Processing/Products No. 58

An introduction to district heating Organisation and technical aspects

Pieter D. Kofman

- *District heating is a way to provide clean energy to multiple users*
- *District heating can use almost any fuel or use waste heat from elsewhere*
- *District heating provides heat to the user via a heat exchanger, meaning that the district heating water does not circulate in the building of the user*
- *By metering the flow and the in- and outgoing temperature, the system calculates the amount of delivered heat*
- *In a well laid out piping network, the transfer losses of energy amount to 10-15%, which is slightly higher than the transmission losses in the electricity supply*

Introduction

District Heating (DH) is a system that transfers heat from a heat source by means of a water-based system to many users. Heat is transported through an underground pipe network, with the water at temperatures of 80 ^{o} C. At the consumer end, heat is transferred to the central heating system of the user by a heat exchange unit. Once the DH water has transferred its heat load it returns to the heating plant to be heated again and begin another cycle (Figure 1).

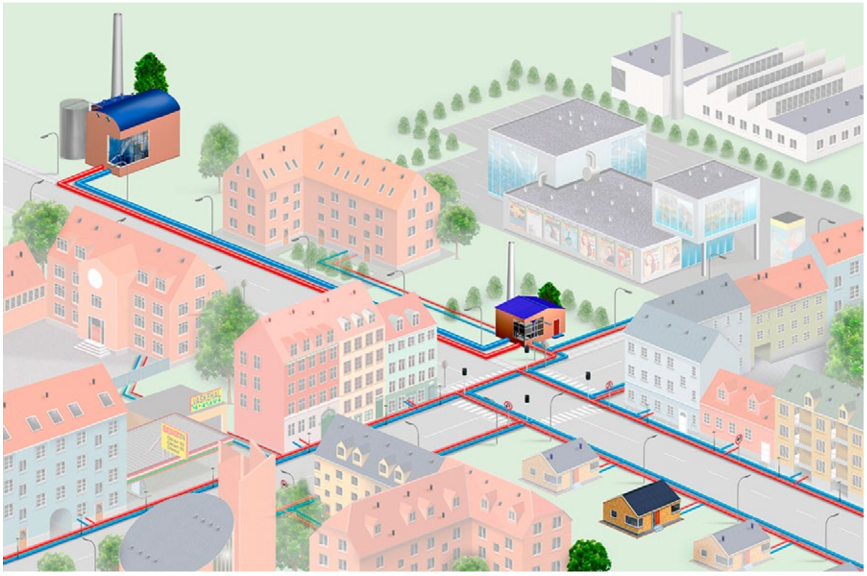

Figure 1: Principle of a district heating system (By kind permission of Fjernvarmeskolen.dk).

DH systems vary in size, but common to all is that one (or more) heat source(s) supplies heat to many households, factories, utilities or businesses often in combination. In practice DH systems vary from a few houses to whole villages, towns or even cities. In many European countries, DH is rather common. For example, in countries such as Denmark, Sweden, Finland, and Austria have a long tradition of district heating. This COFORD Connects Note is based on experiences from Denmark, where 1.84 million households (or 66% of all), comprising some 3.7 million people, are connected to one form of district heating or another.

COFORD
Department of Agriculture, Food and the Marine
Agriculture House, Kildare Street
Dublin 2, Ireland
Email: fsd@agriculture.gov.ie
http://www.coford.ie

An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine

Why district heating

There are many advantages to district heating:

District heating allows the use of fuels that would not be otherwise possible to use in single households. Wet wood chip is a common fuel in Danish district heating plants. Wood chip is a cheap and readily available domestic fuel in Ireland. Wet wood chips cannot be used in single households, as small boilers need a dry fuel, which adds to cost under Irish conditions.

District heating enables emissions of fine dust and noxious gasses to be kept to very small amounts, because the boiler works at an optimal rate with full combustion, and the flue gasses are cleaned before they are emitted.

The reliability of a district heating system is far greater than individual boilers at each residence or end user because many of the systems needed by individual boilers are redundant and back-up systems are incorporated in the DH plant.

For those people who are connected to a DH system, the need for maintenance and repairs of the former individual boiler is removed and, space in the home where the boiler used to be if freed up to other use.

