Fundamental

SERIES 8 MODULE 5

CURRENT THINKING ON...

District Heating

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"District heating is a system where the heat for an area is produced centrally, and hot water or steam is transported to the buildings through a network of pipes."[1]

A district heating network may supply heat to a single building of multiple units, such as a tower block of multiple flats; or it may supply multiple buildings in an area. Heat networks can now be established to supply heat loads up to 30km from the primary heat source, with distribution systems hundreds of kilometres long[2]. These distances are on a city-wide scale, which can be extended by installing additional heat sources along the way. However, it is more common for district heating systems to be confined to smaller communities, campus-based organisations such as universities, hospitals, housing estates and manufacturing sites. The network is simply a means of transporting the heat from the primary heat source to the heat users.

Achieving advantages

By separating the heat source from the heat users, a number of advantages may be achieved, generally associated with economies of scale, but also arising from improved energy efficiency, emissions reductions improved access for maintenance of boilers and other heat sources. The latter can be a key driver in the application of district heating to tenanted or serviced housing estates and can lead to significant cost savings simply through the avoidance of aborted visits to flats and houses to carry out routine or responsive boiler maintenance when the residents are out.

Characteristics of district heating systems in the UK:

- large-scale heat source;
- low-emission technology, such as highly efficient boilers, combined heat and power or biomass;
- supply to multiple buildings on a campus or confined area;
- more common in public sector rather than private sector;
- heat users often include residential sector with purpose-built social housing estates more strongly represented;
- distribution pipework is highly insulated and usually below ground;
- primary heating distribution pipework separated from heat users' heating systems by heat exchangers or calorifiers;
- steam or medium/high pressure hot water;
- management by energy services company or other third party.

Continuous heating

District heating is best suited to continuous heating requirements, as its efficiency is significantly reduced if operated intermittently. It is popular in Northern European countries with extended heating seasons. For example, 60 per cent of Denmark's buildings use district heating, but currently only 1 per cent of buildings in the UK are on a district heating network[3]. It is a technology that is highly applicable to the UK, but has not been exploited to its full potential. Nonetheless, there are thousands of schemes across the British Isles, ranging from numerous gas-fired boiler powered schemes in many University campuses, such as Leicester, Nottingham, Birmingham and Edinburgh. Over 100 acute and general hospitals throughout the UK benefit from the technology as well as industrial sites such as Astra Zeneca in Loughborough, and housing estates in the London boroughs of Southwark and Westminster. In addition, schemes supply whole swathes of inner city areas such as Sheffield and Nottingham's energy from waste schemes. Southampton has a geothermally powered scheme while Birmingham city centre benefits from a CHP-powered schemes. Ground source heat pumps supply the power for Penzance's Penwith Housing Association's district heating scheme while biomass is the heat source for district heating in Barnsley's Sheffield Road Housing Estate.

At some sites the installation of a district heating system is a prerequisite to establishing a sound financial case for highly profitable technologies, such as combined heat and power (CHP) or biomass. The significant investment required for large scale CHP and biomass requires extended running hours each year to enable an acceptable payback period to be achieved. By joining heating loads that occur at different times of the day and different times of year together in a heat network, the duration of significant heating demand 'seen' by the primary heat source can be extended.

General hospitals with operating theatres, accident and emergency, laundries and wards for post-operation recovery and other overnight stays have traditionally

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been constructed with heat networks. This remains common practice for new-build hospitals. Summer demand, while lower than that in winter, remains significant during the daytime due to the domestic hot water, catering and laundry needs of patients, staff and visitors.

It is not uncommon for universities to have an extensive heat network serving their central campus. However, if the activities at the campus are restricted to teaching, this may limit significant heat demand to weekday, daytime in winter, which would be of significantly shorter duration than the 3,000 or 4,000 hours a year before CHP can even begin to be considered. A university with a mixed campus of teaching, research, catering and halls of residences is therefore in a much stronger position to exploit CHP or biomass via a district heating scheme than institutions with modest research activities that locate academic and residential accommodation on separate campuses.

