District Heating in Buildings

Prepared by Euroheat & Power

Task Force Customer Installations

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This paper is published by Euroheat & Power. Our aim is to inform about district heating and cooling as efficient and environmentally benign energy solutions that make use of resources that otherwise would be wasted, delivering reliable and comfortable heating and cooling in return.

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I. Fundamentals of District Heating

I.1 Inside the building & network

A District Heating system's main function is to supply customers with energy for heating and production of domestic warm water. In some cases District Heating also supplies low temperature industrial heat demands.

District Heating is suitable for residential as well as for commercial buildings. The use of District Heating is rapidly spreading from traditional heating and domestic warm water preparation appliances to comfort cooling via absorption chillers and a wider range of domestic appliances.

The main idea of using District Heating for these purposes is to utilise surplus heat and to organize the heat production in a way that is more efficient than individual production.

A District Heating scheme is composed of:

- Production
- Distribution (and Transmission)
- Customer installations

All system parts are interconnected. The system built for consumption – the radiators, the warm water system and the installed control system – sets the requirements for the connection system/substation, which again gives the dimensioning parameters for the distribution system and forward to the dimensioning of the production plant(s). Depending on the type of heat production plant the dimensioning criterions might be in reverse.

The distribution, connection and consumption system parts are in principle simple construction systems. The secret is to do the right dimensioning, construction and controlling of the system.

If it is done in the right way, a District Heating system is incomparably easy to run and maintain for customers.

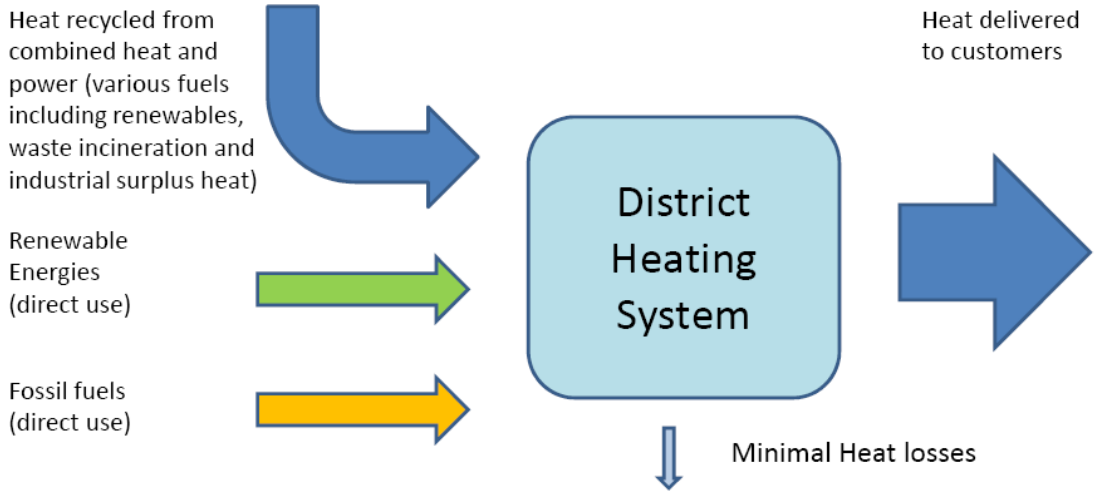
I.2 The fundamental idea

The Basis

The fundamental idea behind modern District Heating and Cooling, as presented in the figure below, is to use local heat and fuel sources that under normal circumstances would be lost or remain unused. The infrastructure enabling the use of these heat sources are well insulated pipe networks.

In order to reduce primary energy demand and CO_2 emissions, District Heat generation in Europe is to a great extent based on recycled heat from power generation (called Combined Heat and Power (CHP)), from industrial processes and from waste incineration. The rest is based on the direct use of renewable energy sources, such as geothermal heat or biomass and fossil fuels, mainly for peak demand.

Figure 1: Fundamental idea of District Heating



Local and renewable energy

Another major benefit of District Heating systems is that they can use a wide variety of local energy sources, including those that are impossible or difficult (less efficiently and cost-effectively) to handle in individual applications. In particular, District Heating can integrate combustible renewables that are difficult to manage in small boilers, which is the case with most combustible renewable, for example wood waste, straw and olive residues as well as the biogenic fractions of municipal waste and sewage sludge. The majority of renewables including bio fuels, geothermal, solar and wind energy can be more effectively utilised when integrated into District Heating networks.

Local pollution prevention and control

District Heating reduces local pollutants as particle emissions, sulphur dioxide and nitrogen oxides by relocating exhausts from individual boilers to centralised chimneys. Due to economies of scale, far more effective pollution prevention and control measures can be implemented in central production facilities.

Increased energy security

At present the EU imports 54% of all primary energy sources from outside its territory. Even in the most positive scenarios this percentage is expected to rise to between 56% and 60% by 2020, and to as high as 70% by 2030.

Past gas crises, notably in 2006-2007 and 2009, have made the vulnerability of the European energy supply system obvious. In several countries and cities District Heating systems were able to considerably ease the situation by switching to alternative fuels.

Flexible and sustainable fuel mix

District Heating and District Cooling enable a highly flexible energy mix. New fuels and energy sources can be integrated with minimal need for restructuring by the operator. For customers no adaptation measures at all are required when a switch of energy source is made.

District Heating and Cooling technology provides an essential infrastructure to ensure large scale integration of renewable energy sources. The majority of energy use for heating and cooling takes place in urban areas where it is most difficult to choose renewable fuels or energies for heating and cooling purposes. The use of solid fuels for example is not welcome in urban areas for reasons of logistics, emissions and space.

