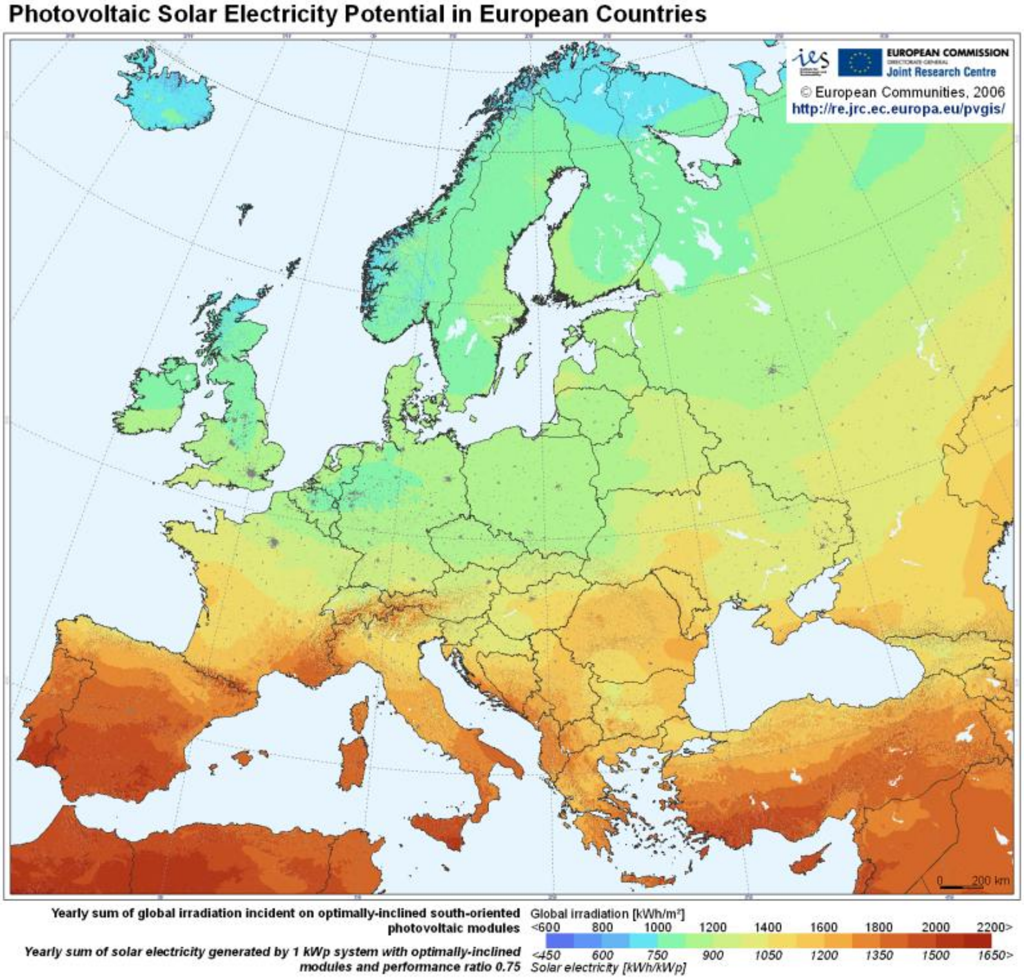


Figure 94. Photovoltaic solar electricity potential in European countries, (cell: European Communities (2006) .http://re.jrc.ec.europa.eu/pvgis/).

5.3.2 Biomass

Figure 95 shows DH generated from combustible renewables in 2003, EcoHeatCool (2006). The amount of heat generated per capita is largest in the Nordic countries (Sweden, Finland, and Denmark).

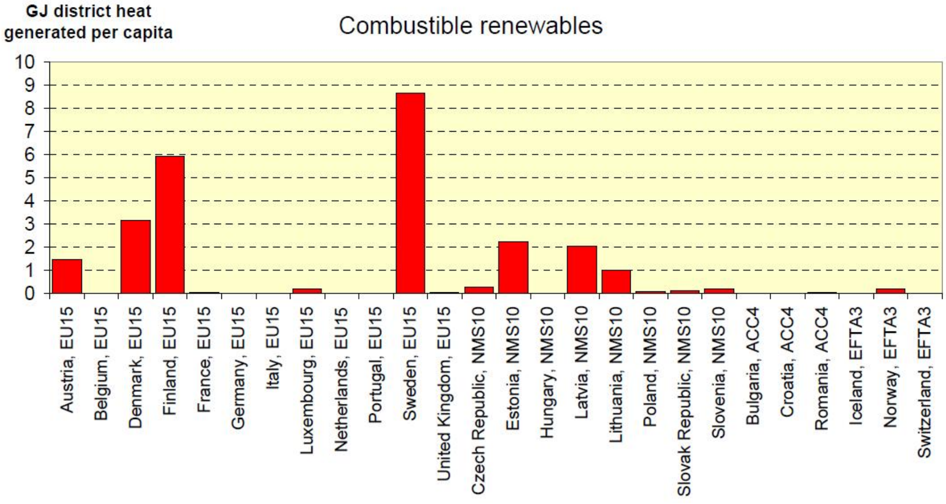


Figure 95. DH generated from combustible renewables, primarily solid biomass during 2003, EcoHeatCool(2006).

Figure 96 shows the potential for biomass in Denmark 2007, and the actual usage, separated into straw, wood, biogas and biodegradable waste. For wood, imported material makes the usage higher than the potential in Denmark.

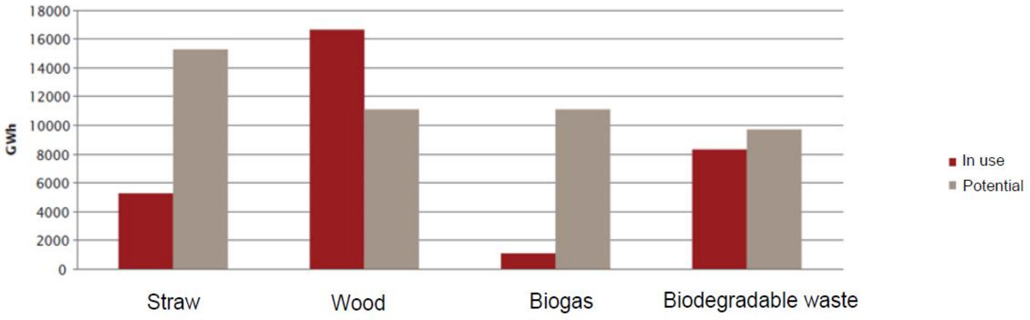


Figure 96. Potential and usage of biomass in Denmark 2007, Danish District Heating Association (2009) based on statistics from Danish Energy Authority.

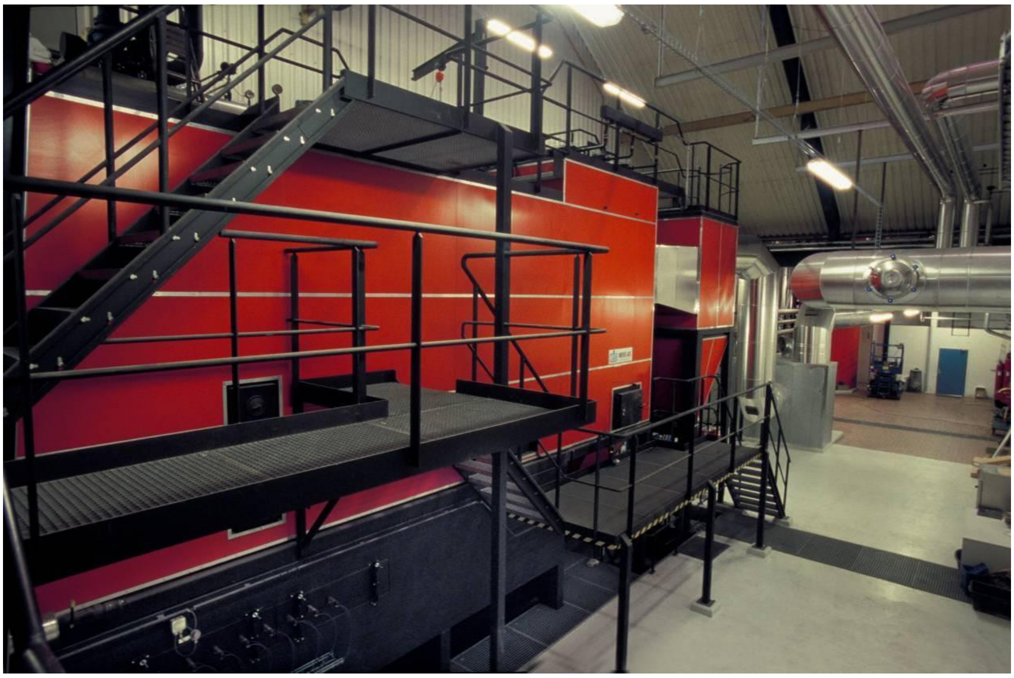


Figure 97. Biomass boiler. Photo Torben Schytte.

Finally, Figure 98 shows the share of biomass compared to other RES in Denmark. At present biomass constitutes 66 % of the Danish RES heat production.