History in social housing

Heat networks have a strong history in the construction of social housing and in purpose-built housing estates in particular. While peak demands will occur outside of the 9-5 working day on residential estates, on an estate of significant size (e.g. 2,000 homes) there can be sufficient daytime and summer loads to justify the installation of a CHP system. Historically, the low efficiency of domestic-scale coal- and oil-fired boilers relative to large, centralised boilers was sufficient to justify the installation of a heat network. However, with the advent of natural gas from the North Sea and the availability of domestic scale condensing boilers at reasonable cost, the intermittency of summer daytime heat demand in housing estates weakens the financial case for the installation of new single estate district heating schemes.

An example of the evolution of district heating in social housing is Sheffield Road flats in Barnsley. It comprises three seven-storey buildings constructed in the 1980s, complete with a coal-fired district heating system. By 2004 the primary heat source was in need of replacement and wood chip boilers were installed, making use of arboriculture waste from the council's own tree surgery and grounds maintenance works.

Heat networks can be used to supply distributed, intermittent loads, but there is rarely a strong financial case for this. Distributing hot water or steam through a network is highly energy intensive and if the typical loads are small and intermittent, parasitic losses may reach a high proportion of total load, reducing system efficiency. A large, modern, high efficiency condensing boiler could be expected to have a seasonal efficiency of in excess of 90 per cent. When supplying a continuous load, whether it is a district heating system, or the central heating system of a single building, the distribution system utilisation efficiency would be classed as 100 per cent. However, the utilisation efficiency would be lower for intermittent loads: 97 per cent for single buildings and 90 per cent for district heating[4]. This 7 per cent reduction in efficiency of district heating is a significant disincentive to applying it to intermittent loads. It is clearly important to minimise this loss by targeting systems of extended use and to overcome residual losses by achieving significant cost improvements through economies of scale and achieving lower emissions by incorporating low or zero carbon (LZC) technologies that would not be viable at the local level.

Central heat source

District heating networks enable multiple heat loads to be served by a central heat source. This is essential for the application of high capital cost technologies, or where individual loads are of insufficient capacity or duration to provide a return on LZC technologies. The exploitation of energy from waste and other fuels subject to the Waste Incineration Directive (WID) often require extensive heat networks to distribute the heat generated due to the large scale generally associated with WID compliant plant. Although the initial capital cost of both the primary heating plant and the district heating networks are typically multiple millions of pounds, they can offer revenue cost advantages over conventional approaches, leading to an attractive rate of return for institutional investors.

By integrating diverse heat loads, district heating schemes can balance the supply and generation of heat, across a number of locations and over differing times of day, week and even seasons. For example, a heat network would see office and residential loads as complimentary across a 24-hour period, with little overlap between their peak demand periods. However, to gain a seasonal balance, further summer heating demands would be required, such as hotels, which are typically busier in summer, or swimming pools that require heat all year round. An option to extend heat demand into summer is to include absorption cooling technologies. Absorption chillers use heat as their primary energy source to generate cooling. This is in contrast to conventional, vapour compression chillers that use electricity. Absorption chillers can use hot water at a temperature as low as 80˚C as their primary energy source. However, their coefficient of performance (COP) is generally below 0.7 at this temperature. But their COP increases significantly as the temperature of the heat source increases and high temperature hot water, or steam will optimise their efficiency.

Including absorption chillers in district heating schemes presents challenges. They are considerably more expensive than vapour compression chillers, have large, low-grade heat rejection loads and specialist maintenance regimes compared to conventional vapour compression chillers. Furthermore, unless the district heating system includes a parallel cooling network, the absorption chillers must be distributed around the heat network, near to the points of cooling demand. Where the heat users are owned by the operators of the district heating system, optimising the location and operation of absorption chillers on the network can be relatively straightforward. However, for mixed use schemes including commercial partners with financial separation between scheme owners and customers, it can be more difficult for scheme designers to influence either the specification of absorption chillers over vapour compression chillers, or the management of their use.

