MORE DHC/CHP GIVES LESS CLIMATE PROBLEMS

A Co-operation Between
The District Heating Associations
Of the Nordic Countries

DAVANTAGE DE CHAUFFAGE URBAIN, DE REFROIDISSEMENT URBAIN ET DE PCCE SIGNIFIE MOINS DE PROBLÈMES CLIMATIQUES

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1 What is DHC/CHP?

DHC stands for District Heating and Cooling. In section 1.1 the concept of District Heating (DH in the text) will be explained and District Cooling (DC) is explained in section 1.3.

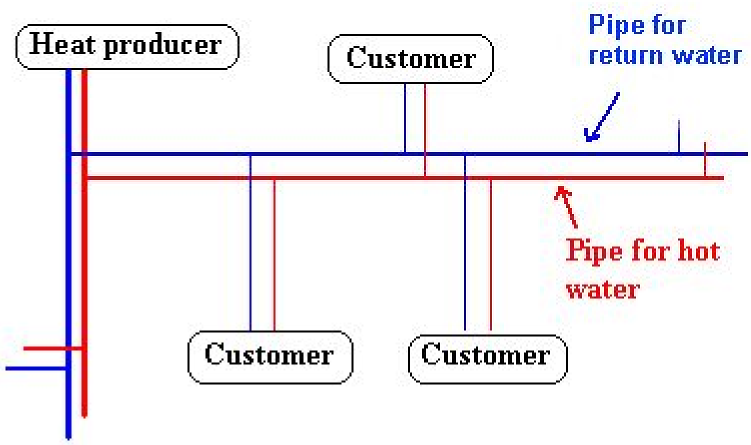
CHP means Combined Heat and Power and that is further explained in section 1.4.

The intention of this paper is to give a brief overview of the many advantages that District Heating (DH), District Cooling (DC) and Combined Heat and Power (CHP) brings to society and the energy sector and not least, the big possibilities they bring to solve the climate change problems.

1.1 What is District Heating?

District Heating can be described in simplifies terms as being a heating system in which water is heated in one place and then delivered to another place where heat is extracted from it. Its main component is a twin pipe system (Figure I) that is used to transport the heated water (or in some cases: steam) to the heating customers and to transport the cooled water back to the producer. The two other important components of the system are of course the facility to heat the water and installations on the premises of the consumer with which they can utilise the heated water.

Figure I



1.1.1 The Benefits of District Heating

As compared to individual heating, DH offers major benefits, mainly from the environmental aspect. As an example, DH has enabled us to use energy sources such as biogas, peat, straw, and heat in lake water and geothermal energy. It also enables us to use fuel with low energy content, and to recover waste heat from industry, refuse incineration plants and sewage water. Last but certainly not least, it allows us to utilise the vast amount of energy that is normally lost as waste heat from thermal electricity production.

Due to its large scale, DH has also made it possible to use very effective flue gas treatment and to achieve high efficiencies – in other words, to extract maximum energy from the fuel. District Heating also enables us to conserve our natural resources, and reduce emissions. Above all, it enables us to centralise the production of nitrogen and sulphur oxides that is associated with much energy conversion, to large production facilities were effective measures to prevent these substances to be emitted to the environment.

Moreover, to the customers DH offers good overall economy, a high standard of heating comfort and trouble-free operation – its reliability is close to 100 %.

1.1.2 District Heating in the Nordic countries[1]

The total population of the Nordic countries[2] is 24 Mio. people. The energy consumption is 4,43 TOE (51,69 MWh) per inhabitant. Almost 26 % of the total energy consumption are used for space heating purposes. That is equal to 1,14 TOE (13,31 MWh)-per inhabitant.

District Heating covers on average 35 % of the total demand for space heating, but coverage varies between 2,4 and 86 %. That is equal to a total heat delivery from DH of 9,6 Mio.TOE (112,2 TWh). The total heat capacity of all Nordic DH is 55,4 GW. Heat is distributed in a network with a length of 45.600 km. Heat density (delivered heat divided with network length) is on average 210,9 TOE (2,46 GWh) per km network.