II. Benefits of District Heating by comparison with other heating options

II.1 Benefits in a nutshell

1. **District heating is suitable for *all* buildings in areas where DH networks are available, irrespective of size or type.**

2. **EQUIPMENT AND MAINTENANCE**
   - DH has minimal space requirements at the customer end with equipment of a compact size, which is simple to use, run and maintain
   - With DH no maintenance is necessary for the customer, the DH utility can take care of energy and service 24 hours a day, typically without ever entering the house
   - Buildings connected to DH have no need for fuel storage facilities, have no boiler or burner and do not require a chimney
   - DH does not require a complementary or backup system
   - The customers take no risks of fires, explosions or dangerous medias inside the house

3. **COMFORT**
   - DH guaranties an unlimited amount of heating and domestic warm water 24/24
   - Customers have no concern over fuel availability
   - DH is easy to handle and works automatically

4. **COSTS**
   - DH entails moderate investment costs and very low maintenance costs for the customer
   - Prices of DH are competitive, predictable and steady, tariffs are public

5. **RELIABILITY AND EFFICIENCY**
   - DH is known as very reliable, because district heat is produced at multiple production facilities using a variety of fuels
   - DH has a flexible and sustainable fuel mix and does not depend on a specific fuel
   - DH substations have a long lifetime and a high efficiency

6. **ENVIRONMENTAL ISSUES**
   - DH is often based on the utilisation of surplus heat which would otherwise be lost (surplus heat from industry, cogeneration of heat and power etc.) and thereby avoids the use of fossil fuels and related emissions
   - DH can use a wide variety of local energy sources and renewables (wood waste, straw, municipal waste and sewage sludge etc.)
   - DH has low climate impact: low primary energy consumption and CO_2 emissions. DH reduces local pollutants as dust, fine particles, sulphur dioxide and nitrogen oxides by relocating exhausts from individual boilers to centralised chimneys. Due to economies of scale, far more effective pollution prevention and control measures can be implemented incentral production facilities.

II.2 Comfort, ease of use, works all the time 'automatically'

<u>Installation and usage</u>

In a building the District Heating installations will be placed mostly in the basement or in separate areas. Thereby only a small part of the installation, mainly pipes and radiators, will be located in apartments or offices/shops. Newest developments in substations have incorporated nice design and very compact sizes, which even enables use in kitchens. Consequently, only a minimal amount of space is occupied by the heating system in each family/tenant unit, this also translates to limited and simple maintenance costs for the end user.

"Automatic comfort"

The usage and operation of the system is simple, since once installed and adjusted, the District Heating system will work automatically and provide warm domestic water at the preset temperature and warm forward water for the radiators (or for floor heating and/or air condition). For the latter the user can to choose either automatic temperature regulation by a thermostat, an alternative form of automatic regulation or manual temperature regulation.

The District Heating system thus provides domestic warm water all the time and in unlimited quantities leaving no shortages for showering or for any other purpose. Further, with the correct installation of the water pipes or by circulation, warm water will also arrive quickly at the tap point at all times.

The temperature comfort in all rooms, offices and shops can, of course, be adjusted individually and the District Heating system will react swiftly to changes in desired temperatures.

Pros and cons of District Heating

The main "con" when applying District Heating in an existing building is the conversion from individual heating which, depending on the type of system used previously, can be rather complicated and needs careful planning. However, seen over the full lifetime of such a system, this investment can be depreciated very reasonably.

On the other hand there is a considerable number of solid "pro's", like the ease of use, the unlimited amount of domestic warm water available constantly, the desired temperature at all times, and reduction in space required by the heating system, as mentioned above.

The customer's experience of a District Heating system will in general be characterised by

- No worries
- No noise
- A higher standard of "air-quality"
- Sustainability
- Predictable price level

District Heating is a very user-friendly heating system thanks to

- No need to purchase and handle fuels
- Required servicing of equipment is limited (no chimney or boiler)
- Heat metering and reading systems managed by utilities help to find/detect problems in the heating system

Finally the District Heating system is a very safe heating system due to

- No local risk of fires or explosions
- No dangerous medias inside the system

II.3 Less risk of failure in energy delivery

The following benefits of District Heating ensure a high reliability of heat delivery:

- The extensive range of primary fuels that can be utilized by District Heating makes heating supply very reliable. Local energy sources can also be utilized. There is almost no risk of lacking fuels because of large storages and intelligent planning.
- District Heating is characterized by well planned and prepared service operation. Spare parts and services are available all day long, every day of the year.
- Large networks include a huge amount of energy, which gives time to take actions in emergency cases. Also big heat accumulators are used widely to ensure stable and safe heat distribution.
- Advanced automation system control enables service personnel to conduct monitoring by remote control systems.

In summary, District Heating works very reliably. Any rare interruption of heat delivery normally lasts only a matter of hours, not days. As is the case with all grid bound products, breaks cause failures in the system. Improvement works in network and road construction works can occasionally cause obligatory breaks depending on the design of the system.

Sudden and unplanned breaks occur very rarely. Utilities make information of heat delivery break beforehand in over 90 % of cases. About half of breaks are outside the heating period.
In Finland annual average heat delivery break time per one customer was 1 hour 45 minutes in 2008. This represents a delivery accuracy of 99,98 %.

II.4 Maintenance & repair benefits for customer support

All heating systems need maintenance and service, however District Heating and substations only require a minimum. The reasons for this are well designed systems, stable conditions and long-term experience of technical systems. Statistics of maintenance costs prove this fact if different heating systems are compared.

With a connection to the District Heating system a building becomes part of the system. This continuous link between supplier and customer is a special and unique advantage.

When connecting to the District Heating network special care is taken of the performance of heating and domestic warm water production appliances in a building. Once installed, the heat substation is subject to the commissioning process which guaranties reliable functioning.

Besides, the District Heating supplier can regularly maintain heat substation and control the heat substation's performance. The reliable functioning of a heat substation is of course in the interest of both, the District Heat supplier and the customer.

Control of heat substation's performance is enabled through heat meters and regulators installed in each substation. District Heating suppliers achieve efficient operation of the system through permanent control and optimization of all elements, among which heat substations have the highest priority. Thus customers receive fast and reliable information about the quality of their building's installations.

Systematic outsourcing of maintenance & repair operations

The most interesting outsourcing solution for maintenance & repair is to hand this over to one external body, in charge of all tasks. Thereby both, the customer and the service provider, benefit from economies of scale.