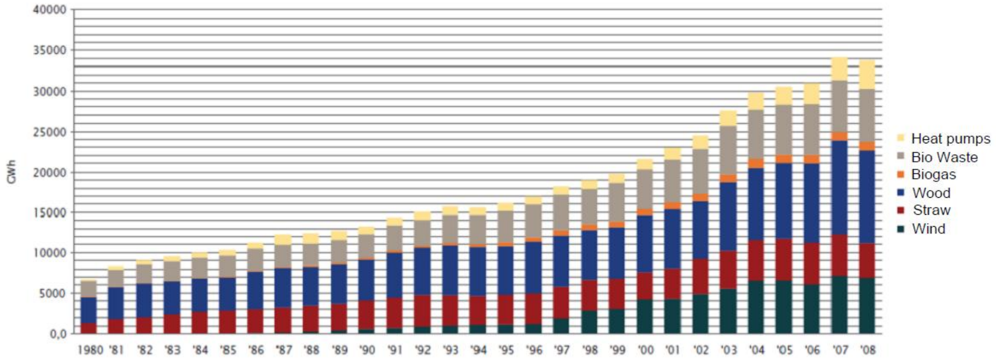


Figure 98. Fuel mix for RES resources in Denmark, Danish District Heating Association (2009) based on statistics from Danish Energy Authority.

5.3.3 Waste

Figure 99 shows DH generated per capita from waste energy plants in 2003, EcoHeatCool (2006). Not only the Nordic countries but also Middle European countries have a high usage of waste. Switzerland and Norway are examples of countries with small DH sectors, but existing systems use waste-to-energy plants to a large extent.

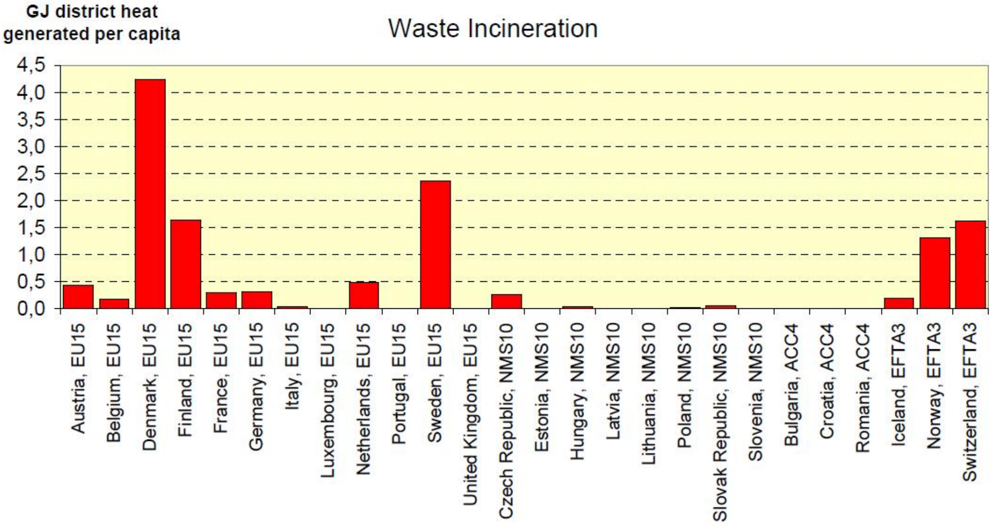


Figure 99. District heat generated per capita from waste to energy plants during 2003, EcoHeatCool (2006).

5.3.4 Geothermal energy systems

Figure 100 shows DH generated per capita from geothermal energy plants, EcoHeatCool (2006). Geothermal heat is not common today in the DH systems, corresponding to approximately 1 % of the total heat produced. Iceland has a unique share of geothermal energy, followed by France and Austria.

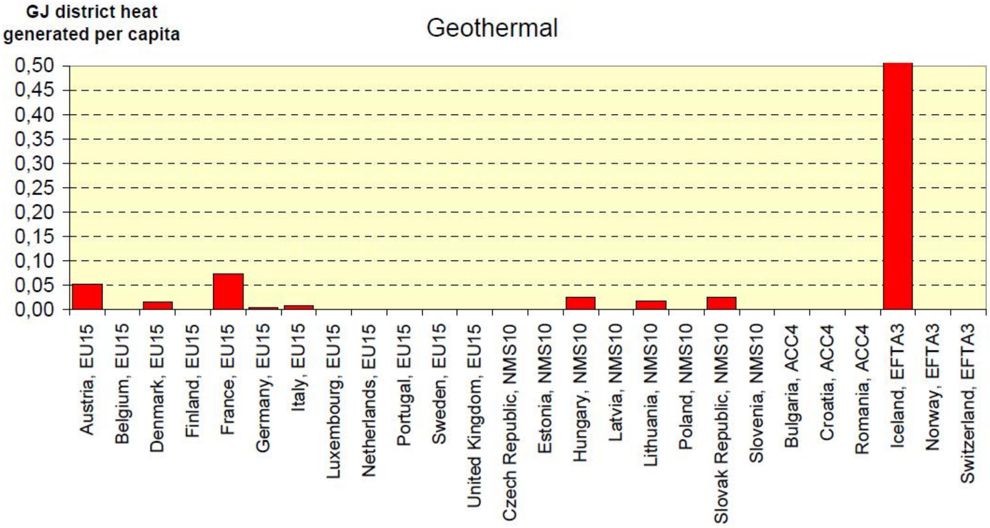


Figure 100. Geothermal district heat supplied during 2003. Broken bar for Iceland due to a high value (67 GJ). EcoHeatCool (2006)

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5.3.5 Electric boilers, heat pumps and surplus electricity

Figure 101 shows the supply of electricity for DH generation during 2003, EcoHeatCool (2006). Electricity was used in Sweden, France, Norway and Iceland for electric boilers and large heat pumps.

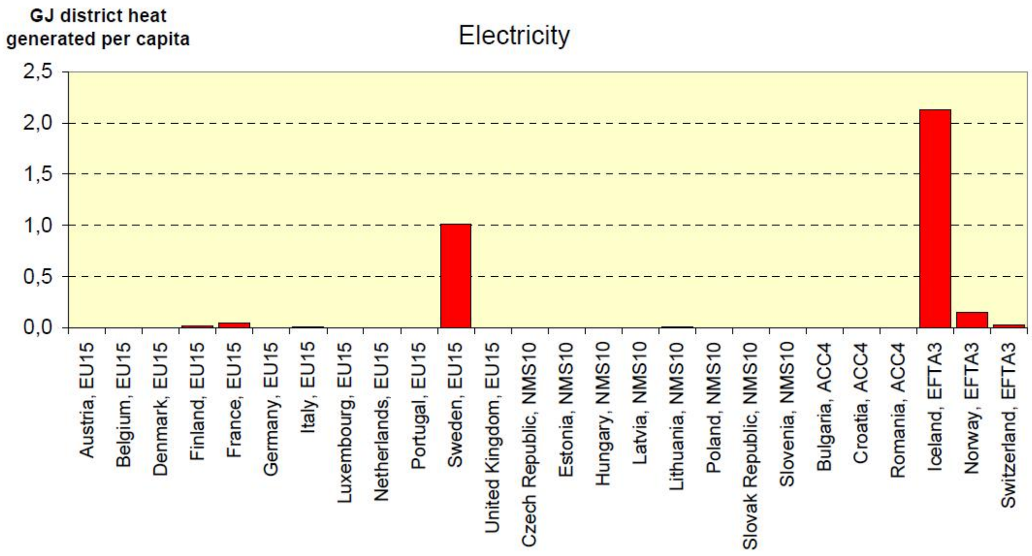

Figure 101. Supply of electricity for district heat generation during 2003, EcoHeatCool (2006).

5.4 How to integrate RES in DH systems for energy efficient building areas

DH systems for areas with energy efficient buildings areas are in many ways similar to ordinary DH systems, however, with the smaller heat demands present, the careful design and the operation of these systems are very critical to achieve a high annual efficiency. Some recommendations are listed in Chapter 3. In general one can say that a low temperature level is beneficial for integrating RES technology, for instance solar heating and heat pumps.

5.4.1 Single family houses

Implicitly in this report it is assumed that the solutions described are economically feasible. This means that very complex systems like the one shown in

Figure 102 are not considered further, because simpler systems are more economic attractive with the present energy costs.

There has been a great interest in Denmark to analyse combinations of solar heating and DH systems with low supply temperatures (50 °C). One example is the "cold DH system", Metro Therm (2009) which uses supply temperatures below 50 °C during the summer and utilises DH together with solar energy or electricity for domestic hot water production, cf. Figure 103.

In Denmark, as well as in Germany, proposals have been made for "two way" DH systems, where roof mounted solar collectors produce heat energy which can be used in the building and/or sent to the DH network. The Ring Søpark project in Brædstrup is one case, illustrated in Figure 104. Due to the financial crises in Europe, the Ring Søpark project has been postponed, but the other parts of the "Laref"-project is carried out as planned, Ramboll (2010a).

Different technical solutions for connecting the house with solar collectors to the DH network have been analysed, for instance a traditional twin pipe or a triple pipe (Figure 105). By using a triple pipe, the heat produced by the collectors can be delivered to the supply pipe of the DH system or to an "intermediate" temperature level in the third pipe, going back to the DH plant - dependent on the temperature level from the solar collectors.

