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MARK THROWER MANAGING EDITOR

The rise of district heating

By Joseph McClelland, senior energy consultant

The basic definition of a district heating system is supply of heat or hot water from one source to a district or group of buildings.

District heating is a system for distributing heat generated in a centralised location through a system of insulated pipes for residential and commercial heating requirements such as space heating and water heating. The heat is often obtained from a cogeneration plant burning fossil fuels or biomass, but heat-only boiler stations; geothermal heating, heat pumps and central solar heating are also used, as well as nuclear power. District heating plants can provide higher efficiencies and better pollution control than localised boilers.

District heating traces its roots to the hot water-heated baths and greenhouses of the ancient Roman Empire. District systems gained prominence in Europe during the Middle Ages and Renaissance, with one system in France in continuous operation since the 14th century. The US Naval Academy in Annapolis began steam district heating service in 1853.

Although these and numerous other systems have operated over the centuries, the first commercially successful district heating system was launched in Lockport, New York, in 1877 by American hydraulic engineer Birdsill Holly, considered the founder of modern district heating.

Four generations of DH

There are four different generations of district heating systems and their energy sources and these systems can be distinguished as follows:

The first generation was a steam-based system fuelled by coal and was first introduced in the US in the 1880s and became popular in some European countries, too. It was state of the art until the 1930s and used concrete ducts, operated with very high temperatures and was therefore not very efficient. However, some of these systems are still in use, for example in New York or Paris.

The second generation was developed in the 1930s and was built until the 1970s. It burned coal and oil and the energy was transmitted through pressurised hot water as heat carrier. The systems usually had supply temperatures above 100°C, used water pipes in concrete ducts, mostly assembled on site, and heavy equipment. While also used in other countries, typical systems of this generation were the Soviet-style district heating systems that were built after World War 2 in several countries in eastern Europe.

In the 1970s the third generation was developed and was subsequently used in most of the systems that followed all over the world. This generation is also called the “Scandinavian district heating technology”, because a lot of the district heating component manufacturers are based in Scandinavia. The third generation uses prefabricated, pre-insulated pipes, which are directly buried into the ground and operates with lower temperatures, usually below 100°C. A primary motivation for building these systems was security of supply by improving the energy efficiency after the two oil crises led to disruption of the oil supply. Therefore, those systems usually used coal, biomass and waste as energy sources, while oil was mostly neglected.

Currently, the 4th generation is being developed, with the transition already in process in and it is designed to combat climate change and integrate high shares of variable renewable energy into the district heating by providing high flexibility to the electricity system.

Compared to the previous generations the temperature levels have been reduced to increase the energy efficiency of the system, with supply side temperatures of 70°C and lower. Potential heat sources are waste heat from industry, CHP plants burning waste, biomass power plants, geothermal and solar thermal energy (central solar heating), large-scale heat pumps, waste heat from cooling purposes and data centres and other sustainable energy sources. With those energy sources and large scale thermal energy storage, including seasonal thermal energy storage, 4th generation district heating systems are expected to provide flexibility for balancing wind and solar power generation, for example by using heat pumps to integrate surplus power as heat when there is much wind energy or providing electricity by biomass plants when back-up power is needed. Therefore, large-scale heat pumps are regarded as a key technology for smart energy systems with high shares of renewable energy up to 100 per cent and advanced 4th generation district heating systems.

The many forms of DH

District heating can take many forms. The key element is the replacement of individual boilers in each building with a network of heat pipes that carry heat to buildings from a central source, or sources, of heat.

The key components of a district heating system are:

- the heat source (in larger systems there can be more than one heat source);
- the heat pipe network; and
- the consumer unit in each building.

The heat pipe network links the heat sources to the heat consumers. The pipes will be made of steel (main elements) or plastic (final connections to consumers). Pipes are pre-insulated in the factory, to provide a low level of heat loss. The size of pipe required is set by the peak heat flow in the system. So the largest pipes are required close to the heat source, with size gradually decreasing further from the heat source.

District heating systems can carry hot water or steam. If the consumers include industrial sites that require steam, then the network will need to be configured to carry steam throughout with buildings typically using hot water for space heating.

Network configurations depend on the topography of heat sources and heat consumers. Simple systems may be radial in nature.

The largest element of capital cost is the heat network. The pipe is expensive plus there are high costs to install the pipe. Installation requires a trench to be dug, preparation of the bed of the trench for the pipe, joining the steel and insulating jacket and reinstatement of the trench. In urban areas the pipe route will need to be navigated around existing services (water, sewage and gas pipes and electricity cables).

‘The carbon abatement costs of district heating can be better than most cost-effective stand-alone renewable technology’

The main explanation for the low penetration to date is the relatively high cost of providing heat through district heating in comparison with conventional gas or electric-based heating systems. This is illustrated in Table 1 which compares the average cost of heat for a range of district heating options and stand-alone renewable heat technologies with gas and electric heating.