To measure the quality of the outsourced maintenance service various parameters can be utilised:

- Customer satisfaction
- Reduction of response time related to single problems
- Decrease in the rate of faults intervention related to the preset maintenance
- Increase of plant efficiency with a consequent consumption decrease
- Observance of the safety standard
- Database reliability

The aim of the maintenance service is the reduction of the overall maintenance cost, consisting of direct costs (man hours, spare parts) and energy costs (heat losses, efficiency, quality, electrical energy costs, etc.).

An important feature of the maintenance service is the design of the maintenance system. This activity is performed through the definition of the most appropriate maintenance policies.

Continuous fault analysis and leak detections are required to prioritise intervention, both from design and maintenance. Furthermore a continuous monitoring of the effectiveness and efficiency of the maintenance plan is important.

If maintenance is the object of an outsourcing process, it can be developed in cooperation between the customer and the heat supplier.

The support service will be on demand. For every intervention a report with the details of each problem and the required activities is filled in. The customer has access to all information to verify the intervention history and the historical consumption. The reports can also be accessed via web, email or a dedicated phone number.

The main advantages of an outsourced service like this can be summarised as follows:

- Cost savings due to economies of scale
- Availability of a specialized worker 24/7
- Avoiding most common faults with scheduled maintenance

Over recent years the maintenance process has moved away from the simple concept of "reparation". The maintenance scenery itself is the centre of a revolution of the concept: from maintenance considered as a simple cost to an optimisation and improvement of concept idea.

II.5 Price aspects

Price structure – a customer's rational decision

Once a customer has decided to be supplied by District Heating the connection can be established swiftly and simply. The technical planning and construction works are taken care of in a professional way and fast by the local District Heating company.

In most cases it is up to the customer to decide whether he wants to be an investor and owner of the substation. Customers cover only part of the total costs of the connection to the District Heating network. The District Heating company covers the rest. In addition costs associated with local boiler house construction, chimneys and other installation are completely avoided.

Various tariffs for District Heat supply are offered to customers. District Heating costs typically comprise of a fixed part, as well as of a consumption dependent variable part.

Heat distribution - flexible tariff

Tariffs and costs for District Heating vary throughout Europe and depend on local conditions. The customer decides independently on the connected heat capacity and is consuming as much heating energy as required at any given time (whether summer or winter).

Modern heat meters measure the exact heat consumption, enabling various, even time dependent, flexible tariffs.

Heat tariffs encourage customers to use the delivered energy rationally. In various cases customer are offered lower prices if they decrease their return temperature.

Examples from several countries confirm that connection to a District Heating network ensures more stable and cheaper prices for customers (see for example figure 3 and 4). One reason for this is that in a District Heating Network a variety of heat sources can be utilized, enabling the operator to choose the most economical one at any given time.

Energy prices are either set under permanent competition or regulated by city councils or other official regulatory bodies. The prices are made available in a transparent way without any hidden costs in the tariff for heating for the customer.

District heating is one of the cheapest heat sources on the market. Statistics show that it is a very stable heat source, making expenditures predictable for customers.

Figure 3: German development of specific full costs in Euro per MWh[1]

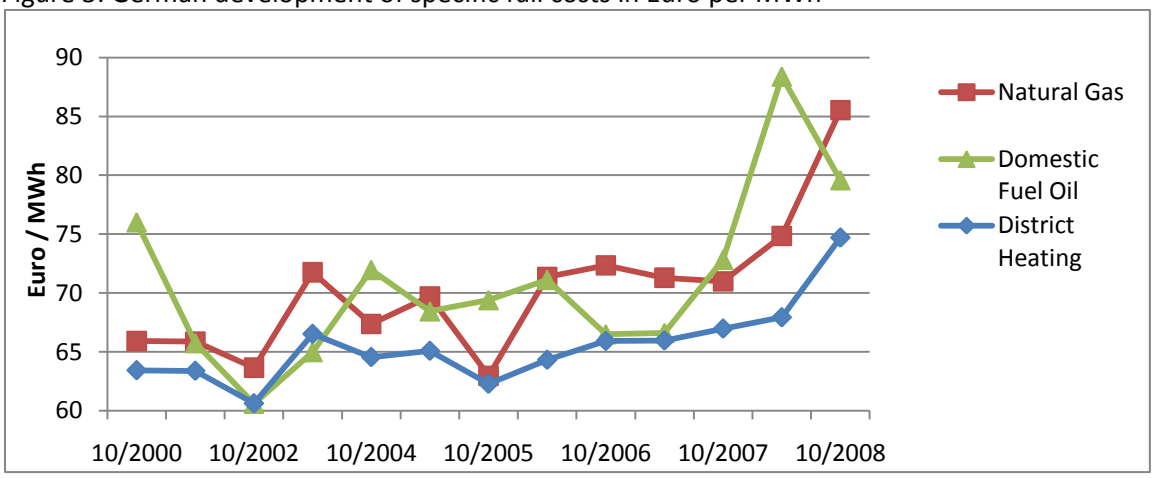
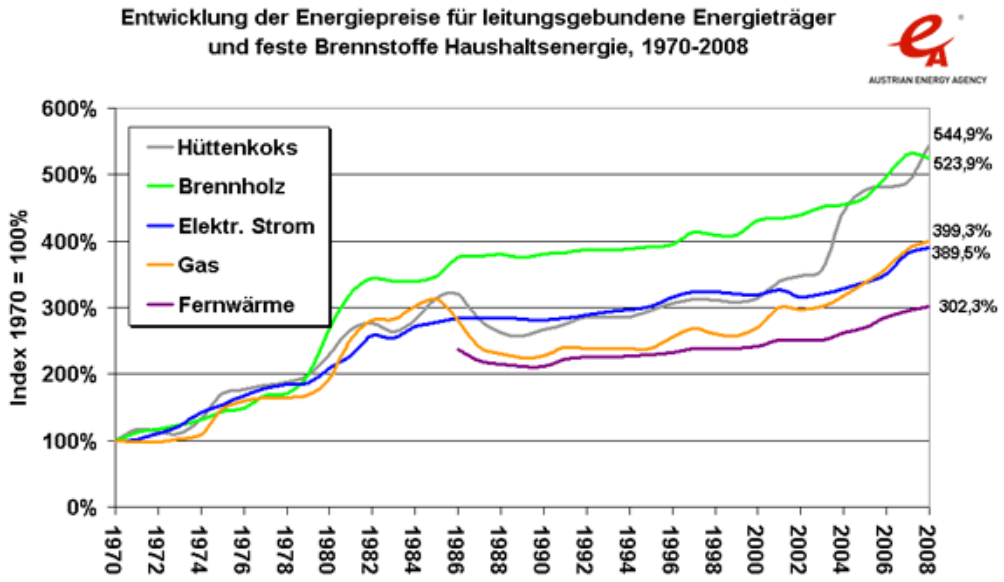