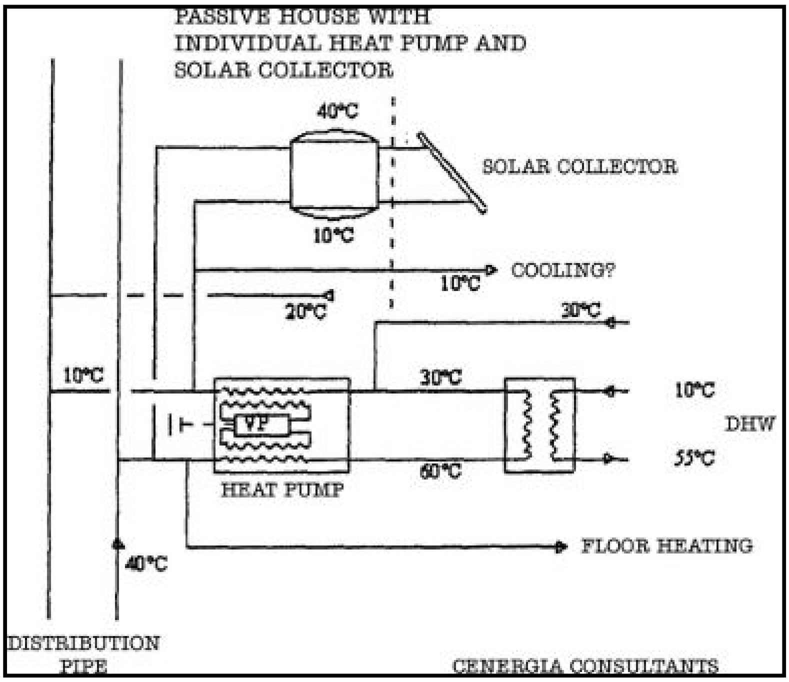

Figure 102. Advanced single family consumer installation combining DH with a heat pump and solar collectors. Design Cenergia Consulting Engineers.

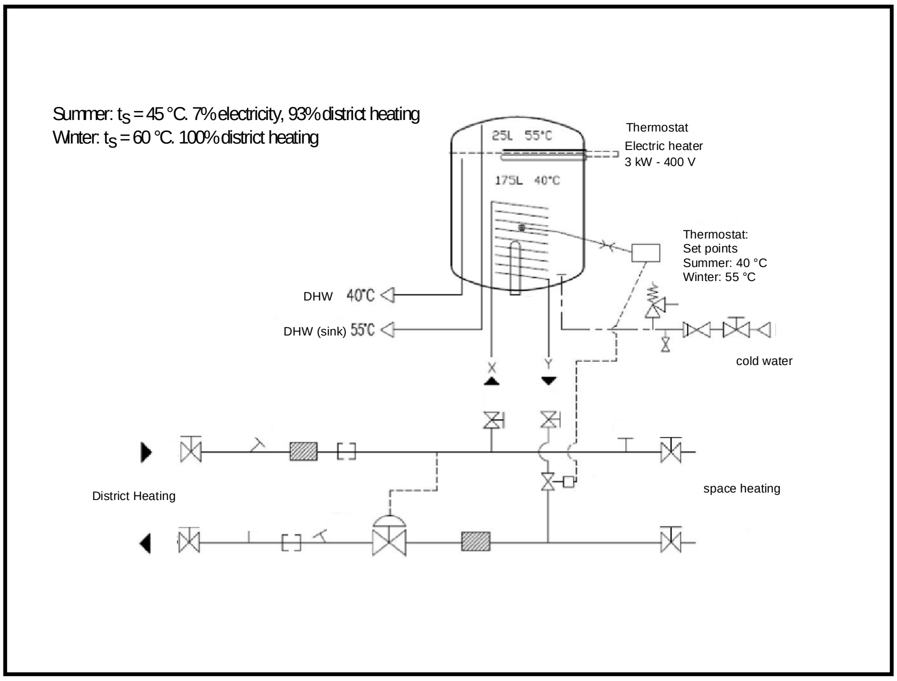

Figure 103. Cold DH combi tank from Metro Therm. In the summer period domestic hot water is produced by either district heating or electricity (or solar heating) by applying a stratified tank and an advanced control scheme. Based on Metro Therm (2009).

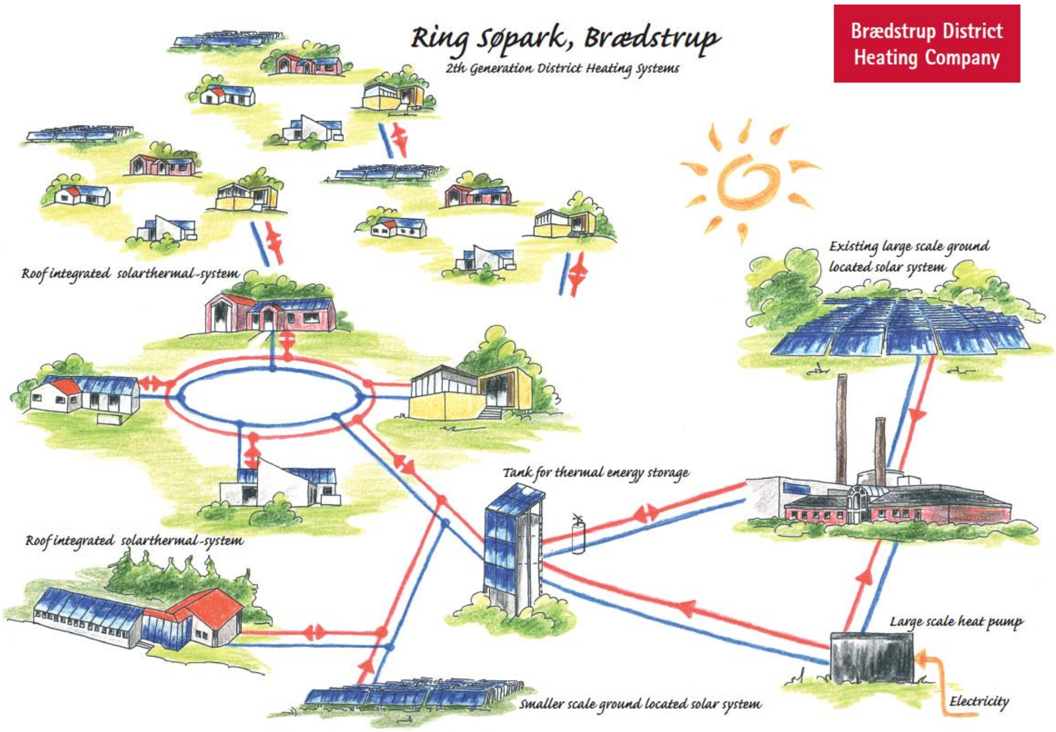

Figure 104. An artist's impression of the Ring Søpark project in Brædstrup. Roof integrated solar collectors on new buildings are connected to a 2-way DH network - in addition to the existing solar field next to the DH CHP plant. Brædstrup (2008).

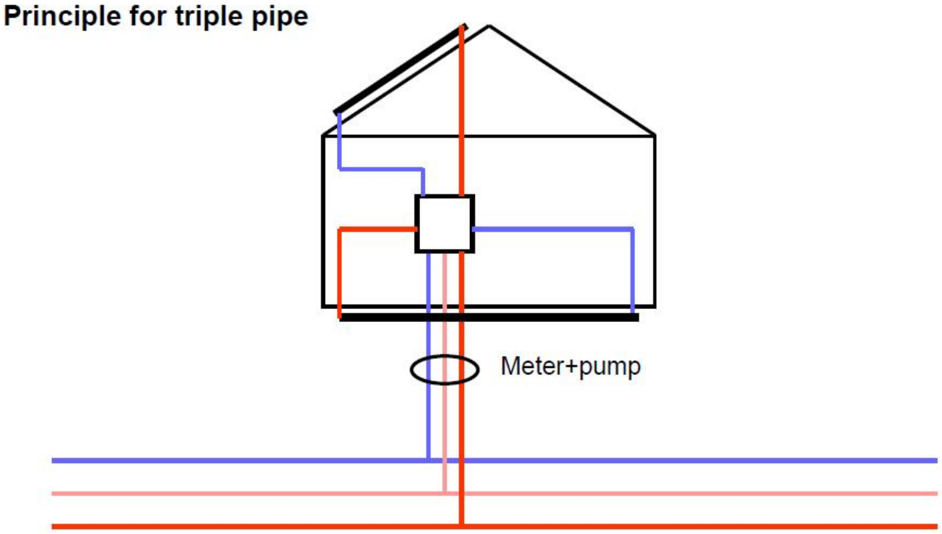

Figure 105. Solution with triple pipe for connecting the building to the DH network, Ramboll (2010a).

5.4.2 Blocks of flats

In the following some examples will be given on how to integrate solar collectors on blocks of flats in a DH network. In Figure 106 a connection to the network on the primary side of the DH substation is shown. Solar heat is supplied to the building as well as the network as much as the capacity of the DH pipe allows.