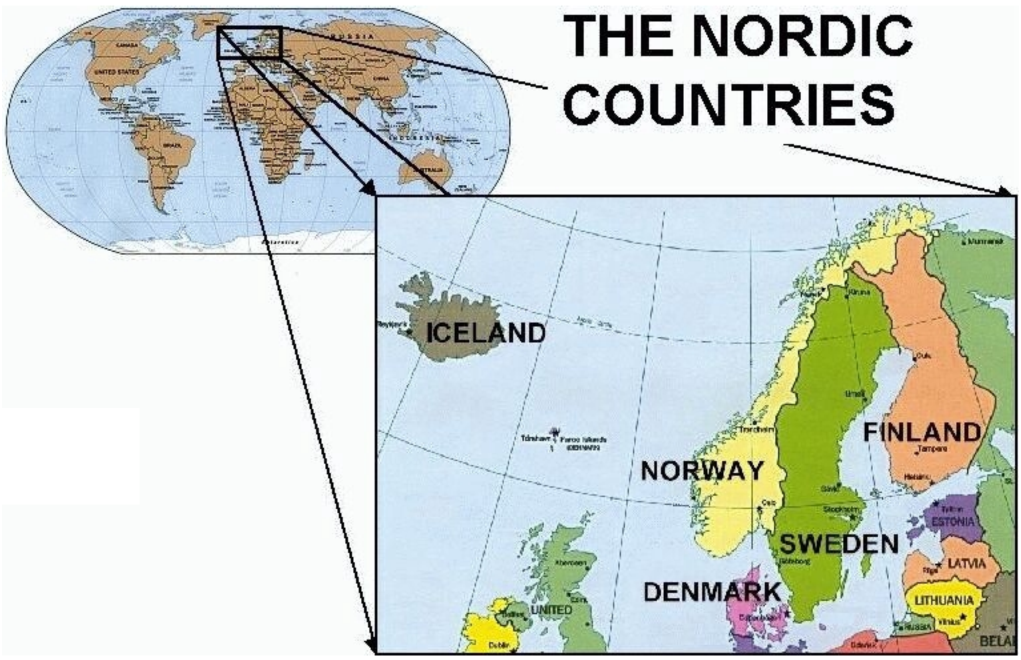


Figure II

District Heating is pluralistic when it comes to organisation, since DH systems can be organised and owned in many different ways. Even among the Nordic countries, this is done differently.

Most of the DH in the Nordic countries is operated by large energy utilities, which often have their roots in the electricity sector. They operate their DH systems on a purely commercial basis, and expansion of sales and the network is fully dependent on their ability to attract customers on commercial terms. Municipalities own many of these commercial companies. Some DH networks are owned and run by municipalities without any connection to the supply of other energy services. In one particular country, DH is by law operated on a non-profit basis, and the consumers through co-operatives therefore mostly own the DH utilities.

1.2 Technology used

1.2.1 In-house installation

In the connected buildings, the DH connection replaces individual heat production units e.g. oil fired boilers. A system to distribute the heat in the house is of course needed. It can be water or air based. In houses with central water heating, the hot water is circulated either directly through the radiators if the temperature of the network water allows this, or through a heat exchanger to pass the heat onto a separate distribution system in the building.

Hot tap water is also produced on the base of the DH supply. It can be with a separate heat exchanger for this purpose or with a water heater. The heat can also be used for cooling purposes, with an absorption cooler, that converts the heat to cooling. DH can also be used for industrial purposes where large quantities of heat or hot water are being consumed.

1.2.2 Distribution

In Nordic DH, it is normal to circulate hot water. Supply with steam is rare. The temperature range for the water arriving at the customers lies between 70 - 115° C (160 - 240° F) in winter with temperatures in summer 5 - 10° C (40 - 50° F) lower. Water leaving the production facility can have a temperature of up to 120 - 150° C (250 - 300° F), as part of the heat is lost during transmission and distribution. The loss occurs in the pipe network, pumping stations and if heat exchangers are used to separate networks. Some 8-20 % of the heat is lost this way, depending of the heat density in the area supplied with DH. The loss is small in built up areas and somewhat larger in suburban areas with detached houses.

To connect an ordinary detached house to the network 2 x 15mm pipes is often sufficient. In modern systems these pipes are often made of plastic materials or copper and are embedded in insulating

Figure III

Connection pipes for detached house.