By using DH, the consumption of electricity will be greatly reduced in comparison to individual heat pumps, so overload on the grid can be avoided.

Who should be using District Heating?

Even though private citizens and their homes will benefit greatly from DH, a good DH always has a mix of private homes, businesses, offices, and public buildings. Often the public buildings offer the greatest incentive. Places like swimming pools, leisure centres, retirement and nursing homes, hospitals, prisons, barracks and schools all have a high year-round energy consumption and are such great customers for a DH.

A DH for domestic homes alone would have a struggle during the summer months, because the heat demand is very low and mainly aimed at providing consumption hot water, but by adding energy demanding facilities, the boiler can be run on a more even footing.

Principal parts of a district heating system

All district Heating systems comprise the following:

- A source of energy to heat water to typically 80 ^{o}C
- A pumping system to circulate the hot water
- A pipe network to convey the hot water to the user and return the cooled water to the heat source
- Individual heat exchangers at each of the users
- Often the system will also contain a heat storage unit, which operates much like a giant hot water bottle.

Sources of heat

Heat energy can be supplied from different sources, such as waste heat from large industries or data centres, waste incineration, electricity production, geothermal heat, or from combustion of fuels ranging from fossil-based coal, oil and gas to biogas and solid biofuels such as wood, straw, and other agricultural waste products or waste-derived fuels. Solar panels (both hot water and photovoltaic), wind, water and tidal power can also be used. In some of the aforementioned heat sources, the production of heat is combined with the generation of electricity. In cogeneration of heat and power, or as it is usually referred to as Combined Heat and Power or more commonly CHP.

An example of a district heating plant using wood chip fuel is shown in Figure 2.

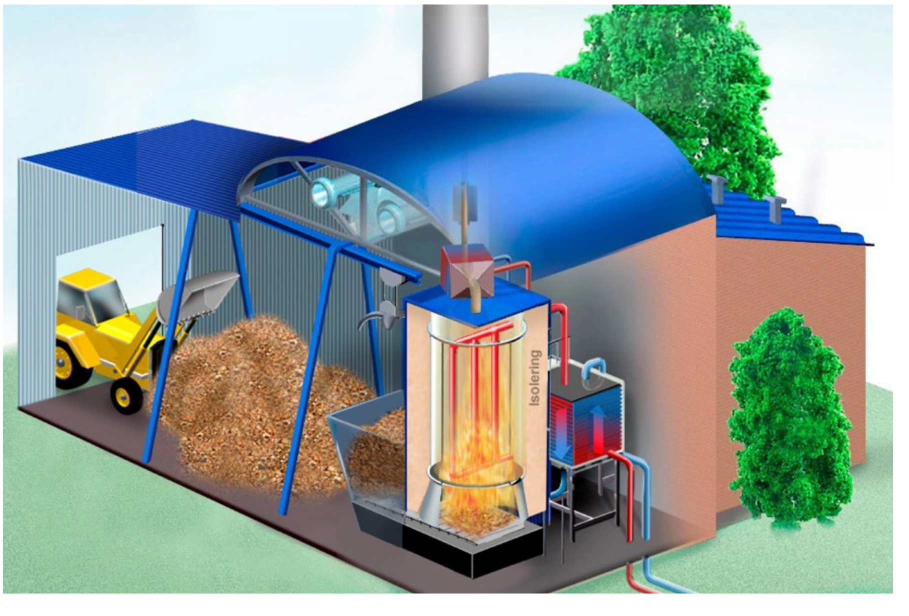

Figure 2: Schematic of a district heating system, using wood chip as a fuel (By kind permission of Fjernvarmeskolen.dk).

Pumping system

Heat is transferred to the end-user by means of hot water, which is pumped through the pipe network. Typically, the heating water leaves the plant at a temperature of 60 -80º C, and once it has shed part of its heat load it returns to the heating plant, at temperatures of 40-45º C.

Pipe network

The pipe network consists of specialised, extremely well insulated pipes. Often the outward and return pipes are placed inside the same insulated mantel, so only one "pipe" needs to be laid in the ground. The main pipe has a considerably larger diameter than the user-end pipes, which branch off from the main pipe. Connection pipes to users are often made from flexible material, so they can be easily laid around obstacles that may surround the building.