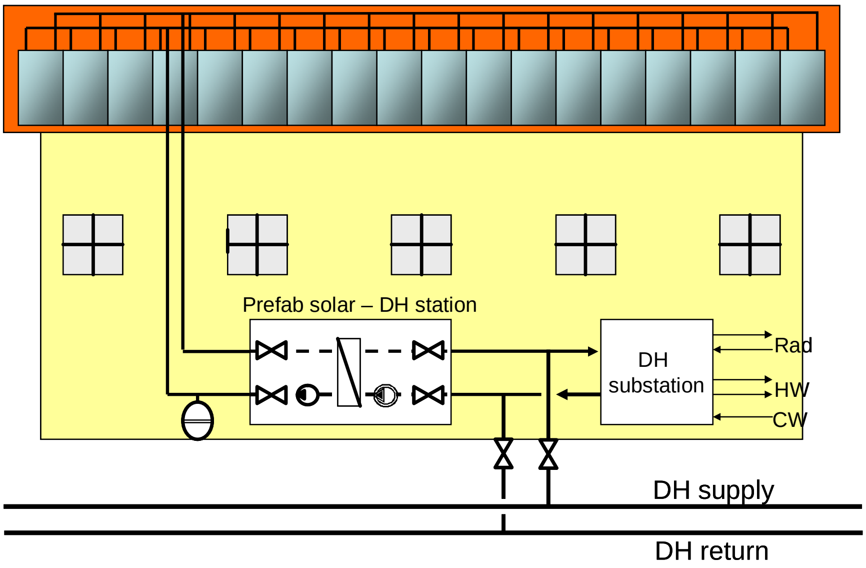

Figure 106. Solar collectors connected to DH network on primary side of DH substation., Zinko (2009).

In Figure 107 and Figure 108 examples of secondary solar connections are shown. In these cases the solar collectors are not supplying heat to the network but they can influence the DH return temperature at the heat exchanger.

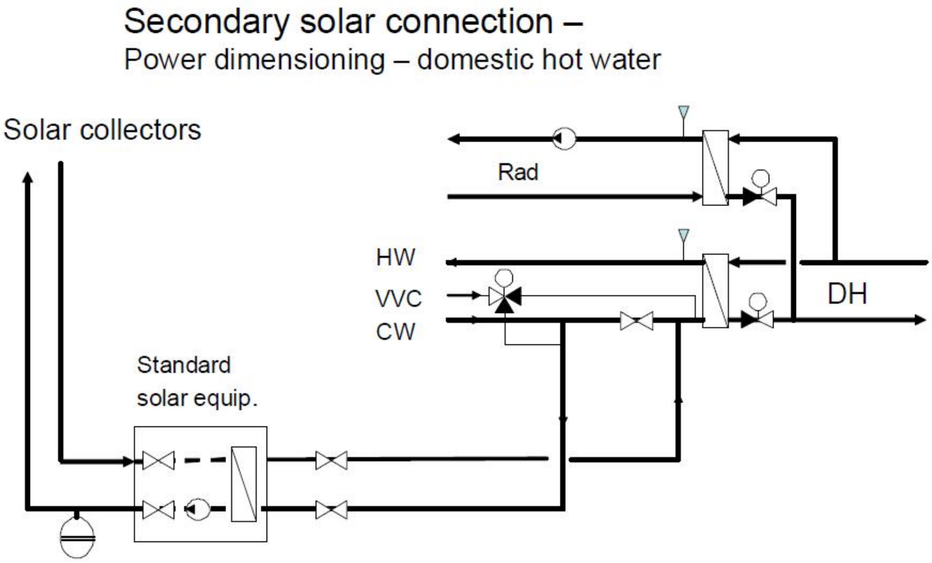

Figure 107. Solar DHW system without a heat storage. Typically 1.4 m2 collector per kW DHW load is recommended. Zinko (2009).

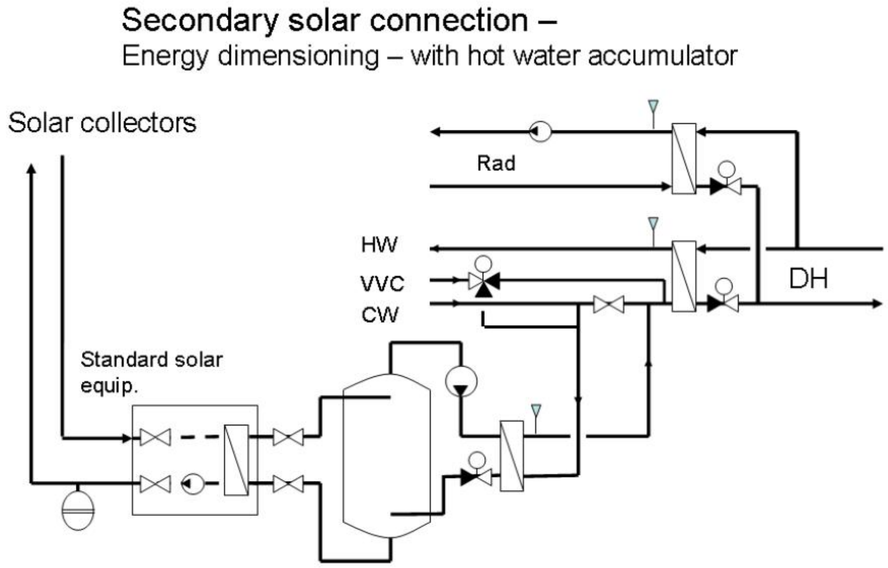

Figure 108. Solar DHW system with a heat storage. Typically 1 m2 collector per person and 50-100 l water storage is needed. Zinko (2009).

5.4.3 DH production plant

Although it is possible to connect smaller solar collector fields directly to the DH return line, most solar collector fields are connected to a diurnal storage tank or a seasonal storage, usually placed next to the (existing) DH production plant.

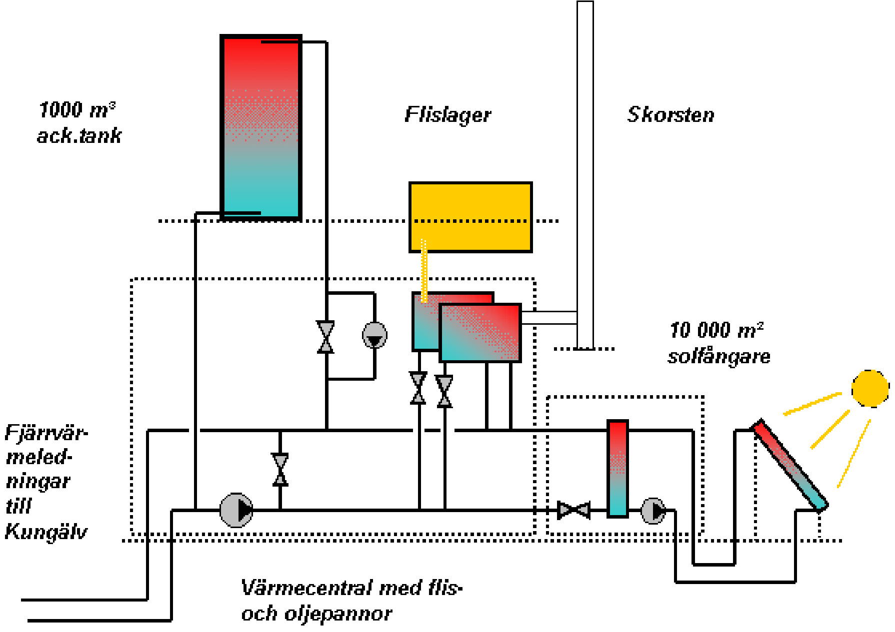

Figure 109. Kungsälv DH plant with 10 000 m2 solar collectors, a diurnal storage and a wood-chips boiler. The solar collectors yields approximately 4 GWh/a, or 4% of the total heat production. Zinko (2009).

5.5 Examples of successful integration of RES in DH system

In this Section examples of successful integration of Renewable Energy Sources in District Heating systems will be described. Although examples from the participating countries in the IEA Annex will be the main focus of interest, some examples from Germany and Austria will be included, as these countries have played an important role in the progress of the integration of RES.

The description will be structured in the way that each technology will be described separately, rather than doing all technologies country by country, i.e. solar heating systems in all countries will be described first, then biomass systems, etc. Furthermore the examples will be separated in DH systems with single, decentralized RES plants connected, in DH systems with a group of decentralized RES plants connected, and finally DH systems with RES centrally connected, often close to the DH production plant.

5.5.1 District Heating systems

5.5.1.1 Solar heating

DH systems with single, decentralised solar collectors connected

There are many examples of this. In some countries the agreement between the DH company and the consumer might forbid the use of other heating sources than district heating, but in other companies this is not the case. In Denmark there is a growing understanding that consumers should be allowed to use solar heating or other types of RES, although previously district heating was the only heating source allowed.

Western Harbour, Malmö, Sweden

In Sweden projects with direct connection to the DH network have been realised. One example is an installation in Malmö where solar heating is used for district heating, supplying heat to both new and existing building areas, using roof-integrated or roof-mounted collectors.