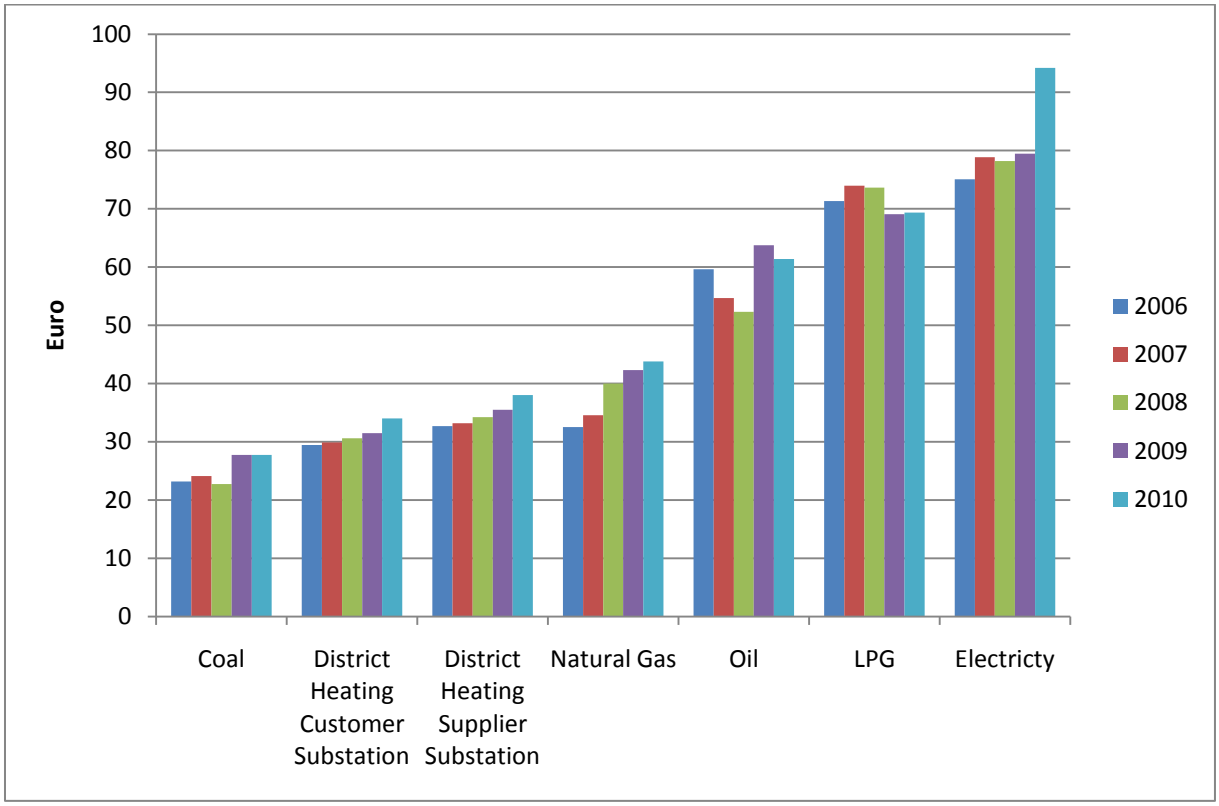
Figure 4: Energy Price Index Austria[2]



[1] Source AGFW; Heat demand 160 kW, 288 MWh annual consumption; Source fuel costs: Domestic fuel oil - Federal Statistical Office; Fachserie 17/2, Natural Gas - Wibera (natural gas price comparison list)District heating - Wibera (weighted district heating costs)

[2] Source Statistic Austria; Based on a calculation by the Austrian Energy Agency

Figure 5: Polish Heat Prices according to heat source



II.6 Environmental benefits by comparison with other heating options

A variety of studies document the environmental benefits of District Heating and Cooling. For example the Ecoheatcool study supported by the European Commission confirms the possibility of saving an extra 404 million tons of CO_2 annually (additional to the 113 million tons/year avoided by DH in 2003) in the time horizon 2020 by doubling and improving District Heating across 32 European countries. At the same time, higher energy efficiency will reduce primary energy supply by 2,6 % (2003) or 2,1 EJ (50,7 Mtoe)/year (equal to primary energy supply of Sweden). Increased security of supply will reduce the import dependency by 4,5 EJ (105,4 Mtoe)/year (equal to primary energy supply of Poland).

The main reason for District Heating being one of the most sustainable heating solutions on the general heating market is the fact that it uses local heat and fuel sources that under normal circumstances would be lost or remain unused, as well as the high efficiency levels achieved in District Heating networks.

In addition the following factors can be observed:

- District heating system provide the possibility to built up CHP production. Overall District Heating systems are very efficient. Modern CHP plants fuel efficiency can be above 90% leading to less fuel consumption and lower emissions.

- District Heating systems make use of as many different production types (CHP, heat pumps, surplus heat from industry, waste incineration) and local available energy sources (biofuels, wastes, coal, gas, ...) as possible. The whole system is very flexible and easily adapted to new technologies and fuels.

- District Heating and CHP are both excellent solutions to reduce emissions locally
  - Better air quality
  - Low climate impact; reducing primary energy consumption, less CO2 -emission, less small particles.