(Photo: Løgstør Rør)

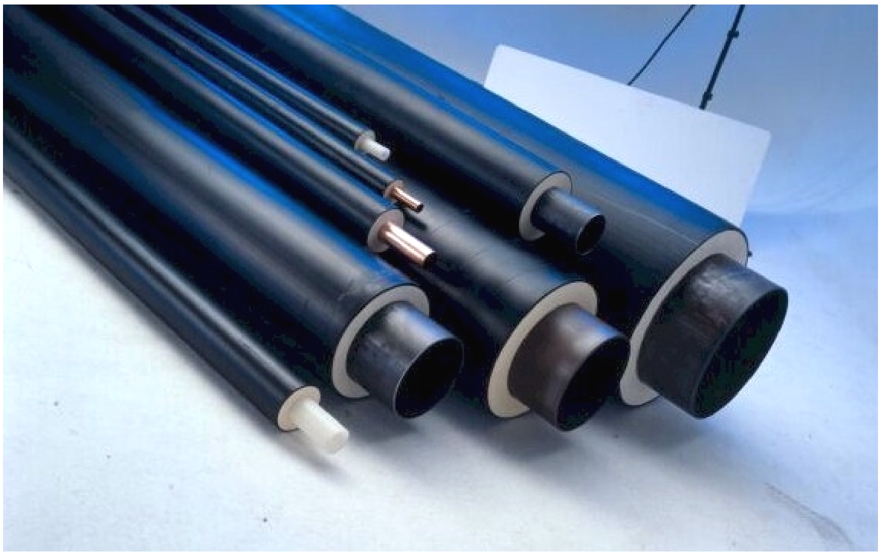
foam in a larger protective pipe of plastic. Such double carrier pipes can be made flexible and in long lengths which greatly eases transport and installation and reduces the cost of connecting houses to the network. (Figure III)

On higher levels in the network, steel pipes are used to distribute and transmit the hot water. On some larger networks, supplying surplus heat from large CHP plants, steel pipes of up to 1200mm are used to handle the large quantity of water with high temperature and high pressure. These pipes are also embedded in insulating foam within a protective plastic outer pipe. (Figure IV)

Figure IV

Collection of DH pipes.

(Photo: Løgstør Rør)



Pipes are mostly laid underground (0,7 - 2 meters below the surface depending on pipe size) and can be placed under paved surfaces. Plastic and steel pipes are welded together, joints are then insulated, and the protective plastic outer pipes is joined and sealed. Copper wires, built into the insulation and joined along the length of the network, can be used in detecting possible moisture in the insulation because of leaks in either network pipes or the protective outer pipe.

Well-constructed systems of this type can have a life span of 50 years or more.

1.2.3 Production

Heat for distribution in DH networks can come from many sources as shown in figure V. In some cases the heat is produced specifically for distribution while in other cases it is a by-product from some other energy use or conversion. It is, however, often the case, that unless the fuel or the heat was utilised through DH it would have been wasted. Either fuels like straw of wood chips would have been left to rot or surplus heat from power production or industrial processes would have to be disposed of. Alternatively, when it comes to waste incineration, place would have to be found to mountains of waste.

1.2.3.1 CHP

More than half of all District Heating in the Nordic countries is covered by heat from production of electricity in Combined Heat and Power (CHP) plants. CHP is covered in more detail in section 1.4.

1.2.3.2 Industrial waste heat

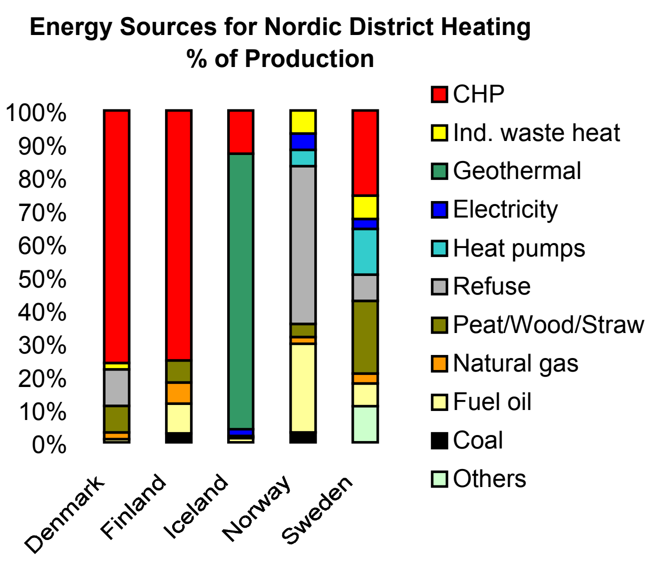
Many industrial processes require large amounts of energy and there is often a related need to dispose of low temperature heat. This can in many cases is used in DH schemes. Since cooling induces a cost, the value of the excess heat is negative for the producer and that gives room for making the necessary investments to sell the heat to those with a heat requirement for heating, cooling or industrial use.