Figure 110. Western Harbour, Malmö, Sweden. (Foto: Stefan Thörnkvist, Malmö stad).

In the Bo01 area in Western Harbour, Malmö, 85 000 m^2 housing area were started to be built in year 2000. E.ON has designed and built the energy system that supplies these buildings with 100 % locally renewable energy. The energy generation is based on 120 m^2 PVs, 1 400 m^2 solar thermal collectors, a 2 MW wind power generator, aquifers for seasonal storage that works with a 1.2 MW heat pump for heat and cooling production. The solar panels are placed on ten different buildings and are directly connected to the district heating network. E.ON owns the solar panels and has a contract with the house owners for this. The energy plants are connected to existing electricity grid and existing district heating system in Malmö. According to the quality program that was worked out, the maximum average specific energy consumption should be 105 kWh/m^2 per year, heat, electricity (incl. household usage) and cooling (if any) together. E.ON estimated the heat consumption to be 70 kWh/m^2 and electricity consumption to 35 kWh/m^2. Besides this, the electricity demand for the heat pump, pumps and fans was estimated and included. Most of the cooling is supplied to commercial buildings outside the Bo01 area, but in the Western harbour. The energy generation is balanced against the energy usage and the estimated figures show that the area will be supplied with energy from 100 % locally renewable sources over the year. The amount of energy end use is however greatly depending on the tenants' behaviour.

Figure 111 shows a diagram of the 100 % locally renewably energy system, with solar collectors and Photo Voltage cells (PV) on the roof, aquifers, heat pump and wind generator. The energy plants are connected to electricity grid, district heating and district cooling networks, E.ON (2007).

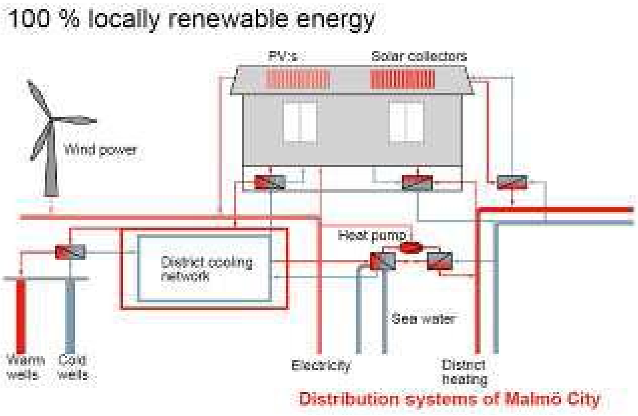

Figure 111. A simplified diagram of the 100% locally renewable energy system in Malmö city, E.ON(2007).

<u>*DH systems with a group of decentralised solar collectors connected*</u>

Ans, Denmark

These kinds of systems are rare, but at least two examples from Denmark are known.
In Ans in Jutland 42 consumers installed solar collectors on a private initiative, Christiansen (1986). The consumers were located on two streets, 8 at Mågevej and 34 at Kærsangervej. As only 3 consumers did not install solar collectors, it was possible to shut down the DH supply for 183 days in the summer period. Measurements were carried out in 1984-1985 at Mågevej and in 1985 at Kærsangervej. Consumers without solar heating used electricity for heating domestic hot water. Savings of approximately 6000 kWh per house were found, which is a high number compared to the heat demand in newly built houses.

The DH company was positive to the experiment but "summer stop" was not used after 1986. This is due to the following facts:

1. The DH network in the area was renovated and with modern preinsulated pipes instead of pipes with mineral wool insulation in concrete ducts, the saving in heat losses from the network was much reduced.

2. The reading of energy meters for the streets and the billing of each consumer for the heat delivered took up too much time for the DH company.

3. The tariff structure of the DH company was changed so that a larger proportion of the annual heating costs were allocated to a fixed part, thus reducing the benefit from the "summer stop".

Today, many of the houses still use the solar collectors for producing domestic hot water, but "summer stop" is not used any longer.

The benefits from practising "summer stop" was analysed by Bøhm & Mikkelsen (1983) and Zinko (2004). In general one can say that the bigger the heat loss from the network supplying the area, and the more costly fuel used for DH production, the bigger the savings by "summer stop" will be.

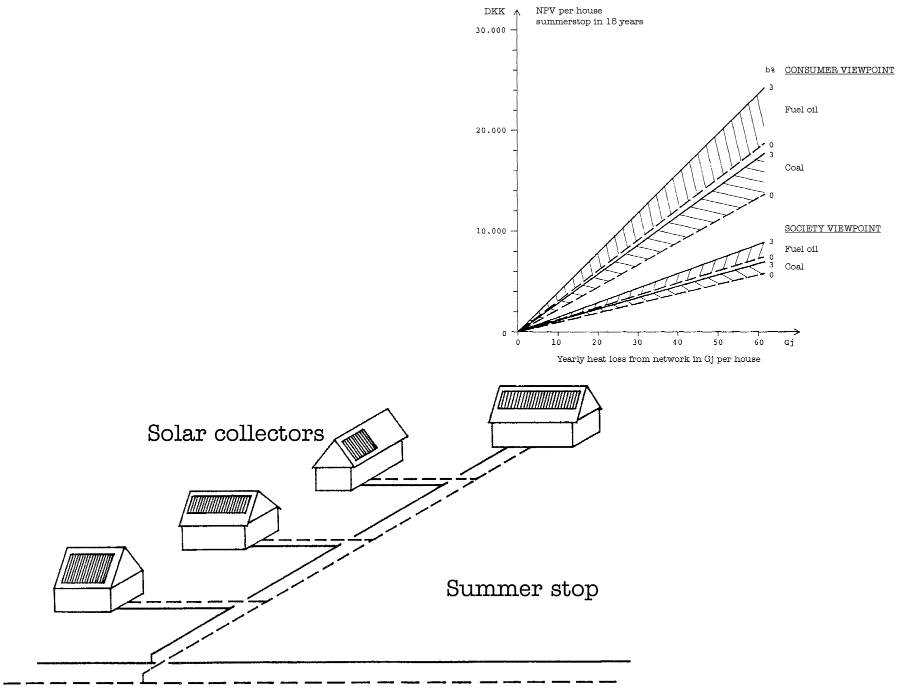

Figure 112. Benefits of practising summer stop, i.e. a shut down of the heat supply in the summer period where solar collectors will produce the domestic hot water in the houses. Inserted is a diagram showing Net Present Value as a function of network heat loss per house and the cost of fuel at the DH plant. From Bøhm and Mikkelsen (1983).

Cold district heating

The idea to reduce the heat loss in the summer period by combining district heating and solar heating/electricity has been persuaded by adapting “cold district heating”. In a recent project in Øster Toreby, Ramboll (2010b), electrically heated hot water tanks were used in the summer period. The DH supply was obtained from the return line of the main DH system resulting in supply temperatures of approximately 42 °C. When the DH supply temperature was too low, electricity was used at each consumer to produce DHW.

The DH-company will compensate the consumers for the difference in heat prices for electricity and district heating. The benefit for the DH-company is the reduced heat loss from the network (10.7 km pipes). There are 105 buildings connected, 90 with combined tanks and 15 with electric DHW tanks (using DH for space heating only). In the report an economic evaluation of the system is carried out, Ramboll (2010b), showing the effect of heat density, network structure and the price difference between district heating and electricity.

The term “cold district heating” is being used for both this system, and for the combined tank described in section 5.2. The difference lies in the tank design, where electricity is used exclusively in Øster Toreby in the summer period, while the Metro Therm combined tank is using district heating and boosting by electricity at the same time.

While the two combined tanks are using electricity in the present design, it is obvious to replace electricity with solar heating at a later stage.

Figure 113. Small DH network in Grænge, Øster Toreby, with "cold district heating", Ramboll (2010b).

Centrally connected solar collectors in the DH system

During the last 10-15 years the majority of plants have had ground mounted collector fields and a pressure less water tank for diurnal storage. Recently the systems have become more advanced, utilising heat pumps and seasonal bore hole heat storage, like a new project in Brædstrup, shown in Figure 114, Brædstrup (2009).