- It is economically and technically easier to install highly efficient cleaning systems to larger production plants (SO2, NOX, small particles, …) than individual installations. Constant air quality measurements ensure a healthy living environment.

- As energy is generated on a large scale, District Heating can integrate combustible renewables that are difficult to manage in small boilers, which is a common characteristic of combustible renewables like wood waste, straw and olive residues as well as waste sources such as municipal waste and sewage sludge. Various renewables including bio fuels, geothermal, solar and wind energy can be more effectively used when integrated into the District Heating networks through an ever expanding range of techniques.

II.7 PEF comparison of District Heating with other heating options

Primary energy factors (PEF) make it possible to compare heating solutions with regard to their contribution to reducing the use of fossil fuels.
Primary energy factors measure the combined effect of efficiency and the use of renewable and recycled energy sources. The assessment encompasses the whole energy cycle – from conversion to delivery to the customer. The lower the PEF value of a technology, the more fossil energy is being saved. Operational data confirms that District Heating schemes consume far less energy than other heating solutions.

The comparison of the typical PEF values of different heating solutions below shows that District Heating is one of the most efficient heating solutions. Values proposed by EN 15603.

Figure 5: Typical Primary Energy Factor (PEF) values of different heating solutions

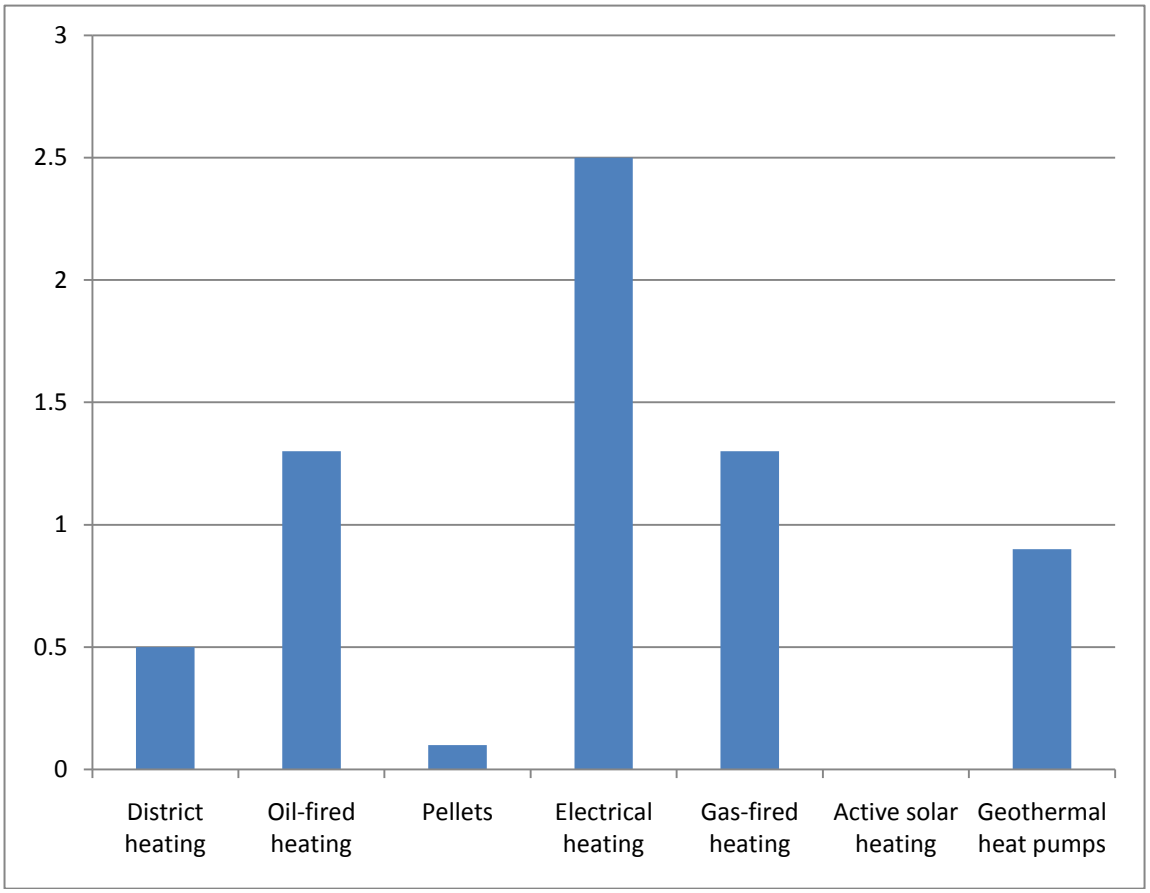
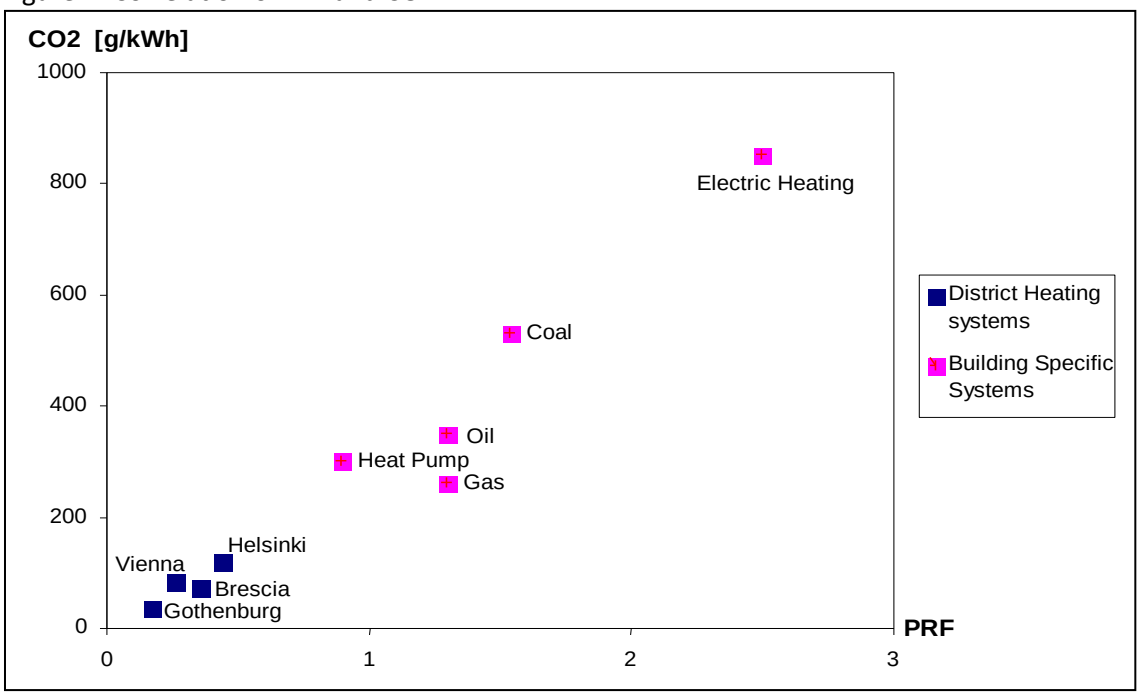