1.2.3.3 Geothermal energy

Geothermal energy when available is easily used in DH, and if temperatures are right can be coupled with production of electricity. The primary example of this energy source is of course that of Iceland, where DH based on geothermal energy covers ¾ of all space heating.

However, even in countries not usually associated with geothermal energy, is it possible to find enough hot water underground to facilitate the use for DH. Denmark has one example of this and the possibility for others is being researched.

Figure V



1.2.3.4 Electricity

At times and in some countries electricity can be attractive to use directly for heat production in electrical boilers. That is the case on the Scandinavian Peninsula where surplus hydro electricity at times is so cheap that it can out-compete especially peak load production on boilers. Electricity can also be used in connection with heat pumps to produce heat for distribution, also based on very low value energy as e.g. the heat in sewage water. Electricity is unlikely though, to be the main source of energy for a DH network, since electricity would be too expensive most of the year.

1.2.3.5 Waste incineration

Still more refuse is produced in modern societies, both from households and from industry and services. Getting rid of this often involves transport to distant disposal sites where it is dumped, annoying neighbours and creating potential health risks.

As an alternative much of the daily waste can be incinerated and be converted to usable heat. Incineration also reduces waste to the size of the ashes left behind. Large incineration plants can also be constructed as CHP-plants and modern equipment can effectively wash the smoke coming from the incineration for harmful substances.

1.2.3.6 Boilers

Boilers can be used directly for producing heat for distribution. Fossil fuels such as oil, natural gas or coal can be used in such boilers, and the centralised heat production would enable a better control of the fuel, emissions, disposal of ashes and so on. Heavy fuel oil and coal are cheap fuels that are difficult or messy to use on an individual basis, but they are easily handled in large boilers in DH systems. Due to the loss of heat in distribution, the overall efficiency would however, in most cases, not exceed that of individual heating solutions.

Parallel to heavy fuel oil and coal, biomass fuels are not always very well suited for individual household use. They take up volumes of space for transport and storage, require a well-constructed boiler and much monitoring to burn efficiently and they leave ashes to deal with.

Boilers for biomass fuels can either be flexible enough to accept a multitude of fuels or they can be converted to another fuel with a small investment. Thereby the can be a flexible and reliable source of heat, using environmentally friendly and locally produced fuels that can often be bought at a price much lower than the price of high quality fuels such as oil or natural gas.

1.2.3.6.1 *Fuels*

One of the strengths of DH is that it can utilise locally produced fuels that otherwise might be worthless. As mentioned before many forms of biomass fuels can be utilised. That even creates an unexpected income for the producers of these fuels, and it replaces costly import of external fuel. A further benefit is for the environment, since biomass fuels are CO_2-neutral.

A switch in fuel is cheaper and much easier for a DH system than for the owner of a household or a small building. If oil or natural gas becomes scarce or the price increases, there are few alternatives for the individual. A DH plant can quickly switch to another fuel like locally produced biomass or cheaper and more abundant coal. Larger DH system can operate a range of production facilities using several fuels which makes it possible to exploit any opportunity for cheap fuel, as well as enhancing security of supply.

1.2.3.6.1.1 Fossil fuels

Easy to use but environmentally unfriendly fossil fuels like oil, coal and natural gas were earlier heavily used directly for heat production in Nordic DH. Now heat only production based on these fuels and only for the purpose of distribution today mainly takes place as peak load and spare capacity production.

1.2.3.6.1.2 Biomass

Biomass fuels are in many areas of the world abundant and multiple. In the Nordic countries, straw is readily available in agricultural areas, as are wood chips in woodlands. Due to a large timber industry, wood pellets produced from its refuse can be obtained throughout the region. Many other forms of biomass fuels can be obtained, nut shells, olive seeds, chaff and much more.

Figure II clearly shows the pluralism in energy sources in DH. CHP plays a significant role in the two countries that, in the absence of hydropower, has had to rely on thermal electricity production. For obvious reasons, geothermal energy dominates in Iceland. Norway, with plenty of hydropower and no CHP, and Sweden with just a little CHP have a more diverse range of sources for their DH.