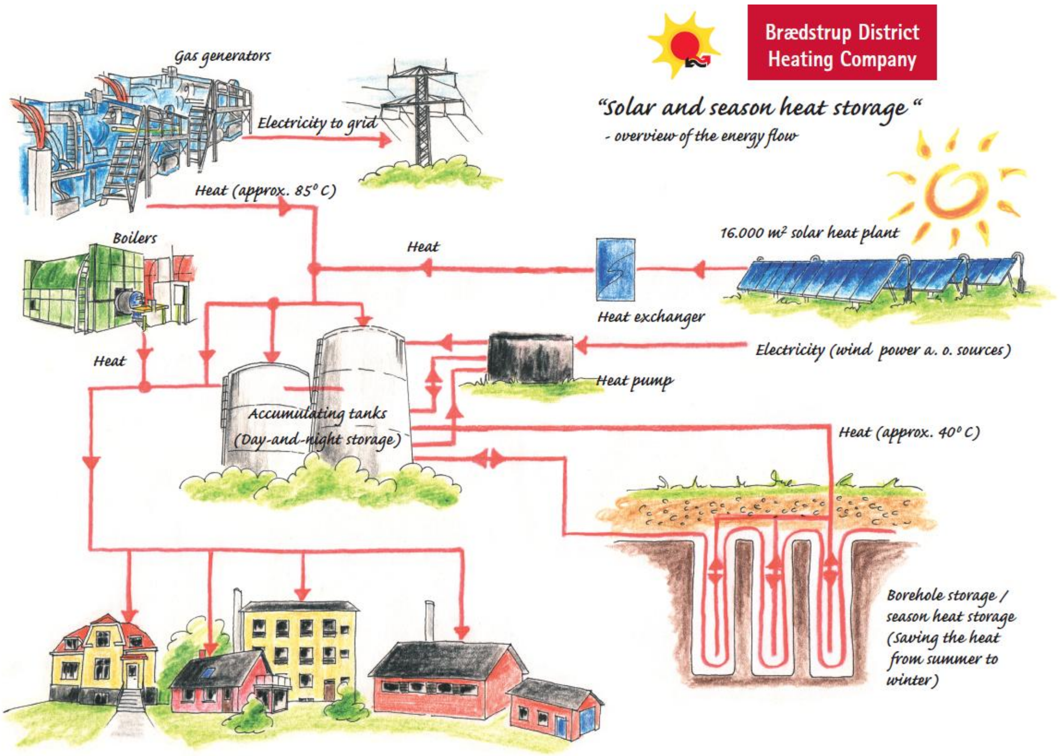

Figure 114. An artist's impression of the new energy system in Brædstrup, Brædstrup (2009).

5.5.1.2 Biomass

DH systems with single, decentralised biomass stoves connected

In Denmark it was common to use a wooden stove as a supplementary heat source in those DH systems which had high running costs. In accordance with the DH tariff this was not permitted but most DH companies did not press sanctions against their consumers.

Centrally connected biomass boilers to the DH system

In the Nordic countries it has been common to use biomass for heat production, like wood (Finland and Sweden) and straw (Denmark).

Figure 115. Wood chips for DH production. (Photo by Jørgen Schytte)

Figure 116. Collecting straw bales for a CHP plant. (Photo by Jørgen Schytte)

Figure 117. The Ålidhem plant, located in the central Umeå, Sweden, has 2 biomass boilers (25/35 MW) and two heat pumps using industrial waste heat (15/20 MW). It also has accumulators storing district heating and district cooling.

5.5.1.3 Waste

In the Nordic countries waste is successfully used to produce district heating.

5.5.1.4 Geothermal energy systems

A number of geothermal systems are in use in Europe and the potential for geothermal heat is very large, cf. Figure 5.3.

A geothermal plant in Thisted, Denmark, has produced heat since 1984. 7 MW heat is extracted from 44 ºC thermal water by absorption heat pumps driven by a straw fired DH boiler. A pilot plant has been established in Copenhagen and exploitation drillings have been made in Sønderborg, Denmark.

In Lund, Sweden, as well as in Southampton, UK, geothermal plants are also in operation. Geothermal heat covers 15 % of the annual heat consumption in Southampton.

5.5.1.5 Wind energy

Electricity produced by large wind mills and used by DH companies directly for electric heating or in heat pumps can also be regarded as a RES source. However, it will not be described further here.

5.5.1.6 Heat pumps

Centrally connected heat pumps to the DH system

Katri Vala heating and cooling plant (Helsinki, Finland)

Katri Vala plant is a facility excavated 25 meters under the Katri Vala park producing district heating and cooling in a single process utilizing heat pumps. While similar facilities exist in a smaller scale, the Katri Vala plant is the first one to produce both district heating and cooling.

The first steps were taken as early as in 1980s when two vertical shafts were excavated beneath the park where waste water and district heating tunnels intersect. The excavation work for the heat pump facility itself began in the summer of 2004. In 2006, the technical equipment was installed. District cooling production began in July 2006 and the full scale commercial operation began at the end of the year 2006.

The facility consists of 5 heat pumps, each with ability to produce 18 MW of heating and 12 MW of cooling at maximum capacity. The system is 100 % automatic and operated remotely. The heat is obtained from cleaned waste water from waste treatment plant in Viikinmäki, and from the district cooling production cycle. The facility is connected to both main district heating and cooling networks in Helsinki.

The plant is well suited to cope with the changing conditions in Finnish climate. In summer, both district heating and cooling is produced using heat pumps. If heating is not needed, the extra heat can be condensed into the sea. When possible, sea water is used to produce needed district cooling.

The process is efficient and environmentally friendly. The carbon dioxide emissions of Katri Vala plant are 80 % smaller compared to conventional production methods of heating and cooling with similar capacities, such as heavy oil based separate heat production and compressor based building specific cooling systems.

Umeå Energy, Umeå, Sweden

The district heating system in Umeå has been developed since the 1970’s when the first waste fired boiler was built. Umeå Energi has a number of DH production plants and the two newest and largest plants are Dåva 1 and 2 just outside the city of Umeå.

Umeå Energi uses waste heat from a paper mill and a waste water cleaning plant to produce district heating with heat pumps. The Ålidhem plant, located in the central city, has two biomass boilers (25/35 MW) and two heat pumps using industrial waste heat (15/20 MW). It also has accumulators storing district heat and district cooling, cf. Figure 118.

Dåva 1 (65 MW) has been voted one of the world's most effective and environmentally adapted waste-fuelled CHP plant. Dåva 2 (105 MW) is a new biomass boiler producing electricity and heat from forest residues.

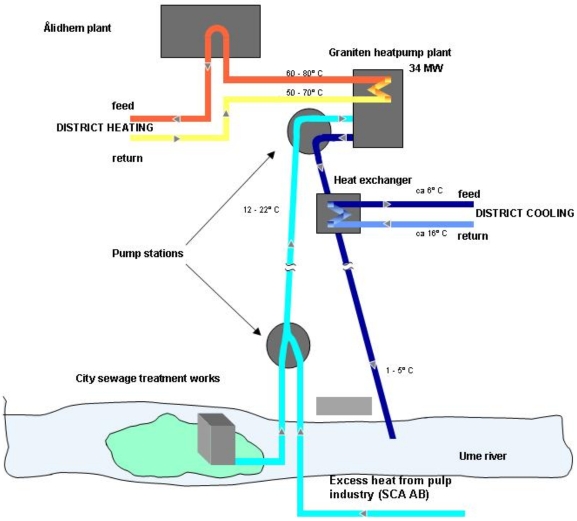

Figure 118. Heat pumps at DH plant Graniten, Umeå. Absorption heat pumps produce 8.5 GWh district cooling. Ulrika: absorption heat pumps only used here?

Individual heat pump systems in buildings

Seglet

Figure 119. Seglet.

The building Seglet ("The Sail") is part of a densification project in an existing residential area, Orrholmen, in Karlstad, Sweden. The building is designed for extremely low energy consumption, while at the same time offering good residential comfort.

Table 19. General Information Seglet.

Location	Karlstad, Sweden
Construction Year	2007
Building Area	2640 m^2
Number of Flats	44
Apartment size	2-3 bedrooms
Primary Heat Source	DH return

The systems for hot-water supply and heating use the residual heat, about 35ºC, of the returning district heating water from the adjacent neighbourhood built in the 1960s. This reduces the temperature in the district heating return pipe from Orrholmen, which in turn lowers DH distribution losses and improves the flue gas cleaning at the DH plant[15], owned by Karlstad Energi. The use of returning district heating water gives the estate owner an economically favourable energy contract. See Figure 120 for the basic principle of the system.

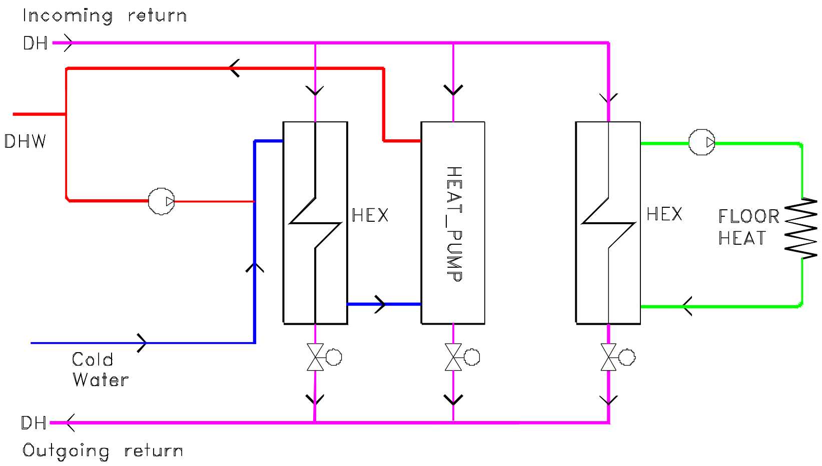

Figure 120. Basic principle for heating and domestic hot water system for Seglet.

A simple floor-heating system makes up for ventilation and transmission heat losses when internal heat is not sufficient, which occurs at outdoor temperatures lower than around +10°C. The water temperature to the coils is controlled by the outdoor temperature. Since the floors are parquet-clad the maximum surface temperature is 27 ºC. There are also reference gauges on the walls measuring the temperature inside the flats. Each tenant can switch the floor heating on or off to compensate for the inertia of the floor-heating system.