Figure 7: Correlation of PEF and CO2



II.8 District Heating companies as providers of both energy and service

Maintenance and normal service

Continuous maintenance and replacement of technical components keeps the use of heat on the right level and improves the life length of the substation. Especially the regulating devises such as valves and actuators have a significant impact on the life time and must be maintained appropriately.

Good technical service from the utility is the best way to create a good reputation for District Heating on the heat market. It is also done in many places and could easily be regarded as a major benefit for DH customers.

Energy services and District Heating

Energy services of most District Heating providers throughout Europe include services regarding the substation and in some cases also services regarding the internal heating system of the building. This kind of business can be developed and provided by every utility within the range of normal maintenance as stated above. Most of these services and maintenance tasks are also proposed in the Guidelines for District Heating substations.

The Guidelines can be downloaded at www.euroheat.org.

External research on customer satisfaction clearly demonstrates that customers are more satisfied when energy companies provide additional services.

The aim of providing energy services is to deliver peace of mind to the customer and at the same time further deepen the relation with him – in other words creating the best conditions for long-term relations.

When providing energy services the District Heating utility has far greater responsibilities than just supplying energy. It is actually a way of further improving the present products, District Heating and Cooling. Thereby the company has a wider range of products to offer their customers.

These “new” energy services are an entirely different concept than the existing ones concerning the substations and heating circuits. It is a way for utilities to meet the future with lower heat demands and more customer orientation. It is also very clear that such a business demands a new approach and organisation. These services concern District Heating and also other building equipment.

As European citizens and businesses are ever more focusing on energy efficiency, sustainability and competitiveness, a clear trend towards energy services can be observed throughout Europe. The general trend to a sustainable society is a clear driver for this development. It comes as no surprise that this kind of business opportunity is seized by District Heating providers, who are already trusted partners of energy customers.

Outsourcing in the building sector is another clear trend that can be observed. In many cases, customers request to receive all services concerning housing facilities from one provider. Through outsourcing, companies also have the opportunity to minimise their costs in property operation by obtaining appropriate level of professional know-how.

In general there is an ever increasing demand for comfortable and productive indoor climates.

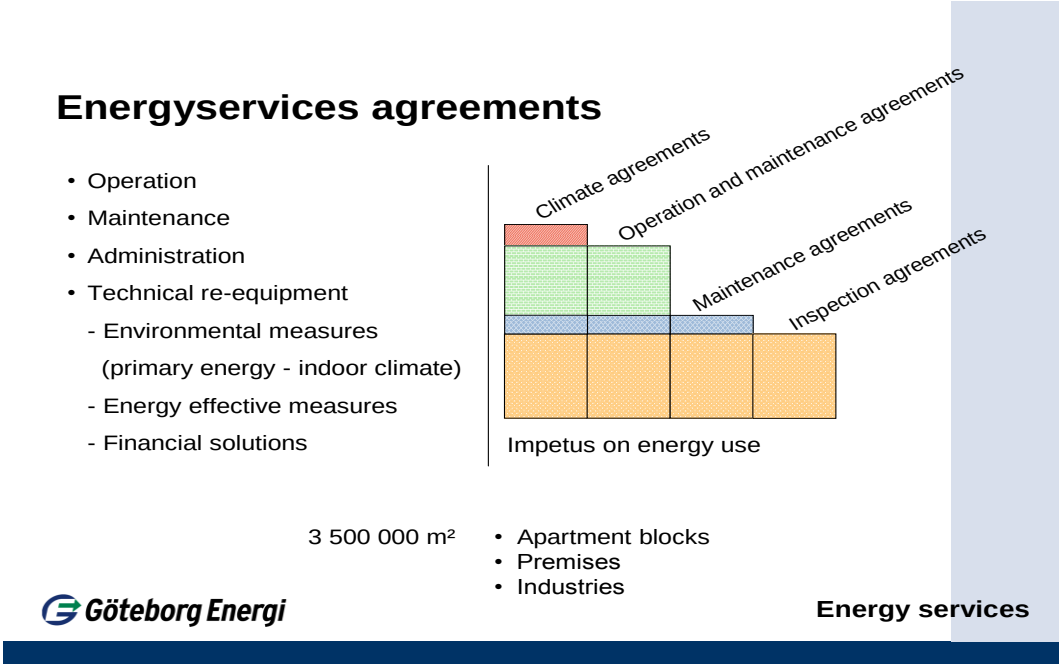
Many customers today purchase heating, electricity, water, cooling and services partially or as separate products. Both the District Heating company and other companies then charge customers for the supplied quantity. The customers have many different suppliers to buy from and therefore many different contacts.

Customer needs of tomorrow and to some degree also today are such that customers demand a one stop shop for all house facilities.

Customers have to be assured that they have a partner who cares about them, who wants to be active and who is able to show them opportunities that they themselves may not see.

The scope of the energy services agreements can vary considerably, from climate agreements where the District Heating Company takes full responsibility, to maintenance agreements only.

Figure 2: Energy Service Agreements; Example from Goteborg



One important and well appreciated service to create is a call centre on duty 24 hours a day to respond to customer enquiries.