1.3 What is District Cooling?

District Cooling (DC) is very similar to DH, but this time it is cooled water that is being pumped around in stead of heated.

1.3.1 The Benefits of District Cooling

An external supply of cold water can replace noisy and voluminous cooling machines operated individually by households or offices. In the production of cooled water, use can be made of the same diverse range of energy sources or fuels as with DH, replacing the use of electricity for cooling purposes.

1.3.2 District Cooling in the Nordic Countries

District Cooling is a relatively new business area in the Nordic countries. Traditionally air conditioning has not been used much in homes but has been used in offices for decades. One reason for this can be the geographical position of the countries, in a temperate climate without excessively hot summers.

However, the use for air conditioning in offices, shopping arcades etc. is growing. District Cooling is the environmentally best alternative. In Sweden DC has since 1992 rapidly been growing by some 50 – 100 % each year. There are more than 20 companies today that sell DC and Stockholm now has one of the largest DC nets in the world.

1.3.3 Technology used

The DC business is much diversified. Each system has specific local conditions. Therefore, different types of production have been used. Free cooling from deep sea or lake water, compression water chillers and absorption water chillers are the most common used techniques.

1.3.3.1 Production

The most efficient and environmental superior way of producing DC is to use deep-water sources. Cold water from the bottom of the sea or lakes with a temperature of 4-6° C is pumped in to the DC networks, where it is transferred over a heat exchanger.

The most common way of producing DC is by using existing large heat pumps, for DH production. The heat pumps use different low temperature waste heat as a heat source. Electrical compressors drive the heat pumps. When producing DH and DC at the same time energy efficiency is very high. For one part electricity, three parts of DC and two parts of DC are produced. Compressor chillers for cooling production only are rare for DC production.

Another way of producing DC is by absorption chillers. The chillers are placed at the customers' site and are driven by the heat from the DH network. There is no DC network involved. The absorption chillers use a lithium bromide solution as cooling media. The DH production must have low costs from waste incineration or equally.

1.3.3.2 Distribution

The DC distribution generally has a temperature of 6° C. A variety of materials are used. There is no universal solution. Both District Heating pre insulated steel pipes (with thinner insulation), un-insulated steel pipes (same as gas pipes) and plastic pipes are used.

1.3.3.3 House installation

One of the best selling arguments for DC is that it saves space for the customer. The house installation for DC is very simple, some shut of valves, heat exchangers and metering equipment. The housing systems are direct connected or with heat exchangers. Today most new connections are with heat exchangers. In order to get a good return temperature to the DC network it is essential that the customers' secondary cooling installations are adapted for a high return temperature.

1.4 *What is Combined Heat and Power?*

When electricity is produced alone on a thermal unit without utilisation of the waste heat, it is a relatively inefficient production, since – on average – more than half of the fuel is wasted in the conversion. Modern coal fired units can have en electrical efficiency of up to 46 % and modern gas fired combined cycle units can have an electrical efficiency of up to 56 %. Those are the best cases. Many electricity producers operate with much lower efficiency. Vast amounts of energy are wasted in the form of heat that is disposed of in cooling towers, rivers or the sea. This heat can be utilised and distributed through a DH system, and it can generate a new income for the electricity producer.

The cost of extracting heat from a power plant is small. Some investments in equipment have to be made, and there will be a small reduction in electricity production, since the heat in some cases has to be extracted at a temperature a little above the normal exit temperature for cooling water from the plant. Increasing the fuel input can compensate this reduction in electricity production or the electricity can be produced on other units. Comparing the extra fuel consumption with the heat extracted from such units gives efficiencies of 150 - 330 %. Fuel costs for the DH are therefore low and give ample room for financing investments in transmission and distribution systems and still maintaining competitiveness.

Even heat from power plants situated far away from potential heat markets can be utilised. In some existing cases, heat is transmitted more than 30 km. New electrical capacity can be placed near markets for both electricity and heat, independently of other cooling facilities such as rivers and the sea.

1.4.1 Technology and fuels used

CHP in the Nordic countries uses many technologies and fuels.

There is the traditional model of boiler and steam turbine. This type is operated both as backpressure units (with no source of cooling other than a DH-network or industrial use of heat) and as extraction units (with a specific cooling possibility in a cooling tower, with river or seawater).