The main pipes are laid in excavated trenches, but it is possible to install the smaller feeder pipes underground without having to dig up the space around the house. Only a relatively small diameter cavity is needed outside of where the pipe will enter the building.

Heat exchangers

The heat exchanger is normally placed where the pipes enter the building. It transfers the heat from the circulating hot water to the internal system of the building. The water used for heating the building does not come in contact with the water in the DH system.

The principle of a heat exchanger is shown in Figure 3.

Heat storage

To ensure a continuous supply of heat to users, the DH system will often contain a large storage tank, where 100s to 1000s of cubic metres of hot water are stored. Storage is scaled to the size of the DH system.

The storage tank also serves as a back-up heat source which can also be used to store hot water when consumption is less than demand, or when water is heated when the fuel or energy source is cheaper, for example night-rate electricity.

The storage tank also has the function of providing extra heat in peak load periods, where the boiler cannot supply all the needed energy. Peak loads are relatively rare and of short duration.

Detailed description

Organisational:

- Who owns the installation?
- How are things paid for, payment?
- Required manpower.

Technical:

- Transfer of heat at the consumer level
- Piping network (transmission losses).

These items are explained in the following sections, all based on the Danish model.

Operational

Operational aspects are dealt with in a separate COFORD Connects Note, where the ins and outs of using woodchip as a fuel in DH and CHP are described.

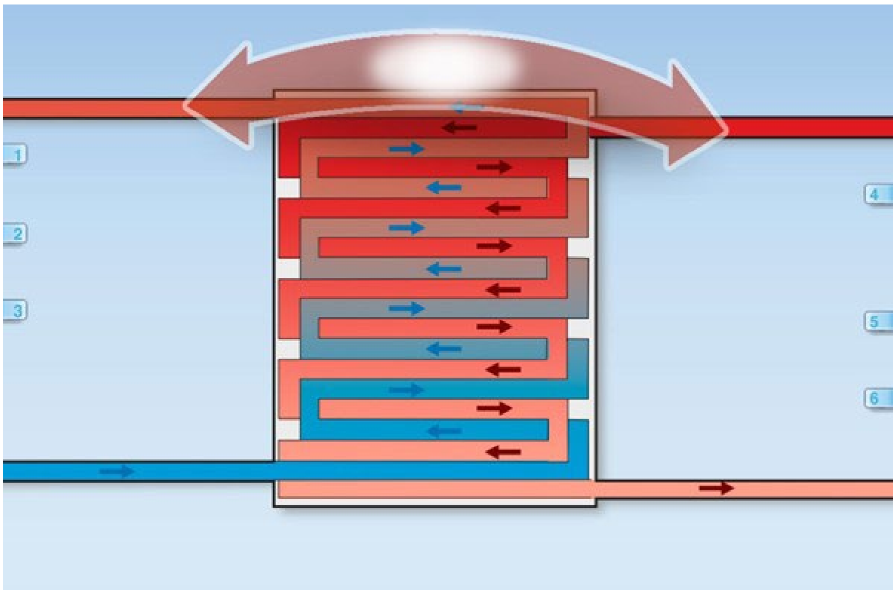

Figure 3: Principle of a hot water heat exchanger used in distract heating systems (By kind permission of Fjernvarmeskolen.dk).

Organisational models

Ownership

A DH/CHP plant can be owned and operated by different entities:

- It can be commercially owned and operated
- It can be owned and run by the (local) authorities
- It can be owned and operated by the users of the DH.

When the DH system is owned and operated by a commercial entity it needs to make a profit, usually meaning that the heat service will be more expensive than in the other cases. This model is rare in Denmark. Those companies that do provide such a service are sometimes called an ESCO (Energy Supply Company).

With very large DH systems for larger towns, often the DH/CHP is owned and operated by the local council. That is for example the case in Copenhagen, where it would be too complicated to have a user-based organisation because there are simply too many users. Usually, these council-operated DH systems are run on a not-for-profit basis.