III. Optimization of the District Heating system inside the building

III.1 Technical recommendations for the optimal dimensioning of the District Heating system.

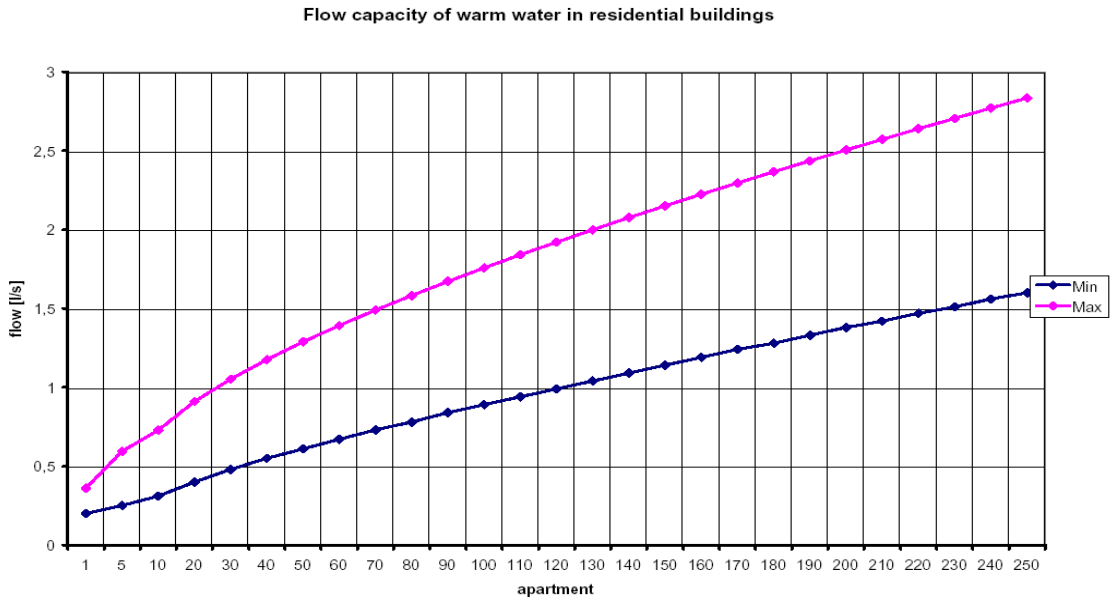
In order to handle dimensioning of substations in an effective way and to achieve optimal solutions concerning the demand for heat and warm water it is essential to be aware of the conditions and technical features of the system in use.

Control valves for both heating and domestic warm water should not be unnecessarily large. There are a number of disadvantages with over-sized valves. By reducing control valve sizes substantially down to the actual capacity demanded by the customer for both heat and domestic warm water there will be a number of benefits for the district heating network.

Regarding pipes and heat exchangers there can indeed be advantages in having some extra capacity for the future. Also, regarding heat transfer in the heat exchanger and the cooling of the return water larger sizes can be useful. But when it comes to valves the situation is totally different. Here, unnecessary over-dimensioning will result in great disadvantages for the network and production.

It is recommended that the sizing of control valves is made in accordance with the curves shown below. This will result in a number of advantages being in line with adequately sized heat exchangers and representing use of the smallest possible valves.

Figure 8: Recommended sizing of control valves for instantaneous heating of domestic warm water in residential buildings



The two curves shown represent realistic, current upper and lower limits for flows in Western and Northern Europe to be applied when sizing control valves in residential buildings. By striving to select control valve sizes in accordance with the lower curve of the graph above, one can obtain better operational economy and less maintenance for all parts of the substation, network, and production chain.

Advantages of appropriate sizing of valves and heat exchangers:

Present dimensioning varies greatly throughout Europe. The real advantages with correct dimensions, especially for valves, are the following:

- Smoother and more dynamic network that will respond better to changes in forward temperature and flow. This means that the highest demands will be smaller and more easy to supply than before
- A start up of the network after a "blow-out" can be performed much quicker than before; The network will be more dumb or more sensitive to changes than before
- Reduced morning peaks which ensure a smoother network operation and lower production costs
- Lower pumping costs
- Creating increased capacity in the local network which can be used for new connections or for transmission purposes
- Better control of both warm water and space heating in the substation means better, smoother and more stable operations. This gives longer lifetime for valves and other equipment, less service demand which results in better economy of the substation
- Warm water circulation functions better
- Decreased risk for laminar flow low flow
- Improved cooling of circulated network water in the summer time

It can be concluded that by striving to make dimensions closer to the lower slope in the figure above, one can obtain better economical and maintenance results for substations, for the network as well as for the production.

This principles regarding sizing of control valves and heat exchangers discussed here above refer to substations with instantaneous warm water heaters and primary connections to the network.

These principles are of course also valid for the primary valves in direct connection.

III.2 Maximize District Heating in floor heating

Optimization and maximization of District Heating are important when it comes to energy efficiency. In this area one of the most important things is a low return temperature along with cooling of the secondary network.
The amount of heat utilized from the circulating District Heating system water depends mainly on the design and adjustment of the building's internal heating systems, but also on the performance and the condition of the District Heating substation. Good cooling of the District Heating water (i.e. more heat subtracted) and good performance of the District Heating substation are in the interests of both the customer and the heat supplier.

The customer will obtain several benefits by using a floor heating system.

- A low temperature heating surface is comfortable under the feet
- There is no risk of burning of the skin as the temperature of the surfaces is lower
- Indoor climate is stable and pleasant
- Floor heating is the perfect solution for low temperature/low energy systems and therefore is ready for the challenges of the future.
- The building materials have longer life time thanks to lower temperatures required for floor heating
- The floor heating represents a flexible solution for several heating sources.

By using typical dimension values for radiators and floor heating there are remarkable differences in flow and return temperatures. With floor heating lower return temperature of 15-25 °C and 25-40 % less flow in the primary side can be achieved.