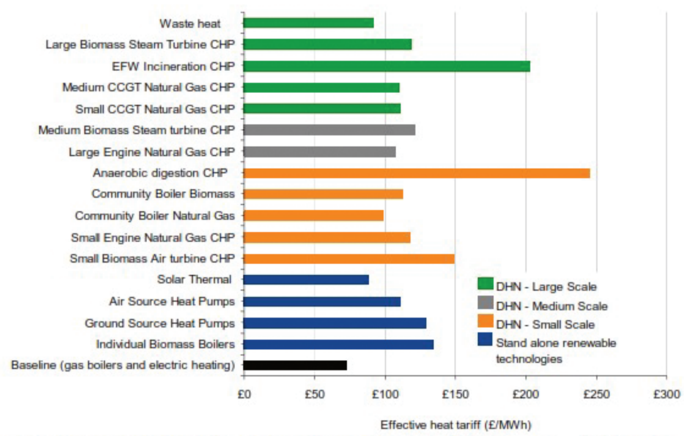
The main driver of the higher cost of district heating is the network of hot water pipes. For example, under current cost assumptions, a heat network to supply 270,000 households would cost in the region of £1.5bn.

Nevertheless, there are some combinations of fuel sources and building types that can reduce the relative cost, for example, where the district heating scheme:

- uses waste heat from conveniently sited power stations, since the heat is essentially produced at a very low marginal cost; and
- replaces electric heating systems; and supplies to commercial premises and high rise flats in high heat density areas.

Even in the current market and regulatory environment, it is estimated that district heating could displace electric heating on economic grounds – but in only 70,000 dwellings and in some non-domestic buildings equating to 14% of the modelled commercial heat demand. Together, these add up to only 0.3% of national heat demand.

Table. 1 – Average cost of heat for a range of district heating options



Notes: Waste heat is heat obtained at very low wholesale cost from power plants or industrial processes. Solar thermal heating applies to water-heating only.

The main benefit of moving to district heating or renewable technologies is expected to be the carbon savings they can deliver with potential annual savings achieved for a composite benchmark dwelling from each technology. For example, it is calculated that a district heating network covering 250,000 households may save between 0.25 Mt CO_2 and 1.25 Mt CO_2 relative to conventional heating systems annually, dependent on the fuel used and the carbon intensity of centralised electricity production.

Given the lack of commercial drivers, the question still arises as to whether it is more attractive to substitute conventional gas and electric heating either with district heating or with renewable heat technologies for conventional gas and electric heating.

Carbon abatement costs

Analysis suggests that, where district heating networks can achieve a high penetration (in the region of 80 per cent) in a built-up area, the carbon abatement costs of district heating options can be better than the most cost-effective stand-alone renewable technology.

Such carbon competitiveness may reduce if:

- DHNs are perceived to be riskier than other technologies – requiring a higher rate of return and a consequent higher heat tariff;
- penetration of the network is lower; or
- the carbon intensity of electricity provided from the national grid falls without a consequent increase in the price of electricity – which then may favour heat pumps.

Although the delivery of renewable energy targets is expected to reduce the average grid electricity carbon intensity in the future, analysis shows that DHNs remain the preferred option for achieving carbon reduction in built-up areas unless electricity can be de-carbonised to a level below 0.15 $kgCO_2/MWh$ (analysis is based on 0.31 $kgCO_2/MWh$) and without raising its wholesale price above current levels (around £45/MWh).

This situation need not be an

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absolute choice between one technology and another. District heating options have the potential to exploit larger volumes of no/low-carbon heat in built- up areas where the stand-alone renewable options may be subject to restrictions on the availability of existing chimneys, roof space and ground, or on the combustion/processing of biomass and waste. Optimisation of the supply of no/low carbon heat to buildings might target the DHN options at the more densely built-up areas, with heat pumps and the limited resource of biomass utilised elsewhere.

Renewable energy targets

Analysis suggests most district heating would be gas-based, at least in the short-term, standalone renewable options are likely still to be needed to assist compliance with the 2020 renewable energy targets.

District heating systems offer security of heat supply benefits compared to individual boilers in buildings. There are two reasons for this. Firstly, many buildings will have only one boiler, whereas a district heating system will normally have several boilers. So one boiler failure would not affect the district heating system. Secondly the focus of the district heating operator is maintaining heat supply, hence reliability of boiler plant, pumps and the heat network are critical to the business. This is not true of ordinary businesses and homes, where boiler maintenance is unlikely to be a priority. To provide an acceptable return on investment the system needs to operate for around 7,000 hours a year. So the system will be generating and producing heat for most of the time, heat will be available all year round.

Typically, when consumers connect to a district heating system when their existing boiler system requires replacement - or when a new building is developed. Connecting to district heating under these circumstances has a number of advantages:

• the cost of a replacement or new boiler is avoided (both cases);
• space may be freed up for other uses (both cases); and
• the cost of a gas (or other fuel) supply is avoided (new buildings).

The customer will typically remove their existing boiler plant or will not install boiler plant. Hence the district heating system becomes the sole source of heat.