Heat from diverse sources

Operationally, district heating systems offer many advantages, including reducing the liability of heat users for the upkeep of primary heating plant. They can be used to integrate heat from diverse sources, reducing their customers' dependence on a single fuel. This is a significant factor in achieving a high level of system reliability, continuity of service, financial certainty and "future-proofing". For example, a heat network designed to exploit a supply of biogas from a landfill site could be converted to energy from waste, or gas-fired CHP when biogas production diminishes, or ceases. Heat networks can also introduce an element of competition into the supply of fuels to district heating customers.

It is typical for the boilers in buildings on district heating systems to be replaced with a plate heat exchanger. This improves reliability, simplifies heating provision for small organisations with no in-house facilities management function and reduces maintenance costs. In city centre, or even campus-based organisations, where space is at a premium, the space saved by using a heat exchanger instead of a boiler can be one of the strongest commercial benefits of connecting to a heat network. The case is further strengthened when there are restrictions upon where flues can be accommodated for new systems, alternative or dual fuels.

The majority of heat networks supply single organisations and are operated by their owners in a similar manner to conventional heating plant – i.e. either in house or via a maintenance contractor. It is not uncommon for such systems to have an annual shut down of perhaps two weeks or more to allow central plant and pipework to be maintained. In such circumstances, summer loads would be met by alternative fuels, such as electric immersion heaters or gas-fired water heaters.

Large district heating schemes supplying multiple organisations or significant proportions of urban areas are generally operated by specialist contractors and often by companies specifically established to design and operate them on an energy services company (ESCO) arrangement. Continuity of service is typically more critical for such schemes and planned maintenance of primary heating plant is carried out without shutting down the district heating network.

Fuels commonly associated with district heating systems in the UK have historically included coal, oil and other fossil fuels, energy from waste and, to a modest extent, cooling water from power stations. The exploitation of natural gas from the North Sea brought gas-fired CHP to prominence. In the last decade biomass has become an increasingly significant contributor to district heating networks, with other LZC technologies.

Increased reliability

19th and early 20th century district heating systems fired by low-cost fuel sources would typically use steel pipework, with modest insulation, buried in trenching. As fuel costs rose in the 1970s the importance of insulation effectiveness and reliability increased, leading to the application of high levels of mineral wool insulation on steel heat network pipes, well protected by cladding. Developments in insulation and plastic pipework manufacturing methods in the 1980s subsequently led to plastic pipe being more commonly used than steel. It is now available pre-insulated with blown polyurethane or other closed-cell, high-performance insulants in unbroken lengths of up to 100m commonly available.

Heat loss has been reduced to less than 1˚C per km. Heat loss from insulated pipes can be further reduced by locating them in trenches. Pipes should be at least 450 mm below ground to provide protection from vehicle loads[5] and deeper for improved thermal insulation.

Where there is a significant difference between summer and winter peak demands, pipework heat loss may be further reduced by operating a three-pipe system. The third pipe is of smaller diameter and has a separate circulation pump. It is used in summer when space heating is not required and has sufficient capacity to supply the primary heating coils of domestic hot water calorifiers supplied by the district heating system. A common pipe is used for heating return in both summer and winter. The surface area of the smaller, summer flow pipe is significantly less than that of the winter pipe, reducing heat loss. Furthermore, the reduced volume flow rate reduces pumping costs.

An alternative arrangement often employed on district heating systems supplying single organisations is to simply switch off the district heating at the end of the heating season and meet domestic hot water requirements from local heat sources – most commonly electric immersion heaters. The cost effectiveness of this option varies on a case-by-case basis and is dependent upon such factors as the size of the domestic hot water load in proportion to the district heating system heat loss and the cost of the local fuel source relative to the district heating system.

The majority of district heating systems separate the primary heating flow circuit from the secondary flow by means of heat exchangers or low-volume calorifiers. This reduces the interdependence of the supplier and heat users' system flow temperatures. It also allows clear demarcation of responsibility for maintenance.

Thermal stores or accumulators can be used to decouple the generation of heat from supply to the network which can assist in meeting peak heating demand, reducing primary heat source cycling and allowing the capacity of primary plant to be reduced below that of the peak heat demand. This latter advantage can significantly reduce the capital cost of technologies such as CHP and biomass boilers which have a considerably higher cost per kWh of delivered heat than thermal stores.