Table 20. Specifics on the buildings heating system.

Heating system	Floor Heating
System temperatures (dimensioning)	30/25°C (maximum floor temperature 27°C)
Heat sources	District heat return combined with heat pump (with DH as heat source)
Balance temperature	+10°C
Ventilation	Heat recovery through HEX

Table 21. Expected yearly energy demand, heat and electricity.

	MWh	**kWh/m^2**
District heat for floor heating	51	19
District heat for DHW	38	14
Heat pump electricity DHW	15	5.7
Operating electricity	48	18
Total heat and electricity excl. domestic electricity	152	57.5
Energy for heating and hot water	104	39.5
Primary energy used for heating and hot water[16]	126.5	47,9
Electricity for domestic use	80	30

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[15] The plant, Hedenbyverket, consists of two boilers; the first is a waste-incineration boiler (17 MW+ 4 MW flue gas condensation). Next is a biofueled CFB (Heat: 80 MW + 20 MW flue gas condensation; el.power: 20 MW)

[16] Using a primary energy factor for electricity of 2,5 and a factor 1 for district heating.

5.5.2 Local community energy systems

By Local Community Energy Systems is meant either block heating stations or small networks with a limited number of dwellings connected. Often more than one RES technology is applied, for instance a pellet burner and solar collectors are often used in these systems.

Hjortshøj, Denmark, individual solar collectors, DH system with pulse operation and summer stop

In 2008-2009 8 low energy buildings with solar collectors were built in Hjortshøj (near Århus, Denmark) and connected to a DH system. The DH system uses pulse operation and summer stop. The houses are equipped with storage tanks of size 350-800 l, dependent on the size of the house. In average the storage tank is 550 l.

In a preliminary report, Olesen (2010b), the first results for the period Oct. 1, 2009 to April 30, 2010 are presented.

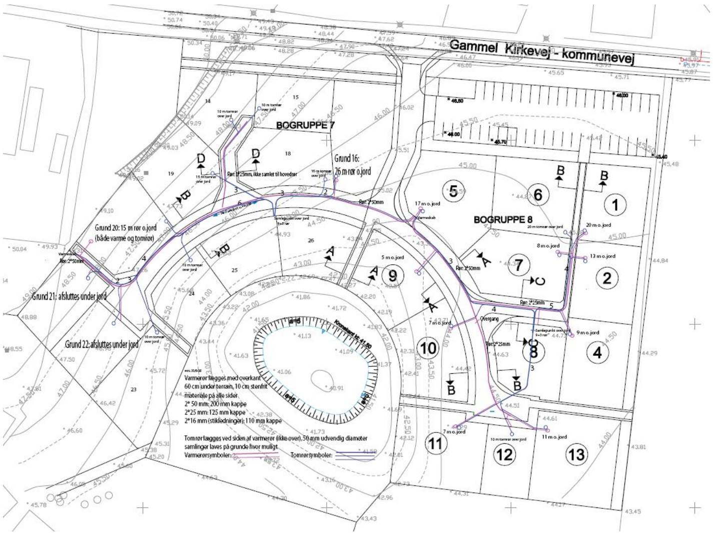

Figure 121. Hjortshøj. District heating with pulse operation and individual solar collectors.

When the outdoor temperature is below -5 ºC the DH system runs all the time and in June-September it is stopped. Pulse operation is used in between with a different number of pulses per day. When the network is in operation for 10 hours per day, 43 % of the heat loss is saved compared with a constant heat supply. In the heating season this corresponds to a saving in heat loss of 27 %. In the summer period May 1 to October 1, 90 % of the heat loss is saved, due to the solar collectors and the storage tank. The yearly savings in heat losses is expected to be 50 % compared with a DH in constant operation and without solar collectors.

The system will be expanded to 12 houses and new measurements will be carried out in the heating season 2010-2011.

Austria and Germany, Decentralised solar district heating systems

Due to a lack of suitable ground areas, in Germany and Austria the development of large solar heating systems was dedicated to decentralised solar system with the collectors mounted on suitable roofs. About 50 large to medium scale projects with short-term storage have been realised.

The next figures show examples of such installations, one in Germany (Neckarsulm, 5470 m^2 solar collectors with seasonal ground storage), and one in Salzburg, Austria.

Figure 122. Solar block-heating Neckarsulm, Germany.Dalenbäck (2010).

The final example is block heating in Salzburg, Austria, with solar collectors, a pellet furnace and air conditioning with heat recovery in low energy apartments.

Figure 123. Solar collectors, pellet furnace and air conditioning with heat recovery in a low energy building. Salzburg, Austria. (Photo Benny Bøhm)

Drake Landing Solar Community Project, Canada

The Drake Landing Solar Community project connects 52 detached energy-efficient houses with a DH and seasonal storage system designed to supply more than 90 % of the space heating requirements with solar energy. 798 flat-plate collectors mounted on roofs of detached garages supply solar thermal energy to charge an underground storage which later supplies heat through a DH network to each building. It is the largest residential solar system in Canada and the first of its kind in North America.

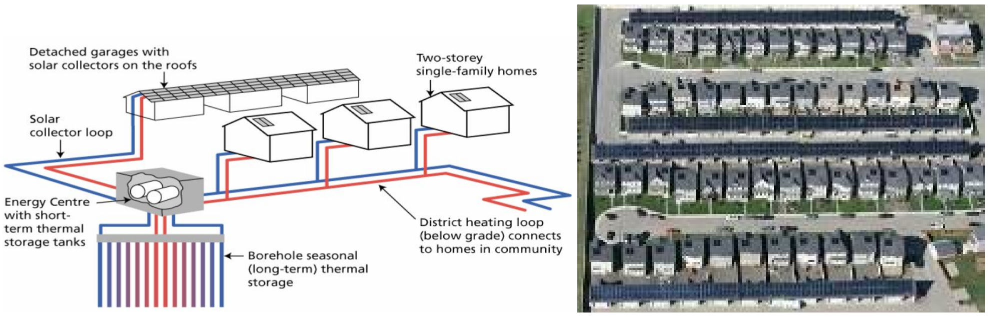

Figure 124. Solar collectors on individual houses and a borehole seasonal thermal storage. Drake Landing Solar Community Project, Canada.

The Summary Energy report April 2010 since July 1, 2009 78 % of the total energy delivered to the district heating loop is provided by the solar collectors; cf. Sibbitt et al. (2010).

5.6 Towards a RES-based district heating sector

In a recent report by Ramboll and Aalborg University, Ramboll (2010c), scenarios have been analysed for a change of the DH sector in Denmark towards a RES-based future in 2050.
Two different scenarios are put forward with regard to the speed of change in the heating sector 2010-2020. By 2050 the two scenarios are almost identical.

The main parts of the plan are:

- Energy savings in the building space heating load of the order of 25% will be carried out

- Buildings outside the DH networks will change from oil, natural gas and biomass burners to individual heat pumps

- Buildings with natural gas supply next to the DH network will convert to district heating

- DH systems will reduce the temperature level and change the production apparatus from fossil fuel to RES by using large scale solar heating plants, geothermal plants, heat pumps driven by surplus electricity from wind mills, etc.

Figure 125 shows the change in the building stock floor area in Mill. m^2 separated on different supply types and the CO_2-emission per MWh heat at the consumers in the period from 1980 to 2050.

It appears from the figure how individual oil and gas burners will be phased out and to a large extent be replaced by individual heat pumps.

Figure 126 shows the resources used for the production of district heating per MWh at the consumer and the CO2-emission per MWh heat at the consumers in the period from 1980 to 2050, Ramboll (2010c).

It appears from the Figure 126 that in 1980 it required almost 1.4 MWh to produce and distribute 1 MWh of heat to the end consumer. From 2030 the figure has fallen to 0.7 MWh/MWh, due to the usage of RES in the form of large scale solar heating, geothermal, electricity from wind mills, waste, biomass, etc.

The report puts forward a number of proposals that must be dealt with to overcome the political and organisatorial barriers before the plan can be realised. The social-economic costs are not greater than to continue with the present DH system.

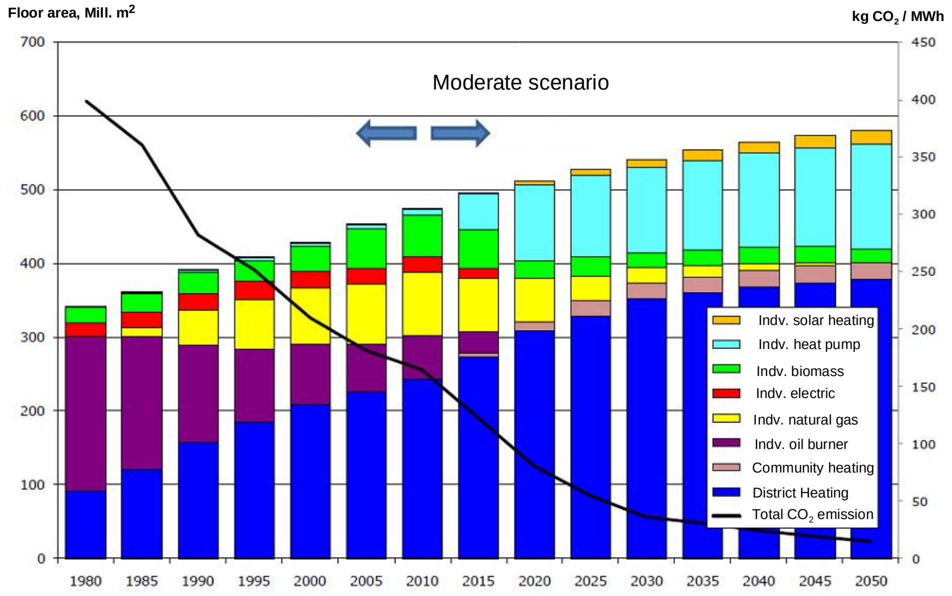

Figure 125. A scenario for the change of the heating sector towards a RES-based future. Left scale is the building stock floor area in Mill. m^2 separated on different supply types, while the right scale shows the CO$_2$-emission per MWh heat at the consumers. Based on Ramboll (2010c).