Annex 1: Systematic comparison of different heating solutions, indicating their Pros and Cons

	EQUIPMENT
District Heating	+ low space requirements, the heat distribution equipment needed is very small + unlimited amount of DHW is available 24/7
Oil-fired heating	- need for a big fuel storage tank - boiler & burner - need to have a chimney
Pellets	- storage facilities for pellets necessary - need for pellet boiler with combustion chamber and pellet feeding system - need to have a chimney
Electrical heating	+ no equipment except radiators necessary for space heating - need for separate DHW tank
Gas-fired heating	- chimney - need for gas burner and boiler
Active solar heating	- solar collectors on e.g. on the roof of the building - need for heat exchanger package - heat storage tank + no need for a separate DHW tank
Heat pumps	- needs a ground heat exchanger (heat pump) as central unit - only for preheating of DHW, needs a separate DHW tank

	MAINTENANCE
District Heating	+ no maintenance necessary for the customer
Oil-fired heating	- yearly maintenance of the burner to ensure efficient use of the fuel - regular cleaning of the storage tank recommended to ensure efficiency.
Pellets	- needs regular control and maintenance + easy to handle - needs regular chimney sweeping and ash removal + regular maintenance of the burner, the boiler and the storage keeps particle emissions low
Electrical heating	+ no maintenance necessary
Gas-fired heating	- must be maintained regularly to ensure high efficiency and security - maintenance work can only be performed by accredited repair shops
Active solar heating	- requires regular supervision and maintenance
Heat pumps	+requires little maintenance as few mechanical components

	COSTS		
	Fuel costs	**Maintenance costs**	**Investment costs**
District Heating	+ no concern about fuel availability for the customer + steady pricing, public tariffs + predictable prices - local pricing differences	+ very low maintenance costs	+ moderate investment costs if the building is already using a centralized waterborne heating system as little equipment is necessary
Oil-fired heating	- uncertain fuel price development and fuel costs + long-term fuel storage possible + almost all oil heating systems can be used with gas as alternative fuel	- large maintenance costs as regular maintenance is needed	- large investment costs
Pellets	+ affordable and predictable fuel costs (not dependent of world events like oil/gas) + different storage ways (different size pellet bags or pellets blown into bigger storage room)	+ moderate maintenance costs	+ large investment costs
Electrical heating	- prices hard to predict - local pricing differences + no fuel availability concern for the customer	+ no maintenance costs	+ very low investment costs
Gas-fired heating	+ no fuel storage space needed, connected directly to the gas grid + cost efficient heating alternative + almost all oil heating systems can be used with gas	- moderate maintenance costs	- large investment costs
Active solar heating	+ no fuel costs	- moderate / large maintenance costs	- large investment costs
Heat pumps	- preheating of the DHW with heat pump will save 25-50% of warm water costs - costs for adjusting the radiators to the system when retrofitting +longer lifespan than conventional heating systems	+ small/very small maintenance costs	- drilling costs depending on location - large investment costs

	RELIABILITY		
	Reliability & efficiency	**Risks**	**Durability**
District Heating	+ very reliable	+ very low risks	lifetime for the substations: typically 20 to 30 years
Oil-fired heating	+ high efficiency + reliability high but subject to fuel availability	+ moderate risks	lifetime for the boiler: 20 years, burner: 10 years
Pellets	+ Consistent fuel size and energy content + Burns predictably - consistent heat output	+ small risks	+ estimated boiler life: 20 years
Electrical heating	+ very reliable	+ very low risks	+ very long lifetime
Gas-fired heating	+ efficiency ratio over 90% + very reliable	+ small risks (mainly related to fuel availability)	+ estimated boiler life: 20 years
Active solar heating	- efficiency and production subject to sunshine hours - cannot be relied upon as only heating system	- moderate risks as it is dependent of the weather	+ life length for the collectors: 10 to 20 years
Heat pumps	+ energy efficient + high reliability and durability	+ moderate risks	+ life length: 15 to 20 years

	ENVIRONMENTAL ISSUES	Primary Energy Factor, PEF (Typical)
District Heating	+ low environmental impact due to heat recycling and use of renewables	**< 0.8 (European average)**
Oil-fired heating	- Fossil fuel - emissions	**1.3**
Pellets	+ very low environmental impact + pellets are renewable fuel - particle emissions	**0.1**
Electrical heating	- subject to the energy source used for the electricity production - low conversion efficiency	**2.5 (European average)**
Gas-fired heating	+ 1/4 less CO2-emissions compared to oil. + no sulphur emissions, small particle emissions	**1.3**
Active solar heating	+small environmental impact - needs complementary heating system	**0**
Geothermal heat pumps	+ energy efficient and environmentally friendly compared direct electrical heating system	**0.9**

Explanatory note : **PEF (Primary Energy Factor – non-renewable convention)**

PEF is a tool for comparing the efficiency of different heating systems to each other as it takes the whole energy chain and the energy market into account. The PEF is defined as the ratio between fossil energy input and the energy used in the building. The lower the PEF, the less fossil fuel is used.

	OTHER
District Heating	+ district heat can be produced through many different production methods and is thus not dependent on a specific fuel + suitable for all kinds and sizes of buildings - only available for buildings in areas where a district heat network is available (urban areas)
Oil-fired heating	+ availability and use not subject to distribution networks + suitable for all kinds and sizes of buildings
Pellets	+ the pellet burner can be used with boiler for pellet use but can also be connected to most oil- and wood used boilers - suitable mostly only small buildings - pellets availability is not unlimited
Electrical heating	+ electricity is available almost everywhere - suitable mostly only small size of buildings
Gas-fired heating	+ possible to use gas for cooking when connected to the gas grid + suitable for all kinds and sizes of buildings - only available for buildings in areas where a gas network is available (urban areas)
Active solar heating	- requires a complementary system + can use both circulating water or forced air as heat distribution system - suitable only small size of buildings
Geothermal heat pumps	- requires electricity to function → heat is produced to 2/3 from renewable geothermal heat and to 1/3 from electricity + can use both central heating and under floor heating as heat distribution system + using under floor heating increases the efficiency ratio of the system - suitable mostly only small size of buildings

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