District heating has many advantages in the right applications, but it is essential to ensure that the high capital cost and heat loss of the extensive pipework is more than outweighed by reductions in cost and emissions achievable by efficient central plant, ideally exploiting LZC technologies.

Advantages and disadvantages of district heating

ADVANTAGES	DISADVANTAGES
Lower capital cost per unit output for primary plant than for decentralised systems	High cost of distribution pipework & higher total capital cost
Higher efficiency of heat generation and delivered heat	Significant heat loss from distribution pipework between buildings. Efficiency can be lower for intermittently operated systems
Greater range of fuel choice	Large scale fuel deliveries & associated vehicle movements required for solid fuels
Greater flexibility for fuel changes, dual firing etc.	Significant investment in fuels and fuel handling systems required
Improved fuel security	The volume of fuel required by large systems can lead to continuity of supply challenges
Higher incidence of including CHP and other LZC technologies	Difficult to incorporate selected LZC technologies on a scale that may be better suited to decentralised systems
Extends the reach of LZC technologies, providing opportunities for technologies that may not otherwise be viable	High temperatures of district heating systems can preclude some technologies, such as small scale CHP
Save space in customers' plant rooms	Large continuous space requirement for primary plant
Customers' maintenance burden is significantly reduced	Specialist maintenance operatives required
Continuity of service is greater than for multiple heat sources	Extent of impact of a failure of key system pipework is considerably greater than for decentralised systems
Supply heat to a wide variety of users	Loss of control & predictability of demand can lead to less than optimal system operating parameters
Assists in the efficient management of supply & demand for heat in a locality	Large scale systems can have an unpredictable impact upon the competitiveness of local fuel supply markets
Lower labour and maintenance costs compared to multiple heating & distribution systems	Treatment of maintenance costs at feasibility stage is notoriously difficult

References

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4) Chartered Institute of Building Services Engineers (CIBSE) Guide F, table 10.9, 2006
5) Fred Hall & Roger Greeno, Building Services Handbook, Fourth Edition, 2007

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This is the fifth of ten modules in the eighth series and focuses on district heating. It is accompanied by a set of multiple-choice questions. To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to ***Energy in Buildings and Industry*** for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course, for a fee of £15 (for members) or £25 (for non-members).

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MARK THROWER, MANAGING EDITOR

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SERIES 8 MODULE 5: QUESTIONS

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.

1. What proportion of UK buildings is currently supplied by district heating schemes?

☐ 1 per cent ☐ 60 per cen ☐ 90 per cent ☐ 97 per cent

2. What proportion of Danish buildings are currently supplied by district heating schemes?

☐ 1 per cent ☐ 60 per cent ☐ 90 per cent ☐ 97 per cent

3. What is a thermal store?

☐ Heat retailer
☐ Vessel that separates heat demand from supply
☐ Low volume calorifier
☐ Heat exchanger

4. Which one of the following is an advantage of district heating?

☐ Free heat
☐ Low cost infrastructure
☐ High cost infrastructure
☐ Suitability for LZC technologies

5. Which one of the following is a disadvantage of district heating?

☐ Free heat
☐ Low cost infrastructure
☐ High cost infrastructure
☐ Suitability for LZC technologies

6. What could the distribution efficiency of an intermittently operated district heating system be expected to be:

☐ 1 per cent ☐ 60 per cent ☐ 90 per cent ☐ 97 per cent

7. What could the distribution efficiency be expected to be for an intermittently operated heating system central to a single building?

☐ 1 per cent ☐ 60 per cent ☐ 90 per cent ☐ 97 per cent

8. District heating networks are common in which of the following building types?

☐ Schools ☐ Hospitals ☐ Churches ☐ Corner shops

9. District heating is common in which of the following areas?

☐ Southern Europe
☐ Northern Europe
☐ British Isles
☐ Caribbean

10. What material has become more common than steel for new district heating systems?

☐ Plastic ☐ Polyurethane ☐ Iron ☐ Rockwool