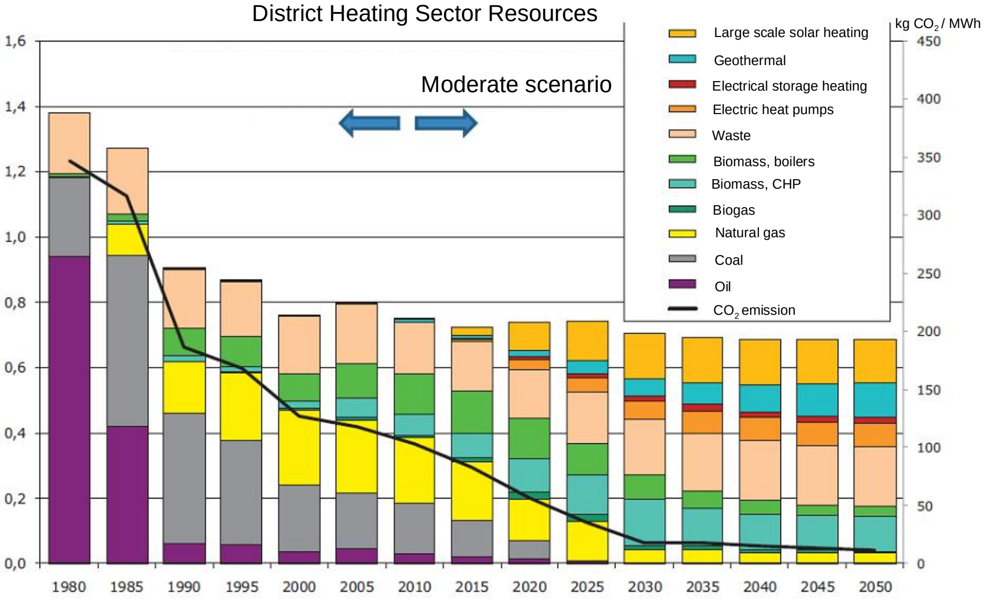

Figure 126. A scenario for the change of the heating sector towards a RES-based future. Left scale shows resources used for production of district heating per MWh at the consumer. Right scale shows the CO^2-emission per MWh heat at the consumers. Based on Ramboll (2010c).

6 Conclusions

Future loads

Environmental and economic requirements will slowly change the composition of existing district heating areas towards lower heat density and lower heat-line density.

As the space heating load reduces, the domestic hot water will have a larger share of the total load. DHW is dominating the district heating load in the summer time. However in some areas, heat driven cooling can add a new load to district heating.

The annual load demand curves of networks will, in general, become flatter. There is, however, an uncertainty about the peak load demand. In some places, district heating will be used for peak load (wintertime), which means that high power loads can be necessary for short duration. This is a concern especially in areas where exhaust/outdoor air heat pumps and/or solar panels have a significant share of the buildings auxiliary heat supply.

The customers may possibly be able to buy dwelling comfort instead of only energy, which also will contribute to even out the load distribution. The comfort means a service of temperature, humidity and pure indoor air.

In some district heating networks, distributed production systems such as solar energy or other renewable heat sources, will also be connected to the grid. This will require careful planning whether the renewable production is to be integrated in an existing system or whether a new system is constructed. Especially with solar energy, district heating flows can exhibit large variability and even change direction.

Future newly built sparse areas will have very low heat densities. This calls for modern distribution technology with very good insulation properties for piping and also improved intelligent control systems.

Consequences of energy efficient buildings on system layout

Energy efficiency in buildings will contribute to decreased heat line density and increased relative heat losses. As a consequence, the temperature drop along the pipes will be an accentuated problem which must be counteracted by improved pipe technology and advanced control strategies.

Existing networks must be operated at as low temperatures and with as high temperature difference as possible. Special consideration will have to be taken for times of low DH load, however; it may be necessary to maintain a minimum flow in the system, at the expense of low return temperature. If the DH flow is too low, the temperature drop in the supply pipe to distant consumers will become unacceptable.

New networks will generally be designed for lower distribution temperatures, taking advantage of new types of heating systems in the buildings, such as floor or wall heating as well as air heating systems. Depending on the supply temperature, DHW topping procedures based on electric heat pumps will have to be applied in some cases. PV- technology could also play an important new role in this.

The increased uses of distributed intermittent RES heat sources will stipulate the uses of storage-technologies in the systems. Such storage systems can either be installed at the consumers, such as DHW accumulators or centrally at the production unit, for example for storing solar heat or heat from other RES intermittent sources.

Consequences of energy efficient buildings on operation

Many systems will be designed as a mixture of building-owned production (such as solar energy or fuel cells) and central production and therefore increased requirements for flexible or adaptable heat distribution systems will be demanded.

The distribution temperatures will generally be lower. In some networks, however, they might increase in summertime, due to the increased use of heat-driven cooling systems.

In the future, concepts with increased producer/consumer interaction such as heat-on-demand or heat-when-available will be enabled through the availability of inexpensive control equipment.

Online energy measurements will inform the user continuously about used energy and applied heating power. This will steer the consumer towards being more active to turn his consumption toward lower total costs.

Integration of renewable heat sources (RES)

The potential for RES in DH systems is very big, primarily in the form of biomass, solar heating and geothermal energy. Already there is a large share of RES in the DH systems, especially in the Nordic countries.

A dramatic change in the use of central solar heating plants has happened in Denmark with more than 110,000 m^2 collectors installed at present. The yearly yield from solar radiation does not differentiate very much in Northern European and Northern American countries, so the potential is very big for large solar heating plants.

A future without fossil fuels in the DH sector in 2030 – 2050 is possible. It will include RES in the form of large solar heating plants, biomass and use of decarbonised electricity in heat pump systems.

Economic consequences

Future decreased heat demand can be compensated by connecting new buildings with more floors in compacted existent areas. New users can also come from connecting new areas, although they generally will exhibit a lower heat density than has been the case so far. This means that the district heating rates have to be adapted to this situation, with higher fixed prices reflecting the larger investments in relation to operating costs.

The economic border line between heating systems based on district heating and those for individual heating systems is different for existing DH systems and new-constructed DH systems. It is influenced by a range of factors including the relative costs of alternative fuels, the capital costs for DH, the capital costs of individual systems, assumptions regarding maintenance costs, etc.

The general trend is that district heating becomes progressively more economically interesting with increased linear heat density. However, the exact cross-over point depends on the local situation. It is more favourable to connect new areas with low linear heat density (~0.5 MWh/m, a) to existing DH networks up a certain distance of 1000 meters. This conclusion applies for many well developed DH heating countries, such as the Scandinavian countries.

In countries with DH systems to be completely new-constructed, the cross-over point will, due to higher investment costs, be at higher heat densities. An example from UK shows that the cross-over point will be at a linear heat density around 1.5 MWh/m, a, although the crossing interval is very broad.

7 Recommendations

Future district heating systems will consist of a mixture of central and distributed production systems (hybrid) based on renewable energy sources (RES). The distribution temperature will be lower than now and the flow variable. This means that future systems should be carefully planned as a total system, including production, distribution and use of heat. Simulation and optimisation programmes for such integrated planning are available today.

Distributed production systems from third parties will be connected to existing or new district heating networks. Operational strategies for the integration of such systems must be further developed.

Existing district heating systems will be complemented with new systems which generally can work at lower temperatures. It is recommended to separate areas with different distribution temperatures in order to facilitate operation.

In order to reduce costs and get more effective operation, new system components and new distribution methods should increasingly be used, such as plastic pipe systems (possibly with super insulation), local or central heat storages, low depth installations, combined customer/ production substations and heat driven cooling. Guidelines and directives for the application of these components and methods should be developed in order to enable a smooth blend of old and new technologies.

CHP production should be integrated with the future DH system. Power-to-heat ratio can be made higher because of lower temperature demand in DH systems.

Pumping capacity might be reasonable to divide in smaller units and to split under intelligent control in the DH pipeline systems.

The district heating business will be more complex in the future, because building owners will want to realize their own ideas about the way to use and to produce energy. This will give district heating companies the opportunity to complement their core business through energy consulting and management of building equipment and systems, thus supporting the customers and finding suitable solutions together, instead of counteracting each other.

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