Stakeholder involvement

The way in which district heating has developed in the UK has taken a number of different forms:

• systems that serve a new housing or mixed use development - initially owned by the property developer;
• systems that serve a university, hospital or large military base - initially owned by the main client, sometimes transferred to a third party;
• systems that serve social housing - typically owned by a local authority or housing association;
• systems that serve public buildings - initially owned by a local authority, sometimes transferred to a third party; and
• systems associated with energy from waste schemes - initially owned by a local authority, sometimes transferred to a third party.

There are many stakeholders involved in a DHC project. Government regulations from central and local levels. At the project level, utilities, equipment manufacturers, specifying engineers, contractors, and architects work in conjunction with facility owners and operators.

‘District heating systems offer security of heat supply benefits compared to individual boilers in buildings’

To expedite planning and decision-making, different procedures can be used, such as the four-phase process. This process guides the district heating project team through four phases:

• an initial assessment to define goals and determine how future growth could affect the system;
• feasibility determination to evaluate the commercial and technical viability of the project;
• project development to coordinate engineering personnel and vendors involved in designing and building the system; and
• operation, optimisation, and expansion to ensure proper operation and implement improvements and upgrades.

Some European countries provide a large majority of their energy from district heating. But now district heating is becoming more common in the UK, especially as part of new-build housing developments. Around 210,000 UK households are currently connected to district heating networks. There is a new one planned for London using waste heat from tube stations.

The main issue with district heating, however, is that it's much easier to plan before building than retrofitting. It also requires the estate management to persuade potential customers that it would be a good idea and that they wouldn't be left carrying the cost of installation.

All in all, district heating is a great idea, but quite hard to get right in practice. There are several problems that make it hard to retrofit on a wider scale in the UK.

One of the main concerns is not over the heating per se, but controlling the heating. The ideal scenario is to ensure district heating is installed with individual customer metering, which allows charging based on how much energy the customer uses.

The benefits of district heating include:

• delivers higher efficiency, especially if using CHP plants, which generate electricity and gas simultaneously; and
• produces lower carbon emissions than individual boilers.

District heating's limitations include:

• the requirement for forward-planning, as it is very difficult to retrofit;
• the requirement for long-term financial commitment; and
• controls and tariffs need to be carefully considered to create the most efficient solution.

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SERIES **16** | MODULE **04** | SEPTEMBER **2018**

CPD ENTRY FORM

DISTRICT HEATING

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

QUESTIONS

1. **What is the temperature difference between Generation 3 and Generation 4 district heating systems?**
   - ☐ 50°C ☐ 30°C
   - ☐ 10°C ☐ 40°C

2. **What would be the approximate cost for the implementation of a heat network to supply 270,000 households?**
   - ☐ £100m ☐ £500m
   - ☐ £1.5bn ☐ £2.0bn

3. **Relative to conventional heating systems annually, dependent on the fuel used and the carbon intensity of centralised electricity production, how much carbon dioxide could a district heating network covering 250,000 households?**
   - ☐ 0.25 Mt CO2 ☐ 0.15Mt CO2
   - ☐ 1.8 Mt CO2 ☐ 2.5 Mt CO2

4. **How many hours a year does a DH system need to operate for to provide an acceptable return on investment?**
   - ☐ c. 8,000 ☐ c. 7,000
   - ☐ c. 5,000 ☐ c. 3,000

5. **Approximately, how many UK households are currently connected to district heating networks?**
   - ☐ 130,000; ☐ 520,000;
   - ☐ 210,000; ☐ 750,000

6. **Above which level of UK electricity de-carbonisation do District Heat Networks remain the preferred option for achieving carbon reduction in built-up areas?**
   - ☐ 0.15 kgCO2/MWh ☐ 0.25 kgCO2/MWh
   - ☐ 0.10 kgCO2/MWh ☐ 0.05 kgCO2/MWh

7. **In how many estimated domestic dwellings could district heating displace electric heating on economic grounds?**
   - ☐ 200,000 ☐ 150,000
   - ☐ 300,000 ☐ 70,000

8. **What is the estimated percentage of non-domestic buildings where district heating could displace electric heating on economic grounds?**
   - ☐ 25 per cent ☐ 32 per cent
   - ☐ 14 per cent ☐ 7 per cent

9. **What estimated percentage of combined domestic dwellings and non-domestic buildings where district heating could displace electric heating on economic grounds?**
   - ☐ 0.3 per cent ☐ 0.5 per cent
   - ☐ 5 per cent ☐ 3 per cent

10. **Which of the following are not benefits of district heating schemes?**
    - ☐ They deliver higher efficiency, especially if using CHP plants, which generate electricity and gas simultaneously
    - ☐ They produce lower carbon emissions than individual boilers
    - ☐ They produce lower carbon emissions than any other heat source
    - ☐ They require more long-term financial commitment

Please complete your details below in block capitals

Name .... (Mr. Mrs, Ms) ....

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Completed answers should be mailed to:

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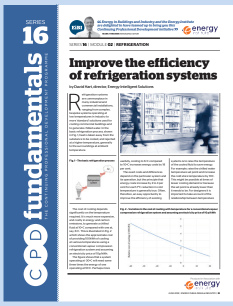

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