The most common organisational system in Denmark is where the whole DH is owned and operated by the users in a limited liability company (LLC). This means that the users are not liable for any costs other than those incurred in supplying their heat. By law in Denmark these organisations may not make a profit, nor suffer a loss. This means that in case a profit does occur within a specific year, the surplus has to be paid back to the customers as soon as possible in the next year. If a loss occurs, the heating costs for the following year must be increased to cover those losses.

The board comprises elected members who hire a professional to run the company, usually a person with an engineering or plumbing background. They will also hire an accounting firm to keep the books. The board is also consulted in case the company needs to hire staff to run the plant and to service installations or the pipe network. The board also sets the price for the heating. An annual meeting is held where issues are discussed with the membership, and board proposals are put to a ballot.

Payment

District heating costs comprise a number of items:

- A fixed amount per unit area of housing, €/m^2
- An amount per metered used energy unit, €/MWh
- Rent for the energy meter, €
- Service cost for the heat transfer unit, €.

The fixed amount per m^2 covers the fixed costs of the plant such as repayment of the loan on the entire installation, the heat unit building, the pipe network, wages of the staff, and such. The fixed cost per m^2 is calculated by dividing the total of the fixed costs by the total number of heated square metres of all the users of the DH system. This assures a progressive allocation of costs over all the users. If you have a small house, you pay less in fixed costs in total than if you have a big house or business.

The amount per consumed unit of energy covers the costs of the fuel that has been used to generate the heat. The user pays a set amount per energy unit that they consume, which will be decided at the annual general meeting.

To measure heat consumption, a meter is installed at the consumer location. The unit measures the in-going and out-going temperature as well as the flow. On that basis the energy consumed is calculated. Normally, meters can be read from the office of the plant, so there is no need for someone to come to the house to read the meter. The meter needs servicing every now and then, and will need to be replaced after 10-15 years. Replacement costs are included in the rental cost of the meter.

To transfer the heat from DH system to the internal distribution system of the user, a heat exchanger is used. This apparatus also needs servicing from time to time. By paying a service fee, the onus is then on the DH company to maintain that unit.

The costs are summarised in table 1. Costs are 2024 Danish figures for a small DH system.

Table 1: Calculation of typical annual user cost of a district heating system

Cost category	€ /yr excl. VAT	Calculation for a typical household €
Cost per MWh	80	12MWh*€80/MWh= 960
Fixed charge per m^2	4	130 *4 m^2 =1200
Rent of measuring unit	70	70
Rent of heat exchanger	300	300
Total annual cost € excl VAT		2530

For a normal one-storey household of 130 m^2 and a consumption of 12 MWh of heat for room heating and hot water the total heating cost per year is €2530 excl. VAT.

Labour requirements

The required labour for a DH or a CHP system greatly depend on its size.

In general DH systems run fully automatically, meaning that staff are only on the premises during normal working hours during weekdays. Outside working hours, on weekends and holidays, the system runs automatically but there is an alarm system that will alert the duty manager when there is a problem with the system. Either the system can be reset remotely, or the manager must go to the plant to fix the problem.

Small DH plants do not even require a full-time staff member but are run by a company that does other similar work and which is hired to do the job. When the plant reaches a certain size of over some MWh output it becomes necessary to have full time staff to maintain it, supervise fuel deliveries and to solve small technical problems as they may arise. For larger plants over say 5 MW installed capacity, the staff increases to at least two persons.

Large systems and especially CHP plants are manned around the clock. CHP usually involves steam turbine driven electricity generators. Such systems need manning around the clock by multiple staff, more being needed during normal working hours, with fewer at night and on the weekends.

Technical aspects

Transfer of heat at the consumer level

As outlined heat transfer from the district water heating system to the individua user circuit uses a heat exchanger.

The water from the district heating system does not circulate through the house, because it is chemically treated to reduce the amount of oxygen in the water to reduce corrosion in the piping system. Sometimes also chemicals are added to reduce the viscosity of the water, so it will take less energy to pump it through the pipes. Another advantage of separating the two systems is that if a leak occurs in the house only a relatively limited amount of water is lost, rather than several 1000 cubic metres from the district heating circuit itself, see Figure 4.