Traditional CHP-plants of this type cover a large share of DH, and many of them use fossil fuels such as coal and natural gas. However, biomass is also making its way into this field, as CHP-technology for biomass fuels has developed and improved. There are several large CHP-plants in the Nordic countries operating on wood chips, straw and waste.

Gas turbines are normally used in larger CHP-plants running on natural gas, usually in combination with exhaust gas boilers and a steam cycle to form a Combined Cycle Gas Turbine. Several such units also produce heat for DH in the Nordic countries.

Smaller CHP plants are usually based on reciprocating engines running on natural gas, and in a few cases biogas. A large number of this type operate in the Nordic countries as back pressure units with no cooling possibility other than mostly a DH-network or in some cases an energy intensive industry.

1.4.2 CHP in the Nordic Countries

The main source of heat for DH in the Nordic countries is still CHP. That is the case in both Finland and Denmark, where thermal production of electricity is dominant. New capacity for electricity production is in the Nordic area today only placed within range of a heat market. In some areas, large share of new capacity has even been constructed near medium and small size heat markets outside the large cities, as small and medium size CHP –plants using natural gas on small reciprocating engines.

As mentioned before, utilisation of waste heat from thermal electricity production can greatly increase the overall thermal efficiency. E.g. the total thermal efficiency of all large Danish CHP plants (>200 MW) combined has increased from 44,5 % in 1977[3] to the present level of 62,5 %[4] through the increased use of their waste heat in DH. In CHP plants where all waste heat is utilised in DH, the total thermal efficiency is normally 85 - 90 %

Traditionally coal has been dominant in Nordic CHP and in recent years, natural gas has been used in many places where it is available. Even biomass as wood chips and peat is used depending on availability.

2 The ultimate replacement

2.1 Replacing individual heating

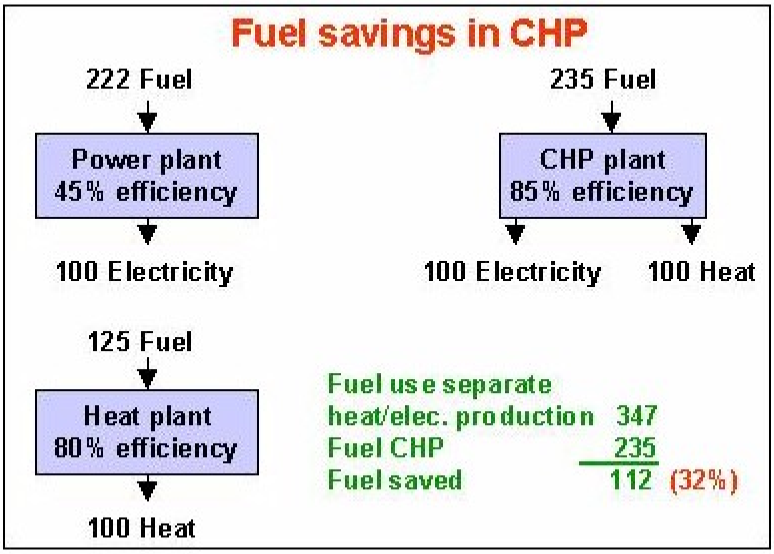


Figure VI

One immediate effect of DHC is that it replaces individual units working for heating or cooling. Such units used in individual households or small office or industrial buildings are often neglected and only attended to if they fail to operate. That means that little attention is given to their efficiency and maintenance. Low efficiency seems of little importance for the individual owner of small units for heating or cooling purposes but on the grand society scale, inefficiency of such machines does matter. Badly maintained units may produce more emissions than necessary or increase the fraction of especially harmful emissions.

Moving production to large-scale production facilities for heat and cooling will make the monitoring of the production facilities easier. The cost of maintenance will also be smaller than the total cost of maintenance for all the replaced units. Generally, the possibilities for and the economy in optimising the production will be better on large units than on a large number of small units.

2.2 Replacing Separate Production of Electricity and Heat

As mentioned before, using waste heat from any source is one of the main forces of District Heating. Using waste heat from electricity production adds a new dimension to both District Heating and electricity production. District Heating gains a vast new heat resource and electricity production achieves a huge increase in overall efficiency. To exemplify fuel savings when combining the production of heat and electricity a small example is made in the figure VI.

3 And the winner is – THE ENVIRONMENT

3.1 Higher Energy Efficiency

Achieving higher energy efficiency should be the main target of any energy policy. Higher energy efficiency reduces the need to find or buy fuel, it reduces fuel costs and it reduces the problem with the emissions and residue from energy consumption. Using fuel or energy that would otherwise have been wasted is a cheap and effective way to increase energy efficiency. No technology is better at doing this than DH. Low quality fuels and low value energy suddenly becomes useful and valuable.

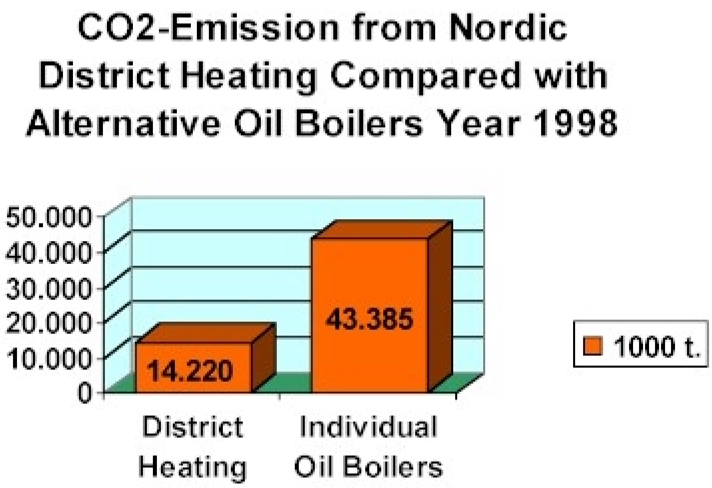
District Heating is a cornerstone in switching energy consumption away from fossil fuels. Without DH, it would have been impossible to replace fossil fuel consumption with straw, wood chips/pellets and refuse. The resulting reductions in CO_2 emissions could not have been achieved without DH.

District Heating is also the cornerstone in utilising waste heat from electricity production. DH is the only technology able to provide a large heat market at the end of their pipes.

3.2 Reduction in CO_2 Emissions

The total CO_2-emission from DH in the Nordic countries amounts to 14,2 Mio. tons per year. This can be compared to an estimated emission of 43 Mio. tons CO_2 if the total heat supply from DH had been produced based on oil fired boilers. In other words, the CO_2-emission associated with the heat supply in question would have been tree times as big. This is illustrated in figure VII.

Figure VII



3.3 DHC/CHP as a Means in Energy Policy

3.3.1 In the European Union

Increasing the share of CHP in the electricity production is seen as a very important means to improve the energy efficiency within the European Union (EU). It has been stated that doubling the use of CHP to 18 % of the union's electricity production is expected to decrease the CO_2 emission with 150 - 350 Mt CO_2/year by 2010.[5]

The Commission of the European Communities has produced a Green Paper concerning a European strategy for the security of energy supply. It stresses the need to counter the structural weakness of Europe regarding energy supply, dependent as it is on imported fuel. One way to counter the risks associated with such dependence is to diversify the sources of energy and use whatever locally available. District Heating is an instrument in such a process.

Such an increase in the use of CHP requires markets ready to use the heat produces. Industry will provide a market but a large market can be found in domestic use of heat. In addition, once the DH networks are there, they can distribute any available heat obtained from any source.

3.3.2 In the Nordic Countries

DH has played different roles in the general national energy policy of the Nordic countries. In one instance, DH has been an important instrument in a general energy policy aimed at shifting the whole energy sector in a country away from total dependence on imported oil towards a diversified energy supply. First towards more coal and more domestically produced fuels and later away again from fossil fuels in order to reduce CO_2-emissions. DH was instrumental in the shift towards such a more pluralistic energy supply.

Sweden has decided to abandon nuclear power and restrictions on CO_2 emissions makes replacement with fossil fuel impossible. They are therefore seeking ways to reduce electricity consumption and one way would be to reduce the widespread use of electricity for heating purposes. The country is rich in biomass fuels and the obvious solution, is therefore to replace electric heating with biomass fuelled DH.

The Nordic experience shows that recognising DH as an efficient technology and as an instrument to be used in a national policy for the environment and energy, it will enhance the chances for success for such a policy.

References:

[1] Miljø i Nordisk Fjernvarme, Nordvarme, January 2001
[2] Iceland, Finland, Norway, Sweden and Denmark with dependencies
[3] Ass. of Danish Electricity Utilities, December 1987.
[4] Ass. of Danish Energy Companies, December 2000
[5] Euroheat, 2001

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