The heat exchanger is adjusted in such a way to ensure maximum cooling of the district heating water as well as to maintain the ideal temperature of the central heating water.

In figure 4 it is shown that the hot water consumption water is done with a hot water boiler, that takes its energy from the district heating water. There is also another solution, where the consumption hot water is produced by a flow through heat exchanger, which makes the boiler superfluous. It requires a ring pipe through the house to connect all the taps. A small pump circulates hot water through that ring pipe, so that immediate access to hot water from every tap is warranted.

Transmission losses

Of course, there are transmission losses of heat from the water being pumped through the pipeline system, even though the pipes are well insulated. Losses vary between systems and can range from 10-15% of the heat energy generated by the plant.

Transmission losses are factored into the costs charged for delivered heat, in the same way as they are included in the price per kWh for electricity (electricity transmission and distribution losses typically vary from 5-8% of the power produced).

Acknowledgements

All illustrations in this COFORD Connects Note are kindly provided by Fjernvarmeskolen.dk in Denmark, an organisation that provides teaching materials on district heating to schools in Denmark.

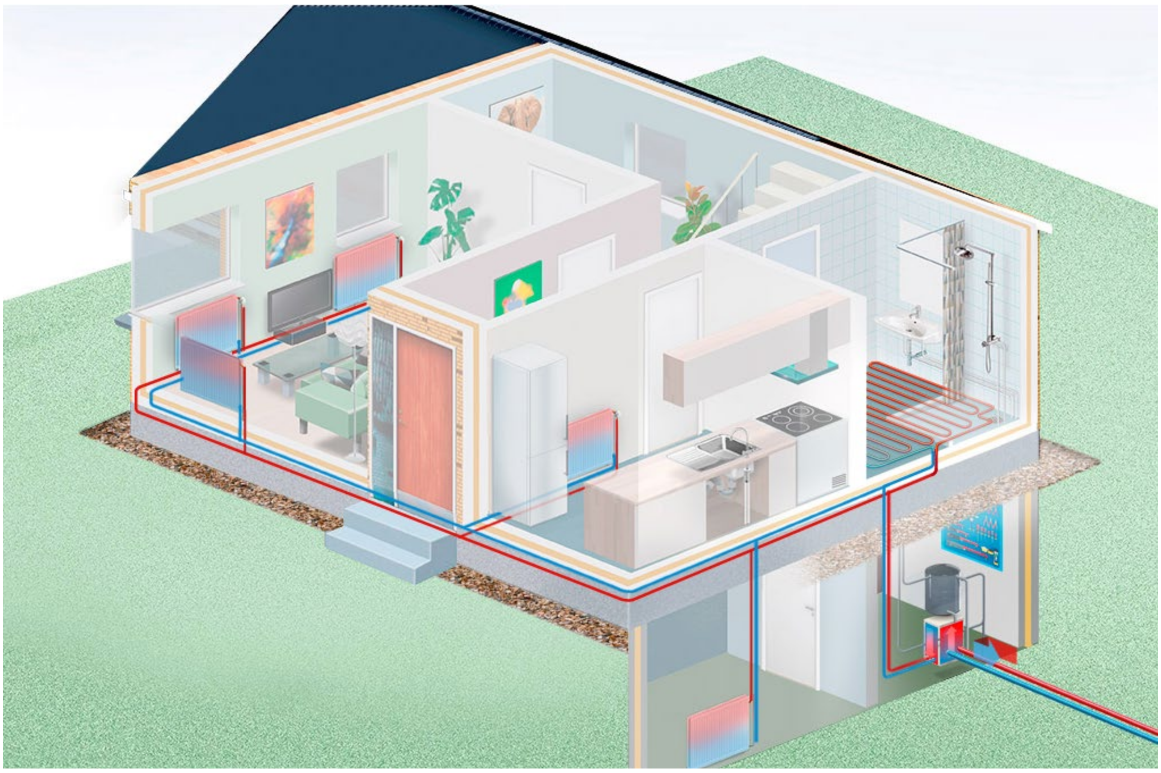

Figure 4: The DH water does not circulate in the house (By kind permission of Fjernvarmeskolen.dk).